

# Teacher Labor Market and the Dynamics of Inequality

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## Abstract

Teachers account for less than 5% of the workforce but have disproportionate impacts on the human capital of future generations. This paper studies how teacher compensation policies affect the dynamics of income inequality in the aggregate labor market. I develop an overlapping-generations model and explore a new mechanism where (1) the dispersion of human capital amplifies the selection effects on teacher quality, and (2) teacher quality affects the dispersion itself through endogenous human capital formation. I use evidence on how duty-to-bargain laws shape teacher labor market and children's outcomes to identify the model in closed form. Counterfactual results suggest that policies that raise the returns to human capital among teachers, e.g., performance-based compensations, have large dynamic spillover effects such as reducing income inequality among non-teachers and boosting intergenerational mobility.

**JEL classification:** I24, J24, J31, J45

**Keywords:** teacher labor market, human capital, inequality

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# 1. Introduction

Teachers play a fundamental role in shaping students' achievements and path to upward mobility (Rivkin et al. 2005, Chetty et al. 2014b, Card et al. 2022). Naturally, education policies that attract the best talent into the teaching profession have profound implications not only on the structure of teacher labor market but also on the human capital of the next generation (Hanushek 2011).

While recent researches have made significant progress in measuring such implications (Biasi et al. 2021, Lovenheim and Willén 2019, Tincani 2021, Card et al. 2022), two important questions remain to be answered. First, because teacher selection shapes the future human capital distribution, how does it affect the time path of inequality in non-teacher labor markets and the propagation of aggregate shocks such as the skill-biased technical changes? Second, how does the magnitude of these effects evolve over time as the children being affected grow up, join the labor market, and (some of which) become teachers themselves? Will the one-generation estimates in the current literature be a lower or upper bound in a dynamic environment? These questions are important for analyzing the long-run general equilibrium impacts of education policies as well as understanding teacher labor market's unique role in shaping aggregate inequalities.

In this paper, I study these two questions in an overlapping-generations economy with heterogeneous agents and endogenous human capital formation. Building on the framework in Bénabou (2002), the model additionally considers occupation selection into teaching and non-teaching professions. The key insight of the model is that the selection effects of education policies depend on the dispersion of human capital in the population to begin with. Therefore, in an environment with human capital formation so that the degree of dispersion is endogenous, changes in teacher selection have large *dynamic* effects.

The mechanism is briefly described as follows: consider a scenario where decreasing rewards to human capital in the teaching profession pushes the most talented individuals into non-teaching occupations and thus reduces teacher quality. Deteriorating teacher quality reduces human capital in the next generation, with the effects being disproportionately larger among low-income families when teacher quality and parental investments are substitutes.<sup>1</sup> As a result, the economy has lower intergenerational mobility and a greater dispersion of human capital to begin with in the next generation.

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<sup>1</sup>See Lee and Seshadri (2019) and Yum (2023). I will also verify in this condition in the calibration results using empirical evidence from duty-to-bargain laws.

Importantly, this increased human capital dispersion reinforces the selection channel and leads to further reductions in teacher quality - a vicious cycle.

To quantify the mechanism, I show that with parametric assumptions, the model provides analytical characterizations of optimal individual decisions as well as the transition path of the equilibrium human capital distribution. I also prove that the key parameters, especially the ones governing the human capital production function, are uniquely identified in closed form using cross-sectional moments and estimates on how teacher compensation scheme affects teacher labor market and children's outcomes. To that end, I utilize variations in duty-to-bargain laws across states and over time to measure the effects of teacher pay compression on teacher labor markets. In particular, I find that the enactment of such laws reduce both employment and earnings dispersion among teachers, while having mildly negative effects on the level of average earnings. I also borrow the corresponding estimates on children's earnings from [Lovenheim and Willén \(2019\)](#) where the authors find that duty-to-bargain laws reduce the earnings of children affected, with the effects being larger among children with parents from disadvantaged backgrounds. As non-targeted moments, the calibrated model also predicts teacher value-added that is very close to the estimates by [Chetty et al. \(2014a\)](#).

In counterfactual analyses, I show that even though teachers account for less than 5% of the total workforce, they have disproportionate impacts on the dynamics of inequality in the aggregate economy due to their fundamental roles in human capital formation. In addition, the feedback mechanism proposed in this paper results in large amplifications of skill-biased technical changes (SBTC) along the transition path.

In the first counterfactual experiment, I raise the returns to human capital in the teaching profession by 5% to mimic a performance-based compensation reform. The magnitude of 5% is chosen to be the same as the initial impacts that duty-to-bargain laws had on the income dispersion among teachers in the empirical findings, albeit in a different direction. I find that only two-fifth of the initial impacts on teachers' income inequality, measured in the coefficient of variations, survive in the long-run steady state. Income inequality among non-teachers, however, reduces significantly by 3%, reflecting changes in the human capital dispersion itself. Intergenerational elasticity of earnings also decreases from 0.36 to 0.27 in the long run. In other words, changing returns to human capital in the teaching profession pushes the economy along the Great Gatsby curve ([Corak 2013](#)) towards less inequality and more intergenerational mobility. I also show that the magnitude of these effects varies along the transition path, approach-

ing the new steady-state in about two generations. As a result, static or one-generation analyses overstate the effects of performance-based compensation reforms on income inequality within teachers and understate the spillover effects on intergenerational mobility and the income inequality among non-teachers.

In the second counterfactual, I study the role of teacher selection in propagating aggregate shocks, in particular on how the “convexification” of non-teaching occupations (Autor et al. 2020) affect income inequalities. I find that absent changes in teacher quality, the increase in income inequality among non-teachers would be 50% smaller in the long run. This is because increasing rewards to human capital in the non-teaching profession reduces teacher quality significantly, leading to a much larger dispersion of human capital in consecutive generations. A model-based decomposition also shows that to neutralize the effects of the skilled-biased technical change (SBTC), the returns to human capital in the teaching profession needs to rise *relatively more* than that in non-teaching occupations. This is to compensate for the fact that the SBTC also widens the gap in parental income and their investments in children’s human capital formation.

## Related Literature

This paper builds on the literature that studies the determinants of inequality and intergenerational mobility. The literature has traditionally focused on factors that affect the demand for education, such as credit constraints (Lee and Seshadri 2019, Caucutt and Lochner 2020), information frictions (Hoxby and Turner 2015), and neighborhood effects (Chetty et al. 2014b, Durlauf and Seshadri 2018, Fogli and Guerrieri 2019). This paper contributes to the relatively small literature studying the supply side of education (e.g., Agostinelli et al. (2021) and Fu et al. (2022) on the spatial distribution of college access) by showing that teacher market reforms could be powerful instruments that move the economy along the Great Gatsby curve toward lower inequalities and greater intergenerational mobility.

This paper is also related to the large body of literature in labor and education economics that studies the structure of teacher labor market and its implications on students. The most related papers include Hoxby (1996) and Lovenheim (2009) on teacher unions, Bacolod (2007) on the importance of women’s alternative employment opportunities, Lovenheim and Willén (2019), Biasi et al. (2021), and Tincani (2021) on college bargaining and performance-based compensation, and Card et al. (2022) on school quality and minimum teacher salary laws. In various institutional settings, the liter-

ature finds that rewarding more effective teachers raises teacher quality and result in improved children's outcomes, especially for those with disadvantaged backgrounds. This paper contributes to the literature by incorporating these one-generation estimates into an overlapping-generations general equilibrium setting and uncover large dynamic spillover effects into non-teaching professions.

Last, this paper is related to the literature that studies the aggregate impacts of reward structure in some special occupations, such as government officials (Murphy et al. 1991, Acemoglu 1995) and entrepreneurs (King and Levine 1993, Baumol 1996). This paper contributes to the literature by studying another key occupation in the economy, i.e., teachers, and by developing a quantification strategy that utilizes both cross-sectional moments and quasi-experimental estimates. If the same set of information used in identification are available, the framework developed here could be fruitfully applied or extended to analyze the spillover effects of other occupations.

The rest of the paper is organized as follows. I present the model setup and solution in Section 2. Section 3 shows the identification argument and the empirical results on duty-to-bargain laws. Section 4 displays the main results on counterfactuals. Section 5 discusses the robustness checks. Section 6 concludes.

## 2. Model

I study an overlapping-generations economy populated by agents that live for two periods - children and adults. Children do not make any decisions. Their human capital is formed through a production function that takes teacher quality and parental investments as inputs. Adults with different levels of human capital supply labor inelastically and select into two occupations: teachers and workers (non-teachers). After occupation selection, adult parents choose child investments that maximizes their utility from consumption and preferences on their children's human capital.

### 2.1 Occupation Selection

In the beginning of each period, adults with human capital  $h$  make occupation choice after observing idiosyncratic preference shock  $\nu$  that follows a Gumbel distribution with

scale parameter  $\theta$ . They solve the following occupation choice problem:

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

where  $w$  is the relative wage across occupations,  $\kappa$  captures the systematic cost or taste for becoming teachers, and  $\psi_j$  is the occupation-specific returns to human capital.

Assume that the underlying human capital distribution of adults  $F(h)$  follows a log-normal distribution

$$\log(h) \sim F(h) = \mathcal{N}(\mu, \sigma^2)$$

The log-normality of the human capital distribution is a condition that I will verify in the equilibrium. Because human capital is endogenously formed, the values of  $\mu$  and  $\sigma^2$  are both equilibrium objects in the steady state.

I define teacher quality  $\xi$  as the z-score of average (log) human capital of teachers in the population, i.e.,

$$\xi \equiv \frac{\overline{\log(h_1)} - \mu}{\sigma} \quad (1)$$

## 2.2 Human Capital Formation

After the occupation selection stage, adult workers have children<sup>2</sup> and solve the following maximization problem

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

subject to budget constraint

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

and human capital production function

$$\log(h') = A + \underbrace{\log(\epsilon)}_{\text{normal dist.}} + \underbrace{\delta_0 \xi + \delta_1 \log(e) + \delta_2 \log(e)\xi}_{\text{translog}} + \underbrace{\rho \log(h)}_{\text{residual persistence}} \quad (2)$$

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<sup>2</sup>I assume that only workers have children for analytical tractability of the model. I do not think that including teachers' children in this stage will change the results significantly because teachers account for less than 5% of the adult population.

where  $c$  is consumption,  $e$  is education investments,  $h'$  is children's human capital, and  $\epsilon$  is an idiosyncratic shock that follows log-normal distribution

$$\log(\epsilon) \sim \mathcal{N}(-\sigma_\epsilon^2/2, \sigma_\epsilon^2)$$

so that  $\mathbb{E}(\epsilon) = 1$ .

I assume that average teacher quality  $\xi$  and parental investments  $e$  interact in the human capital production function (2) in a translog fashion.<sup>3</sup> Parameter  $\delta_2$  governs whether they are gross complements or substitutes. I also allow for a direct spillover effect of parents' human capital to the next generation governed by  $\rho$ .

Because teachers are heterogeneous in the model, the human capital production function (2) should be interpreted as a reduced-form way of modeling how parental inputs and the pool of teachers jointly determine children's outcome. An explicit micro-foundation of the assignment problem between heterogeneous students and teachers (e.g., [Seshadri 2000](#)) is potentially important but *not* the main focus of this paper. Beyond purchasing books and computers, the role of  $\delta_1 \log(e)$  reflects parents' efforts in matching their own children to better teachers in the economy. Likewise, the interaction term  $\delta_2 \log(e)\xi$  captures the idea that need to compete for better teachers varies as the total amount of teaching resource changes.

## 2.3 Discussions

There are several points worth noting here regarding the modeling choices on occupation selection and teacher quality.

First, I have assumed that individuals differ by a one-dimensional human capital  $h$  and an idiosyncratic taste shock  $\nu$ . Human capital here summarizes a broad set of personal traits that affect productivities, including but not limited to cognitive ability, non-cognitive ability, experience, and education. An alternative modeling choice is to use a multi-dimensional human capital model à la [Roy \(1952\)](#) where individuals have comparative advantage in one of the occupations ([Borjas 2002](#), [Bacolod 2007](#)). With strong positive correlation between different abilities, the Roy-style model offers the same intuition on the selection effects. Such a model, however, requires us to model separate production functions for each dimension of human capital and the corresponding map-

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<sup>3</sup>One can also view the translog production function as the [Kmenta \(1967\)](#) approximation to the more commonly-used CES production function.

pings to productivities across occupations. In the current analysis, I restrict to the one-dimensional case for data availability reasons, but I acknowledge that the quantitative results will be smaller if *relative to* overall earnings, skills that are more important in the teaching profession (e.g., communication and interpersonal relation skills) are less affected by changes in human capital production inputs.

To investigate this concern further, I collect data on the importance of five cross-functional skills by occupation from O\*NET, including complex problem solving skills, resource management skills, social skills, system skills, and technical skills. I find that for each skill, the value of teachers are all within one standard deviation of the values across other non-teaching occupations (see Table 1). Thus, I do not expect including multi-dimensional human capital will change the results significantly.

**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.

Second, in our definition teacher quality  $\xi$  reflects the *relative* position of teachers' human capital in the population. In other words, parallel shifts in the population-wide human capital distribution, i.e., changes in  $\mu$ , does not affect teacher quality  $\xi$ . I use this definition to emphasize the selection channel and its amplification mechanisms. Our results will be stronger if teacher quality also depends on the absolute level of teachers' human capital because there will be an additional feedback loop where teacher quality feeds back on average human capital in the population and so on.

Third, I have adopted a rather stylized model of occupation selection. To focus on the propagation mechanism through endogenous human capital formation, I have abstracted away from some important margins in the context of teacher selection and quality such as the role of risk preferences (Cortes and Pan 2018), dynamic learning



(Rothstein 2015), the allocation of teachers across schools or districts (Biasi et al. 2021), and teacher efforts (Bold et al. 2017). I view these possibilities as intriguing avenues for future research.

## 2.4 Model Solution

The share of adults that becomes teachers by human capital  $h$  is given by

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

Integrating  $l(h)$  across the human capital distribution  $F(h)$ , the aggregate share of teachers  $\pi$  is

$$\pi = \int l(h) dF(h) = (w\kappa)^\theta \cdot \exp\left(\mu(\psi_1 - \psi_2)\theta + \frac{((\psi_1 - \psi_2)\sigma\theta)^2}{2}\right)$$

Using the definition in Equation (1), teacher quality  $\xi$  can be solved as

$$\xi = (\psi_1 - \psi_2) \cdot \sigma\theta \quad (3)$$

Equation (3) is important as it shows that teacher quality depends on three objects. First, the relative skill bias across sectors  $\psi_1 - \psi_2$  represents the selection mechanism. If the relative return to human capital between teaching and non-teaching occupation rises, teacher quality  $\xi$  improves. Second, teacher quality is proportional to the dispersion of human capital among potential teachers  $\sigma$ . This captures the idea that selection is powerful when agents become more heterogeneous. Last, teacher quality also depends on  $\theta$  which reflects the elasticity that individuals move across occupations in response to changes in valuations. The novel part of the model is to recognize that in a dynamic environment,  $\sigma$  is an endogenous object. In light of this, Equation (3) also provides a decomposition formula that will be used in later analysis:

$$\underbrace{d\log(\xi)}_{\text{change in teacher quality}} = \underbrace{d\log(\psi_1 - \psi_2)}_{\text{change in selection}} + \underbrace{d\log(\sigma)}_{\text{change in h.c. dispersion}} \quad (4)$$

Now I turn to optimal individual decisions. For interior solutions of  $e$ , the optimal

investment to income ratio is

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

Substitute  $e$  back into the human capital production function, we have

$$\log(h') = A + \log(\epsilon) + f(\xi; \vec{\delta}) + (\rho + \psi_2(\delta_1 + \delta_2\xi)) \log(h) \quad (5)$$

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

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

The dynamics of Equation (5) indicate that when  $\log(h)$  is normal,  $\log(h')$  stays normal. The transition path of human capital distribution is therefore analytically characterized:

$$\begin{cases} \mu' = A + f(\xi; \vec{\delta}) + (\rho + \psi_2(\delta_1 + \delta_2\xi)) \cdot \mu - \sigma_\epsilon^2/2 \\ (\sigma')^2 = (\rho + \psi_2(\delta_1 + \delta_2\xi))^2 \cdot \sigma^2 + \sigma_\epsilon^2 \\ \xi = (\psi_1 - \psi_2) \cdot \sigma\theta \end{cases} \quad (6)$$

The system in (6) has a close relationship to [Bénabou \(2002\)](#) which exploits the properties of the normal distribution to study the relationship between tax and education policies. The key difference here is the third equation in (6) where teacher quality  $\xi$  is an endogenous object and enters the evolution of human capital. As a result, changing  $\psi_1$  or  $\psi_2$  has dynamic implications through  $\xi$  and endogenous human capital distribution.

Equation (6) also highlights the key role that  $\delta_2$  plays in determining whether teacher quality is amplified or dampened when the dispersion of human capital  $\sigma$  is endogenous. Consider a small decrease of  $\xi$  and focus on how  $\sigma'$  changes. If  $\delta_2 < 0$ , then the intergenerational persistence  $(\rho + \psi_2(\delta_1 + \delta_2\xi))$  is higher and we have higher  $\sigma'$ . This feeds back to the determination of teacher quality in the next period and leads to further declines in  $\xi'$ . On the other hand,  $\sigma'$  will be smaller when teacher quality decreases when  $\delta_2 > 0$ . Therefore, relating back to the human capital production function in Equation (2), endogenous human capital amplifies (dampens) changes in selection if and only if teacher quality is gross substitute (complement) to parental investments.

### 3. Identification and Calibration

In this section, I carry out the calibration of the model by proving identification and finding empirical counterparts to the model's predictions.

#### 3.1 Model Identification

The objects that need to be identified include

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

The steady-state of the model can be summarized in the following equations:

$$\frac{\mathbb{E}(y_1)}{\mathbb{E}(y_2)} = w \cdot \exp \left( \mu(\psi_1 - \psi_2) + \frac{\sigma^2}{2}(\psi_1 - \psi_2)(\psi_1 + \psi_2 + 2\psi_1\theta) \right) \quad (7)$$

$$\text{CV}(y_1) = \sigma\psi_1 \quad (8)$$

$$\text{CV}(y_2) = \sigma\psi_2 \quad (9)$$

$$\pi = (w\kappa)^\theta \cdot \exp \left( \frac{\mu\xi}{\sigma} + \frac{\xi^2}{2} \right) \quad (10)$$

$$\xi = (\psi_1 - \psi_2) \cdot \theta\sigma \quad (11)$$

$$\text{IGE} = \rho + \psi_2(\delta_1 + \delta_2\xi) \quad (12)$$

$$\sigma^2 = \frac{\sigma_\epsilon^2}{1 - \text{IGE}^2} \quad (13)$$

$$\mu = \frac{A + \delta_0\xi + (\delta_1 + \delta_2\xi) \cdot \log \left( \frac{e}{y} \right) - \sigma_\epsilon^2/2}{1 - \text{IGE}} \quad (14)$$

$$\frac{e}{y} = \beta(\delta_1 + \delta_2\xi) \quad (15)$$

where  $\text{CV}(x)$  denotes the coefficient of variation of variable  $x$  and IGE denotes intergenerational elasticity of earnings when both parent and children work as non-teachers.

I can measure  $\mathbb{E}(y_1)$ ,  $\mathbb{E}(y_2)$ ,  $\text{CV}(y_1)$ ,  $\text{CV}(y_2)$ ,  $\pi$ , IGE,  $e/y$  in the data - more details below. Because the unit of human capital is undetermined, I have the freedom to make one normalization. After normalizing  $\psi_2 = 1$ , I need more information because there are 14

unknowns with 9 equations.<sup>4</sup> I can gather additional information from the model's comparative statics regarding a small change to the returns to human capital in the teacher market  $\psi_1$ :

$$\frac{\partial \overline{\log(y')}}{\partial \psi_1} = \psi_2 \cdot \underbrace{\frac{\sigma \theta}{\frac{\partial \xi}{\partial \psi_1}}}_{\text{direct}} \left[ \underbrace{\delta_0 + \delta_2 \log(e/y) + \psi_2 \delta_2 \mu}_{\text{direct}} + \underbrace{\beta \delta_2 \cdot \frac{\delta_1 + \delta_2 \xi}{e/y}}_{\text{indirect}} \right] \quad (16)$$

$$\frac{\partial^2 \log y'}{\partial \psi_1 \partial \log y} = \sigma \theta \cdot \psi_2 \cdot \delta_2 \quad (17)$$

$$\frac{\partial \mathbb{E}(y_1)}{\partial \psi_1} = \mathbb{E}(y_1) \cdot (\mu + \sigma^2(\psi_1 + \theta(2\psi_1 - \psi_2))) \quad (18)$$

$$\frac{\partial \pi}{\partial \psi_1} = \pi \cdot (\theta \mu + \sigma \theta \xi) \quad (19)$$

where  $y'$  denotes the average earnings of the next generation.

Equation (16) and (17) quantify how changes in  $\psi_1$  affect income in the next generation. In (16), the effect on next generation's average income combines a direct effect coming from changes in teacher quality  $\xi$  and an indirect effect capturing parents' responses through endogenous investments  $e$ . Equation (17) highlights that the key parameter  $\delta_2$  is identified from the differential impacts across parents with different income. On the other hand, Equations (18) and (19) quantifies how changes in  $\psi_1$  affect teacher employment and outcome.

With these additional information, the identification argument is presented next.

**Proposition 1:** The model is identified up to the calibration of  $\rho$  if we observe  $\mathbb{E}(y_1)/\mathbb{E}(y_2)$ ,  $\text{CV}(y_1)$ ,  $\text{CV}(y_2)$ ,  $\pi$ , IGE,  $e/y$  and measure the left-hand-sides of Equations (16)-(19).

*Proof.* Given that  $\psi_2 = 1$ , Equation (9) identifies  $\sigma$ ; then Equation (8) identifies  $\psi_1$ ; Equation (13) identifies  $\sigma_\epsilon$ . Combining Equations (18) and (19) by substituting out  $\mu$  identifies  $\theta$ . Then, Equation (11) identifies  $\xi$ ; Equation (19) identifies  $\mu$ ; Equation (7) identifies  $w$ ; Equation (10) identifies  $\kappa$ ; Equation (17) identifies  $\delta_2$ ; Equation (12) identifies  $\delta_1$  given that I calibrated  $\rho$ ; Equation (15) identifies  $\beta$ ; and lastly Equation (14) identifies  $A$ .  $\square$

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<sup>4</sup>Normalizing  $\psi_2 = 1$  is without loss of generality. It is equivalent to normalizing  $\psi_1$ ,  $\sigma_\epsilon$ , or  $A$ .

### 3.2 Empirical Evidence

I measure the left-hand-sides of Equations (16)-(19) using the variations coming from the passage of duty-to-bargain (DTB) laws across states between 1960 and 1996.

Prior to 1960, teachers' unions in the United States played little role in the negotiation of contracts between teachers and school district and collective bargaining took place in only some large, urban school districts. Beginning with Wisconsin in 1960, however, states start to pass public sector duty-to-bargain (DTB) laws, which mandated that districts have to negotiate in good faith with a union that has been elected for the purposes of collective bargaining. These laws gave considerable power to teachers' unions in the collective bargaining process, leading to a sharp rise in teacher unionization and collectively bargained contracts.

To examine the (differential) effects of DTB laws on the next generation's human capital and income, [Lovenheim and Willén \(2019\)](#) run the regression

$$Y_i = \alpha_1 \cdot \text{DTB exposure}_i + \zeta X_i + \varepsilon \quad (20)$$

using individual-level data from the American Community Survey (ACS). They find that a 10-year exposure to teachers under DTB laws reduces annual earnings by 2.36% (averaging men and women). Moreover, compared with Black and Hispanic children, the negative effects are 4.9 percentage points smaller among White and Asian children, whose parents had 60% higher income after adjusting for the number of children (calculated using data from the Current Population Survey (CPS) March Supplement). Similar findings are also reported in [Tincani \(2021\)](#) where the authors find that tying public school teacher wages to skills and introducing minimum competency requirement for teacher reduce the achievement gap between the poorest and richest 25% of students by a third.

Complementing their findings on children's earnings, I run additional regressions to measure Equations (18) and (19). In particular, I collect data on full-time workers from the CPS-ASEC, categorize whether individuals are teachers or not based on occupation codes, and use standard two-way fixed effects methods to examine the how duty-to-bargain laws affect employment share and teacher earnings statistics

$$Y_{\text{state,year}} = \alpha_2 \cdot \text{DTB}_{\text{state,year}} + \text{State FE} + \text{Year FE} + \varepsilon \quad (21)$$

where observations are at state-year level. The regression results are shown in Table 2.

Table 2: Regression Results

	(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.

I find that DTB laws have negative (but statistically insignificant) effects on average earnings of teachers  $\mathbb{E}(y_1)$  while reducing the coefficient of variations of teacher earnings by 0.03 from a base of 0.56. In addition, DTB laws reduce teacher employment share by 0.35 percentage points from a base of 4.6%. These findings are consistent with the literature that uses the recent expiration of collective bargaining agreements in some states as a source of exogenous variation. In particular, [Biasi et al. \(2021\)](#) shows that introducing flexible pay scheme attracted teachers from other school districts, raised the salaries of high-quality teachers, increased teacher pay dispersion measured by the coefficient of variation, and resulted in higher teacher quality.

Overall, the regression results are consistent with the interpretation that these laws mainly affect teacher market by changing the returns to human capital  $\psi_1$ . One potential worry is that variations in employment and wages could also reflect other effects of DTB laws, such as changes in relative wages  $w$  or entry barriers  $\kappa$ . I provide a detailed discussion about how this possibility affects the identification and our results in Section 5.

To utilize these estimates, I revisit Equations (16)-(19) and rewrite them as:

$$\frac{\Delta \overline{\log(y')}}{\Delta \psi_1} = \text{CV}(y_2) \cdot \theta \left[ \delta_0 + \delta_2 \log(e/y) + \psi_2 \delta_2 \mu + \beta \delta_2 \cdot \frac{\delta_1 + \delta_2 \xi}{e/y} \right] \quad (16')$$

$$\frac{\Delta^2 \log y'}{\Delta \psi_1 \Delta \log y} = \theta \delta_2 \cdot \text{CV}(y_2) \quad (17')$$

$$\frac{\Delta \log(y_1)}{\Delta \psi_1} = \mu + \sigma^2(\psi_1 + \theta(2\psi_1 - \psi_2)) \quad (18')$$

$$\frac{\Delta\pi}{\pi\Delta\psi_1} = \theta\mu + \sigma\theta\xi \quad (19')$$

The regression results in Table 2, together with the estimates in Lovenheim and Willén (2019), inform the left-hand-sides of these equations. In addition, the magnitude of changes in  $\psi_1$  can be measured using changes in the coefficient of variations in teachers' earnings:

$$\Delta\psi_1 = \psi_1 \cdot \frac{\Delta CV(y_1)}{CV(y_1)} \quad (22)$$

### 3.3 Calibration Results

I calibrate  $\rho = 0.6 \times \text{IGE}$  following the results in Lefgren et al. (2012). It represents a “measure of ignorance” in our understandings of the determinants of intergenerational mobility. Other target moments, including  $\frac{\mathbb{E}(y_1)}{\mathbb{E}(y_2)} = 0.96$ ,  $CV(y_1) = 0.56$ ,  $CV(y_2) = 0.77$ ,  $\pi = 4.6\%$ ,  $\text{IGE} = 0.36$ , and  $e/y = 0.05$ , are derived from the Current Population Survey (CPS), the Panel Study of Income Dynamics (PSID), and the past literature on parental investments in children's education (Lee and Seshadri 2019, Daruich 2018) for years closest to 2000. Because the model is just identified, these data moments will be exactly matched in the calibration procedure following Proposition 1.

Table 3: Calibration Results

Human capital formation parameters			Preference parameters		Value
$\delta_0$	teacher effect (level)	-0.48	$\kappa$	teacher cost	0.21
$\delta_1$	investment effect	-0.42	$\theta$	taste shock dispersion	3.07
$\delta_2$	teacher effect (gradient)	-0.88	$\beta$	weight on children's h.c.	0.35
$A$	TFP of h.c. production	1.12			
$\rho$	residual persistence	0.22			
$\sigma_\epsilon$	ability shock dispersion	0.72			
Labor market parameters			Equilibrium objects		Value
$\psi_1$	skill bias (teachers)	0.73	$\xi$	teacher quality	-0.64
$\psi_2$	skill bias (non-teachers)	1	$w$	relative wage	2.18
			$\mu$	average h.c.	1.15
			$\sigma$	h.c. dispersion	0.77

Notes: This table displays the calibration results. See text for the identification and target moments.

The parameters of particular interest are those in the human capital production function. Combining the results on  $\{\delta_0, \delta_1, \delta_2\}$  with the observed level of  $e/y$ , I find that a one standard deviation change of teacher quality throughout ones' education leads to a rise in human capital by 1.6 percent. The implied result from the structural model here is slightly larger but broadly consistent with [Chetty et al. \(2014a\)](#), who conclude that “a one standard deviation increase in teacher quality in a single grade raises annual earnings by 1.3 percent.” The result that  $\delta_2 < 0$  is of particular importance because as discussed before, it implies that the endogenous human capital formation serves as an amplifying mechanism of the teacher selection channel and that public schooling serves as the “great equalizer” in the economy ([Agostinelli et al. 2022](#)). Using the approximation formula in [Kmenta \(1967\)](#), the implied elasticity of substitution between parental investment and teacher quality is around 2 in the calibrated model. This value is consistent with existing estimates, such as 1.92 by [Blankenau and Youderian \(2015\)](#) and 2.43 by [Kotera and Seshadri \(2017\)](#).

## 4. Counterfactual Analyses

In this section, I analyze two counterfactual to better understand the role of teacher quality and human capital formation in shaping the dynamics of inequality and intergenerational mobility.

### 4.1 Performance-Based Compensation

In the first counterfactual, I permanently increase the returns to human capital by 5% in the teaching profession to mimic a performance-based compensation. The magnitude of 5% is chosen to be the same as the initial impacts that duty-to-bargain laws had on the income dispersion among teachers in the empirical findings, albeit in a different direction. Figures [1a](#) to [1d](#) shows the transition path of  $CV(\text{teacher})$ ,  $CV(\text{non-teacher})$ , teacher quality  $\xi$ , and IGE from the original economy to the new steady state.

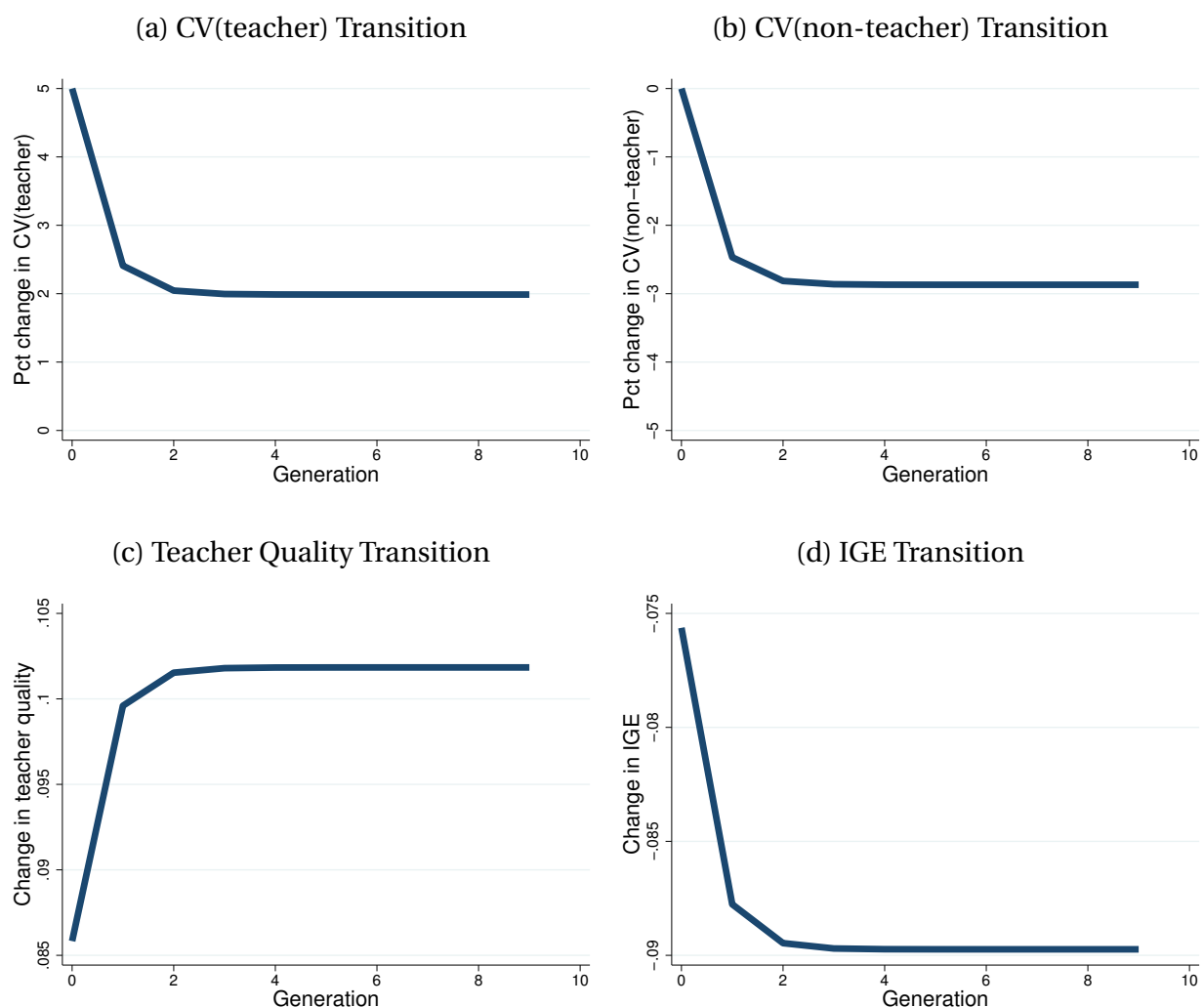
I find that inequality within the teaching profession jumps initially. But in the long-run steady-state, only two-fifth of the initial impacts on  $CV(\text{teacher})$  survive. In contrast,  $CV(\text{non-teacher})$  decreases drastically by 3%, reflecting changes in the dispersion of human capital  $\sigma$ . Intergenerational elasticity of earnings falls from 0.36 to 0.27, due to the fact that higher teacher quality diminishes the role of private parental investments and



hence intergenerational persistence of human capital.

The results also indicate that the magnitude of these effects vary along the transition path. In particular, empirical analyses that focus on short-run effects, i.e.,  $t = 0$  or  $t = 1$ , could overstate the effects of performance-based compensation on  $CV(\text{teacher})$  and understate the dynamic effects on teacher quality  $\xi$ , non-teacher inequality  $CV(\text{non-teacher})$ , and intergenerational mobility IGE.

**Figure 1: Increasing Return to Human Capital Among Teachers**



*Notes:* These figures plot the transition path of  $CV(\text{teacher})$ ,  $CV(\text{non-teacher})$ , teacher quality  $\xi$ , and IGE following a 5% permanent increase of  $\psi_1$  in the steady-state economy.

## 4.2 Skill-Biased Technical Change

In the second counterfactual, instead of changing  $\psi_1$ , I let  $\psi_2$  rise by 1% permanently to mimic a small skill-biased technical change (SBTC), i.e., the “convexification” of the non-teaching labor market (Autor et al. 2020). Figures 2a to 2d shows the transition path of CV(teacher), CV(non-teacher), teacher quality  $\xi$ , and IGE from the original economy to the new steady state.

I find that when  $\psi_2$  increases, it not only raises inequalities within non-teachers but also those within teachers, reflecting changes in  $\sigma$ . Higher returns to human capital in non-teaching occupations attract the most talented workers and reduce teacher quality, with the effects being much larger in the long run (see Figure 2a). Interestingly, intergenerational elasticity of earnings increases for two reasons. The first reason is the same as that in the previous counterfactual - reduced teacher quality raises the role of parental investments and hence intergenerational persistence. The second reason is that the dispersion of parental income is also greater due to higher  $\psi_2$ , magnifying disparities in parental investments.

To better understand the relative importance of these different channel, I conduct a model-based decomposition of CV( $y_2$ ) in the following steps:

1. First, because  $CV(y_2) \equiv \sigma\psi_2$ , I decompose  $CV(y_2)$ :

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

I find that the direct effect of changing  $\psi_2$  accounts for 48% of total changes in CV( $y_2$ ) in the long run, with the rest being explained by changing  $\sigma$ .

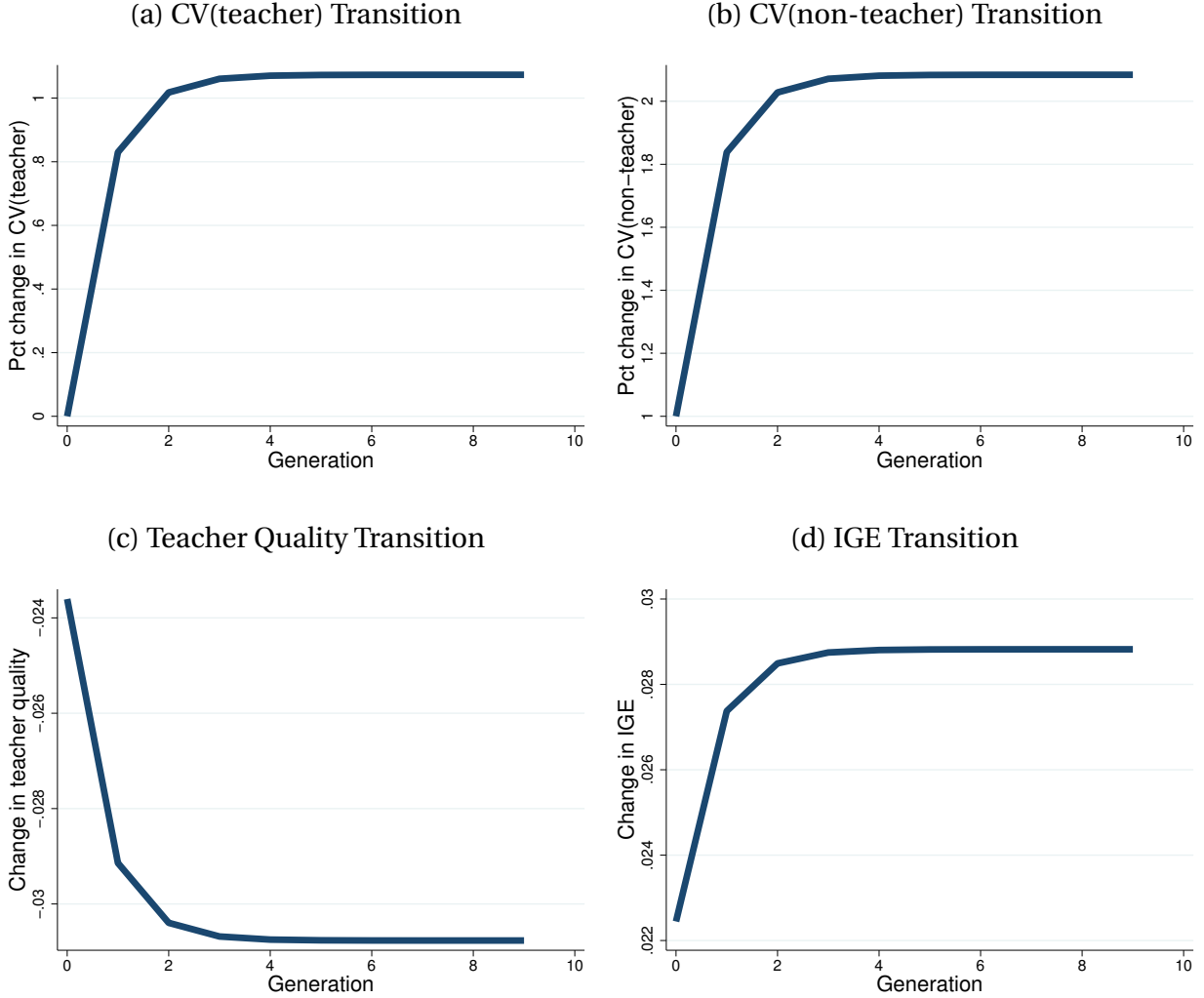
2. To understand what drives changes in  $\sigma$ , I conduct a decomposition of IGE because in the steady-state  $\sigma$  is proportional to  $\sqrt{1 - IGE^2}$ . The formula  $IGE = \rho + \psi_2(\delta_1 + \delta_2\xi)$  motivates the following decomposition:

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

I find that teacher quality channel accounts for 94% of changes in IGE with the rest being explained by changes in parental income dispersion.

These decomposition results lead to an intriguing policy implication. Suppose  $\psi_2$  increases by 1%, one can counteract its contemporaneous effects on teacher quality by

Figure 2: Skill-Biased Technical Change



Notes: These figures plot the transition path of CV(teacher), CV(non-teacher), teacher quality  $\xi$ , and IGE following a 1% permanent increase in  $\psi_2$  in the steady-state economy.

also raising  $\psi_1$  by 1%. But with the additional channel through parental income, this 1% increase is not enough to maintain teacher quality in later periods. Therefore, to neutralize the effects of the SBTC, the returns to human capital in the teaching profession needs to rise *relatively more* than that in the non-teaching profession. If instead, policymakers or teacher unions shield teachers from rising inequality elsewhere by reducing  $\psi_1$ , income inequalities among non-teachers will become even more severe in the future.

## 5. Robustness

In this section, I discuss the robustness of the main results.

### 5.1 Mapping DTB Laws to the Model

As discussed before, one potential worry is that variations in employment and wages following DTB laws could also reflect changes in relative wages  $w$  or entry barriers  $\kappa$ . In that case, instead of Equations (18') and (19'), we have

$$\begin{cases} \Delta \log(y_1) = \Delta \psi_1 [\mu + \sigma^2(\psi_1 + \theta(2\psi_1 - \psi_2))] + \Delta w \\ \frac{\Delta \pi}{\pi} = \Delta \psi_1 \cdot (\theta \mu + \sigma \theta \xi) + \theta(\Delta w + \Delta \kappa) \end{cases} \quad (23)$$

Note that potential changes in  $w$  and  $\kappa$  does not affect the interpretation of other equations including (16'), (17'), and (22) because they do not alter teacher quality  $\xi$  in the model. They, however, do affect the calibration of other parameters. I divide the analysis into three cases.

First, suppose DTB laws affect entry barriers  $\kappa$  but not relative wage  $w$ . Then Equation (18') survives but equation (19') is contaminated because I do not have a direct measure of  $\Delta \kappa$  in the data. In this case, I need to calibrate  $\theta$  outside of the model and choose a value from the literature. An important insight here is that different value of  $\theta$  does not affect the calibration of other variables except  $\{\delta_0, \delta_2, \xi, w, \kappa\}$ , and the results in all counterfactuals remain unchanged.

To see this, suppose  $\theta$  is doubled. To make Equation (17') hold,  $\delta_2$  needs to halve. Similarly,  $\delta_0$  needs to halve to make Equation (16') hold.  $\xi$  needs to double because  $\xi = (\text{CV}(y_1) - \text{CV}(y_2)) \cdot \theta$ . Lastly,  $w$  and  $\kappa$  needs to adjust to maintain Equations (7) and (10). Beyond that, no other parameters need to change because  $\delta_0$ ,  $\delta_2$ , and  $\xi$  enter the rest of the model, especially human capital dynamics, in a multiplicative fashion and these changes exactly cancel out.

Second, suppose DTB laws affect  $w$  but not  $\kappa$ . I can multiply the first equation in (23) by  $\theta$  and subtract the second equation to cancel out  $\Delta w$ . Then, I can proceed like the previous case by calibrating  $\theta$  exogenously. The results in counterfactuals are not affected.

Last, suppose DTB laws affect  $w$  as well as  $\kappa$ . Then the empirical results on how DTB laws affect teacher labor markets are not informative about parameters and I need to

find additional calibration targets. One option is to equate the effects of a one standard deviation increase in teacher quality on children's income, which is  $(\delta_0 + \delta_2 \log(e/y)) \cdot \psi_1$  in the model, to existing empirical estimates (e.g., [Chetty et al. 2014a](#)). Then, I can calibrate  $\theta$  exogenously, and the counterfactual results are again not affected. As discussed before, when I compare teacher value added in the model to [Chetty et al. \(2014a\)](#) after calibration, the two values are quite similar.

To sum up, while potential changes in  $w$  and  $\kappa$  threaten the identification of  $\theta$ , the counterfactual results will not be affected if I calibrate  $\theta$  exogenously outside of the model.

## 5.2 Heterogeneous Preference

In the baseline model, I have assumed that the idiosyncratic preference shock  $\nu$  is not correlated with human capital  $h$ . Suppose instead there is a systematic relationship between taste and human capital, consider

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

where  $\psi_3$  governs the degree of correlation and  $\tilde{\nu}$  is an idiosyncratic shock.

Then, individual's choice problem becomes

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

This leads to changes in the formulas of  $\pi$  and  $\xi$  where  $\psi_1$  needs to be replaced by  $\psi_1 + \psi_3$ , which also implies that there is an additional parameter  $\psi_3$  to be calibrated.

One solution is to equate the effects of a one standard deviation increase in teacher quality on children's income, which is  $(\delta_0 + \delta_2 \log(e/y)) \cdot (\psi_1 + \psi_3)$  in this case, to existing empirical estimates (e.g., [Chetty et al. 2014a](#)). This gives an additional condition that allows us to separately identify  $\psi_3$  from  $\psi_1$  (which is identified using the dispersion of teachers' earnings). As discussed before, when I compare teacher value added in the model to [Chetty et al. \(2014a\)](#) after calibration, the two values are quite similar. This implies that the main results will not be significantly affected if I allow this form of correlation between preference and human capital.

## 6. Conclusion

In this paper, I study how teacher selection affects inequality and intergenerational mobility. In a model with occupation choice and child investments, I investigate the feedback mechanism between teacher quality and human capital distribution. Human capital dispersion amplifies the selection channel in determining teacher quality, and teacher quality affects the degree of dispersion itself through human capital formation. The model is identified using empirical evidence on how duty-to-bargain laws affect teacher labor market and children's long-run outcomes. In counterfactuals, I find that tying compensation to performance in the teaching profession raises income inequality among teachers but reduces inequality among non-teachers and improves intergenerational mobility. Teacher labor market also plays an important role in propagating aggregate shocks. In particular, I find that increasing returns to human capital among teachers could alleviate the effects of skill-biased technical change on inequalities.

Lastly, I would like to suggest that while this paper studies teachers, the same argument holds for other occupations, such as doctors and elected officials, as long as worker quality spills over to the productivity of future generations. These effects can be quantified in the same way through combining structural modeling and empirical analysis. I leave this as interesting future avenues of research.

## References

- Acemoglu, Daron, “Reward structures and the allocation of talent,” *European Economic Review*, 1995, 39 (1), 17–33.
- Agostinelli, Francesco, Margaux Luflade, Paolo Martellini et al., “On the spatial determinants of educational access,” Technical Report 2021.
- , Matthias Doepke, Giuseppe Sorrenti, and Fabrizio Zilibotti, “When the great equalizer shuts down: Schools, peers, and parents in pandemic times,” *Journal of Public Economics*, 2022, 206, 104574.
- Autor, David, Claudia Goldin, and Lawrence F Katz, “Extending the race between education and technology,” in “AEA Papers and Proceedings,” Vol. 110 American Economic Association 2014 Broadway, Suite 305, Nashville, TN 37203 2020, pp. 347–351.
- Bacolod, Marigee P, “Do alternative opportunities matter? The role of female labor markets in the decline of teacher quality,” *The Review of Economics and Statistics*, 2007, 89 (4), 737–751.
- Baumol, William J, “Entrepreneurship: Productive, unproductive, and destructive,” *Journal of business venturing*, 1996, 11 (1), 3–22.
- Bénabou, Roland, “Tax and education policy in a heterogeneous-agent economy: What levels of redistribution maximize growth and efficiency?,” *Econometrica*, 2002, 70 (2), 481–517.
- Biasi, Barbara, Chao Fu, and John Stromme, “Equilibrium in the market for public school teachers: District wage strategies and teacher comparative advantage,” Technical Report, National Bureau of Economic Research 2021.
- Blankenau, William and Xiaoyan Youderian, “Early childhood education expenditures and the intergenerational persistence of income,” *Review of Economic Dynamics*, 2015, 18 (2), 334–349.
- Bold, Tessa, Deon Filmer, Gayle Martin, Ezequiel Molina, Brian Stacy, Christophe Rockmore, Jakob Svensson, and Waly Wane, “Enrollment without learning: Teacher effort, knowledge, and skill in primary schools in Africa,” *Journal of Economic Perspectives*, 2017, 31 (4), 185–204.
- Borjas, George J, “The wage structure and the sorting of workers into the public sector,” 2002.

- Card, David, Ciprian Domnisoru, and Lowell Taylor, “The intergenerational transmission of human capital: Evidence from the golden age of upward mobility,” *Journal of Labor Economics*, 2022, 40 (S1), S39–S95.
- Caucutt, Elizabeth M and Lance Lochner, “Early and late human capital investments, borrowing constraints, and the family,” *Journal of Political Economy*, 2020, 128 (3), 1065–1147.
- Chetty, Raj, John N Friedman, and Jonah E Rockoff, “Measuring the impacts of teachers II: Teacher value-added and student outcomes in adulthood,” *American Economic Review*, 2014, 104 (9), 2633–2679.
- , Nathaniel Hendren, Patrick Kline, and Emmanuel Saez, “Where is the land of opportunity? The geography of intergenerational mobility in the United States,” *The Quarterly Journal of Economics*, 2014, 129 (4), 1553–1623.
- Corak, Miles, “Income inequality, equality of opportunity, and intergenerational mobility,” *Journal of Economic Perspectives*, 2013, 27 (3), 79–102.
- Cortes, Patricia and Jessica Pan, “Occupation and gender,” *The Oxford handbook of women and the economy*, 2018, pp. 425–452.
- Daruich, Diego, “The macroeconomic consequences of early childhood development policies,” *FRB St. Louis Working Paper*, 2018, (2018-29).
- Durlauf, Steven N and Ananth Seshadri, “Understanding the Great Gatsby curve,” *NBER Macroeconomics Annual*, 2018, 32 (1), 333–393.
- Fogli, Alessandra and Veronica Guerrieri, “The end of the american dream? inequality and segregation in us cities,” Technical Report, National Bureau of Economic Research 2019.
- Fu, Chao, Junjie Guo, Adam J Smith, and Alan Sorensen, “Students’ heterogeneous preferences and the uneven spatial distribution of colleges,” *Journal of Monetary Economics*, 2022, 129, 49–64.
- Hanushek, Eric A, “The economic value of higher teacher quality,” *Economics of Education Review*, 2011, 30 (3), 466–479.



- Hoxby, Caroline M and Sarah Turner, "What high-achieving low-income students know about college," *American Economic Review*, 2015, 105 (5), 514–517.
- Hoxby, Caroline Minter, "How teachers' unions affect education production," *The Quarterly Journal of Economics*, 1996, 111 (3), 671–718.
- King, Robert G and Ross Levine, "Finance, entrepreneurship and growth," *Journal of Monetary economics*, 1993, 32 (3), 513–542.
- Kmenta, Jan, "On estimation of the CES production function," *International Economic Review*, 1967, 8 (2), 180–189.
- Kotera, Tomoaki and Ananth Seshadri, "Educational policy and intergenerational mobility," *Review of Economic Dynamics*, 2017, 25, 187–207.
- Lee, Sang Yoon and Ananth Seshadri, "On the intergenerational transmission of economic status," *Journal of Political Economy*, 2019, 127 (2), 855–921.
- Lefgren, Lars, David Sims, and Matthew J Lindquist, "Rich dad, smart dad: Decomposing the intergenerational transmission of income," *Journal of Political Economy*, 2012, 120 (2), 268–303.
- Lovenheim, Michael F, "The effect of teachers' unions on education production: Evidence from union election certifications in three midwestern states," *Journal of Labor Economics*, 2009, 27 (4), 525–587.
- and Alexander Willén, "The long-run effects of teacher collective bargaining," *American Economic Journal: Economic Policy*, 2019, 11 (3), 292–324.
- Murphy, Kevin M, Andrei Shleifer, and Robert W Vishny, "The allocation of talent: Implications for growth," *The quarterly journal of economics*, 1991, 106 (2), 503–530.
- Rivkin, Steven G, Eric A Hanushek, and John F Kain, "Teachers, schools, and academic achievement," *Econometrica*, 2005, 73 (2), 417–458.
- Rothstein, Jesse, "Teacher quality policy when supply matters," *American Economic Review*, 2015, 105 (1), 100–130.

Roy, Andrew Donald, “Safety first and the holding of assets,” *Econometrica*, 1952, pp. 431–449.

Seshadri, Ananth, “Specialization in education,” Technical Report, mimeo, University of Wisconsin 2000.

Tincani, Michela M, “Teacher labor markets, school vouchers, and student cognitive achievement: Evidence from Chile,” *Quantitative Economics*, 2021, 12 (1), 173–216.

Yum, Minchul, “Parental time investment and intergenerational mobility,” *International Economic Review*, 2023, 64 (1), 187–223.