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GOVERNMENT EXPENDITURE ON THE PUBLIC EDUCATION SYSTEM*

BY CHAO FU, SHOYA ISHIMARU, AND JOHN KENNAN

University of Wisconsin and NBER, USA; Hitotsubashi University, Japan

We investigate equilibrium impacts of federal policies such as free-college proposals, taking into account that human capital is cumulative and that state governments have resource constraints. In our model, a state government cares about household welfare and aggregate educational attainment. The government chooses income tax rates, per-student expenditures on K-12 and college education, college tuition, and the provision of other public goods. We estimate the model using U.S. data. Our simulations suggest that free-college policies would decrease state expenditure on education. More students would obtain college degrees. Most households would "pay" for the free-college policies through negative welfare effects.

1. INTRODUCTION

As one of the most important determinants of one's lifetime income, college education has attracted much policy interest, largely centered around accessibility. For example, the Obama administration proposed free tuition in two-year public colleges; Senator Bernie Sanders proposed free tuition in all public colleges in his 2016 and 2020 presidential campaigns; the American Families Plan proposed by President Biden would guarantee two years of free community college. Policies of this sort are meant to improve college opportunities for disadvantaged individuals. However, to assess these policies, one needs to look beyond their intended effects and account for at least two factors. First, human capital production is a cumulative process, in that later achievements rely on investments made in the past.[1] As such, if precollege investment by households and/or government does not increase for disadvantaged students, free college education alone may not help them effectively.[2] Second, without revenues from college tuition, the government may have fewer resources to invest in the public education system: K-12 and college. After all, how free can "free" colleges be?

We develop and estimate an equilibrium model that incorporates the factors mentioned above in a coherent framework. In the model, educational outcomes depend on student characteristics (including past achievement) and monetary inputs, that is, tuition in the private sector and government expenditure in the public sector, via technologies that may differ across the two sectors. Agents in the model include a government and a distribution of households. The government makes decisions on income tax rates, per-student expenditure levels on public K-12 and college education, college tuition, and the provision of other public goods, subject to a budget constraint. Households care about consumption, their children's education,

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[1] See, for example, Becker (1975), Todd and Wolpin (2003), Restuccia and Urrutia (2004), Cunha and Heckman (2007), Cunha et al. (2010), and Del Boca et al. (2013).

[2] Conversely, if households increase investment in their children's precollege education in expectation of easier college access, the impact of free-tuition policies can be enhanced.

and the burden of college loans. Taking the government's decision as given, households first choose between private and public K-12 schools. Then, given how well students have performed at the K-12 level, households may choose further education at the college level. The college options consist of two-year colleges and four-year public or private colleges. In order to finance their children's college education, households can receive financial aid and they also have access to student loans. Realizing that household choices and hence equilibrium outcomes vary with its decisions, the government chooses the policy that maximizes its objective, which involves household welfare (with welfare weights that may differ across household categories) and which may also involve aggregate educational attainment.

Although the essence of the model and its main policy implications apply to any public education system, the United States is a particularly interesting case. Public expenditure on education in the United States is largely controlled at the state level, with significant cross-state variation in education outcomes and in the proportions of revenues allocated to lower and higher education. We treat each state in the United States as a single economy in our empirical application. States differ observably in their (nontax) revenues and distributions of households, and unobservably in how productive their public education systems are, which jointly lead to different government policies and equilibrium outcomes. We estimate the model via indirect inference; our main data sources are the Education Longitudinal Study (ELS), the American Community Survey (ACS), and the Survey of Governments. In particular, we estimate structural parameters that are essential information for assessing counterfactual education policies, including parameters governing educational production technologies, household preferences, and state government objectives.

We use our estimated model to evaluate the effects of counterfactual free-college policies. Presumably, policy interventions of this kind aim to increase educational attainment (especially among low-income households who may be borrowing-constrained) and to redistribute resources toward disadvantaged groups. We are interested in measuring the extent to which such interventions might succeed after accounting for how a state government would respond.

We evaluate two alternative free-college policies. The first mandates that state governments charge zero tuition in public colleges. In response, state governments increase tax rates and decrease per-student expenditure on both K-12 and college education. College enrollment increases but the graduation rate decreases from 62% to 57% in public four-year colleges; the net effect is a small increase in the fraction of students with a two-year or four-year college degree. A large majority of households would be worse off in this scenario.

In the second (perhaps more realistic) counterfactual scenario, each state government chooses whether or not to make their colleges free, in exchange for a subsidy from the federal government: The subsidy per enrolled student amounts to a certain fraction of the state's baseline college tuition. The federal subsidy is funded via a proportional increase in federal income taxes paid by all households (including those in states that do not adopt the free-college policy). The total subsidy is an equilibrium outcome that depends on how many state governments take the subsidy, how they change their own policies, and how many students attend public colleges in these states. State and household responses in turn depend on the subsidy rate and the federal tax surcharge. At different federal subsidy rates, we solve for the budget-balancing federal tax surcharge and trace the rate at which states take up the offer, and also the changes in educational outcomes and social welfare. We find that a 10% subsidy rate would induce 8% of states to comply, whereas 98% of states would comply at a 30% subsidy rate. In general, subsidized free-college policies lead to less disturbance in state policies. The welfare effects are similar to those in the mandatory case.

Our article relates to several literatures. The first literature studies the effects of cross-state college tuition differences, as summarized in Kane (2006, 2007). A major challenge in these studies is that the variation in tuition levels across states is not random, and that omitted variables may be correlated with both tuition and education outcomes. One approach to tackle this issue has been to use large changes in the net cost of college attendance induced by interventions such as the introduction of the Georgia Hope Scholarship (Dynarski, 2000), the elimination of college subsidies for children of disabled or deceased parents (Dynarski, 2003), and the introduction of the D.C. Tuition Assistance Grant program (Kane, 2007). Using variation in exposure to state budget shocks, Deming and Walters (2018) find large impacts of spending on enrollment and degree completion, with limited impacts of tuition changes. Using a structural model of joint migration and college enrollment decisions, Kennan (2020) finds substantial evidence that both tuition and spending affect enrollment. Murphy et al. (2019) study the shift of the English higher education system from a free-college system to one with high tuition fees, and find that the shift has resulted in increased funding per head, rising enrollments, and a narrowing of the participation gap between advantaged and disadvantaged students. Our approach deals with the nonrandomness of tuition and educational expenditure by explicitly considering how state governments set them given unobserved differences in educational production technologies as well as observed differences in demographic structures and revenue sources. Although the cross-state variation in these variables is not necessarily random either, we show in Section 5 below that tuition and expenditure effects in our estimated model broadly match the results found in studies using quasi-experimental variation. This suggests that the nonrandomness of our explanatory variables is not in fact a major concern.

There is a relatively small recent literature examining education policies while taking into account the dynamic complementarity of human capital investments as highlighted in works such as Cunha and Heckman (2007). For example, Caucutt and Lochner (2020) develop a dynastic model of household investment in children to study the importance of borrowing constraints and uninsured labor market risk. Using the calibrated model, they explore the effects of policies targeted at different ages. Abbott et al. (2019) examine the equilibrium effects of college financial aid policies in an overlapping generations life cycle model and find significant crowd-out of parental transfers by government programs. Also using an overlapping generations life cycle model, Becker et al. (2018) study the interplay of taxation and education subsidy policies. Our article well complements these studies. Although they focus on household responses to given policies, we are more interested in how state policies are chosen in response to federal policies. As such, we embed a simpler and more stylized household decision model in an equilibrium framework with government policy choices. However, it is important to recognize that our results are obtained from a static equilibrium model, whereas the relevant policy variables have been changing during the period that we study. Analyzing the data in the context of a dynamic equilibrium model is a much more challenging problem.

The role of government in education has been studied for a long time.[3] In a general equilibrium model of school attendance, labor supply, wage determination, and aggregate production, Hanushek et al. (2003) compare tuition subsidy and alternative redistribution devices and find that wage subsidies generally dominate tuition subsidies. There is also a literature focusing on the performance of government in providing education, as reviewed by Hanushek (2002), who provides an evaluation of various controversial aspects including issues of causality, consumer behavior, and estimation approaches. Although abstracting from some important details, such as those involving political economy considerations, our article takes a step forward in addressing these issues. We explicitly model dynamic choices by households, the cumulative nature of human capital production, and state governments' decisions on educational expenditure and tuition. Although our work focuses on government decisions at the state level, other studies (e.g., Epple and Sieg, 1999; Epple and Romano, 2003; Ferreyra, 2007, and Epple and Ferreyra, 2008) have explored heterogeneous impacts of school finance reforms across local areas within a state.

The rest of the article is organized as follows. Section 2 describes the model. Section 3 explains our estimation strategy. Section 4 describes the data and our auxiliary models. Section 5

[3] See Friedman (1955), for example

shows the estimation results. Section 6 analyzes the counterfactual experiments. Section 7 concludes. Additional details and tables are in the Appendix.

2. MODEL

There are S states, each treated in isolation. State s is characterized by a state-specific distribution $F_s(x)$ of households with characteristics x, a vector of other observed state characteristics z, and an unobserved productivity vector $\eta_s = (\eta_{s1}, \eta_{s2})$ for public K-12 (η_{s1}) and public college education (η_{s2}).[4] We will suppress the state and individual subscripts s and i except where they are needed for clarity. Time is discrete, with three periods.

- Period 0: The state government chooses its policy $\psi = (\tau, \underline{t}, t, e_1, e_2, g)$: an income tax schedule τ, tuition for public two-year college ($\underline{t}$) and public four-year college (t), per-student expenditure levels for public K-12 education (e_1) and public college education (e_2), and per-capita expenditure on other public goods (g).
- Period 1: With probability $q(x)$, a household with characteristics x will have a child, in which case, they choose public or private K-12 education, denoted as $o_1 \in \{0, 1\}$.[5]
- Period 2: K-12 educational outcomes are realized; households with children make decisions on higher education (o_2) and college debt (d), where $o_2 \in \{0, 1, 2, 3\}$, corresponding to {no college, two-year college, four-year public college, four-year private college}.[6]

2.1. *Technology.* There is a finite number of possible outcomes at each educational stage; these are stage-specific stochastic functions of inputs, via technologies that may differ between the public and the private sectors. All children are exposed to K-12 education, and the outcome is denoted as $k_1 \in \{1, .., 5\}$, with $k_1 = 1$ indicating a dropout and $k_1 = 5$ being the highest quartile of achievement (as measured by test scores). College enrollment is optional, and the outcome is denoted as $k_2 \in \{0, 1, 2\}$ (no college degree, two-year degree, four-year degree).

2.1.1. *K-12 education.* A child can attend the public school for free; the outcome depends on the state and household characteristics z, η_1, and x, as well as the per-student government expenditure e_1 . A household can alternatively pay p_1 for the child to attend private school. As most private schools are nonprofit, private tuition is likely to be highly correlated with how much private schools spend on educating students. As such, we model the outcome of a child as dependent on z, x, and p_1, if she attends private school (for the same reason, we will include private college tuition as an input in the private college production function). The K-12 outcome (k_1) is given by a sector-specific ordered-logit function[7]

$$\tilde{k}_1 \sim \begin{cases} L_1^0(x, z, e_1, \eta_1) & \text{if } o_1 = 0 \\ L_1^1(x, z, p_1) & \text{if } o_1 = 1 \end{cases}. \tag{1}$$

[4] The household characteristics are income (x_1), parental education (x_2), and race (x_3). The observed state characteristics are nontax revenue (z_1) , which includes federal transfer revenue (z_1^f), and region (z_2).

[5] Here, we present a simplified model, where a household makes one choice for the entire K-12 education. In the full model that we apply to the data, one choice is made for elementary education and another for secondary education (see Appendix A.1.1)

[6] In the empirical analysis, students choosing out-of-state public colleges are treated as if they had chosen a private college. Of all four-year college enrollees in our sample, only 8% attended some out-of-state public colleges. Note that the proportion of out-of-state enrollments in the leading public universities is much higher, but these universities are not at all typical. For example, in 2021, the proportion of out-of-state undergraduates at the Ann Arbor campus of the University of Michigan was almost 50%, but the corresponding proportions at the Flint and Dearborn campuses were well below 10%. We further assume that tuition paid by out-of-state students at public colleges is equal to the amount spent on them, with zero net impact on a state government budget. This assumption allows us to avoid having to model inter–state-government strategic interactions. See further discussion in Subsection 2.5.

[7] We use $\tilde{k}_1$ to denote the random variable and k_1 as the realized value (and similarly for other random variables).

2.1.2. *College education.* Students can choose a two-year public college with (gross) tuition $\underline{t}$, or a four-year public college with tuition t, or a private (four-year) college with tuition p_2.[8] Educational outcomes in public colleges depend on z, η_2, x, K-12 achievement (k_1), and per-student total expenditure on higher education e_2. Educational outcomes in the private college depend on x, k_1, and p_2. In order to distinguish two-year degrees from four-year degrees, we denote the outcome variable as $k_2 \in \{0, 1\}$ (no degree, two-year degree) for two-year college outcomes, and $k_2 \in \{0, 2\}$ (no degree, four-year degree) for four-year college outcomes. The outcome is deterministic with $k_2 = 0$ (no college) for high school dropouts ($k_1 = 1$) or those who choose not to attend college ($o_2 = 0$). Otherwise, the outcome k_2 is given by a sector-specific logit function

$$\tilde{k}_2 \sim \begin{cases} L_2^1(k_1, x, z, e_2, \eta_2) & \text{if } o_2 = 1, k_1 > 1 \\ L_2^2(k_1, x, z, e_2, \eta_2) & \text{if } o_2 = 2, k_1 > 1 \\ L_2^3(k_1, x, p_2) & \text{if } o_2 = 3, k_1 > 1 \end{cases}. \tag{2}$$

2.1.3. *Unobserved productivity differences.* We model $\tilde{\eta} \in \{\underline{\eta}_1, \overline{\eta}_1\} \times \{\underline{\eta}_2, \overline{\eta}_2\}$ as a draw from a distribution that varies with population characteristics X, given by

$$\begin{aligned} \Pr(\tilde{\eta}_1 = \overline{\eta}_1 \mid X) &= \mathbb{L}(\rho_{10} + \rho_{11} X), \\ \Pr(\tilde{\eta}_2 = \overline{\eta}_2 \mid X, \eta_1 = \overline{\eta}_1) &= \mathbb{L}(\rho_{20} + \rho_{21} X + \rho_{22}), \\ \Pr\left(\tilde{\eta}_2 = \overline{\eta}_2 \mid X, \eta_1 = \underline{\eta}_1\right) &= \mathbb{L}(\rho_{20} + \rho_{21} X - \rho_{22}), \\ \mathbb{E}(\tilde{\eta}_1) = \mathbb{E}(\tilde{\eta}_2) = 0,\ Var(\tilde{\eta}_1) &= \sigma^2_{\eta_1},\ Var(\tilde{\eta}_2) = \sigma^2_{\eta_2}, \end{aligned} \tag{3}$$

where $\mathbb{L}$ is the logistic function. The parameters (ρ_{11}, ρ_{21}) capture the correlation between a state's educational productivity at the K-12 and college levels and observed state characteristics, whereas ρ_{22} allows for correlation between productivity at the two education levels conditional on the state characteristics. In the estimated model, X in (3) is the fraction of college-educated adults in the state.[9]

2.1.4. *Comment on the production technology.* Two aspects of the production technology deserve comment. First, we allow for unobserved state factors η in the public but not the private education sector, because our data do not have large enough sample size per state for private school students and our focus is on the heterogeneity of public education across states.[10]

Second, households within each x group are assumed to be homogeneous up to random shocks, that is, we abstract from household unobserved heterogeneity (e.g., unobserved ability), which has been the focus of a large literature on households' education choices. Relative to this literature, we have a different goal: studying the equilibrium impact of federal policies across states and across households of different socioeconomic statuses (x). An important confounding factor in studying these effects is unobserved state-level characteristics, which might be correlated with state policies. In particular, a state government chooses its educational expenditure with the knowledge of how productive its investment would be, presumably using more information than we have. A given level of government expenditure in education might yield higher achievements in a state where the educational technology is better or the overall ability of children is higher. However, we cannot distinguish between these two

[8] We abstract from private two-year colleges and model all two-year colleges as in-state and public. Focusing on cross-state heterogeneity in the public sector, we assume a common (average) private four-year college for students in all states.

[9] We have estimated an expanded version of (3) that includes state average income. Since this does little to improve the fit, we chose the simpler specification.

[10] Private K-12 schools differ observably in their tuition levels across states.

explanations. As a way to account for state-level unobservable characteristics, based on which governments make decisions, we allow for differences in educational productivity (η_s).[11]

Another concern is that abstracting from household unobserved ability may bias our estimated effect of private schools on achievement, if households sort into private schools based on unobserved ability. Previous studies on this issue have found little evidence of such selection (e.g., Evans and Schwab, 1995; Neal, 1997; Rouse, 1998, and Altonji et al., 2005). In order to gauge the selection problem in our data, we have also estimated a set of regressions of various measures of educational attainment on observables, comparing ordinary least squares (OLS) and instrumental variables (IV) specifications.[12] Consistent with previous studies, this comparison using our data fails to suggest that households attending private schools have higher unobserved ability.[13]

2.2. *Household Problem.* Given government policy ψ, the problem for households with children can be solved backwards.[14]

2.2.1. *Decision 2: College education.* Let x_1 be household income, and let $A(C, x, k_1)$ be total financial aid (from all sources), which is a function of college cost (C), household characteristics x, and K-12 achievement (k_1). Let $v(x, k_1, k_2, d)$ be the terminal value as a function of household characteristics, educational outcomes (k_1, k_2) and college debt d. The terminal value function includes an interaction between x and d so that the cost of debt differs across households, to allow for the possibility that different households may face different borrowing constraints or other frictions.[15] A household's problem at the college stage is

$$V_2(x, k_1, \epsilon_2; \psi, z, \eta) = \theta(x, z)\ln(g) + \max_{o_2, d \geq 0}\left\{\ln(c_2) + \lambda_2(o_2, x) + \delta\mathbb{E}v\big(x, k_1, \tilde{k}_2(o_2), d\big) + \sigma_2\epsilon_2(o_2)\right\}$$

$$\begin{aligned}\text{s.t. } y(\tau, \tau_0, x_1) + d &= c_2 + C(o_2) - A(C(o_2), x, k_1),\\ C(o_2) &= \underline{t}\mathbb{I}(o_2 = 1) + t\mathbb{I}(o_2 = 2) + p_2\mathbb{I}(o_2 = 3),\\ d &= 0 \text{ if } o_2 = 0.\end{aligned}$$

Households derive utility from consumption, other government expenditure (g), and college enrollment (depending on college type). Households with different characteristics may value public goods and colleges differently (relative to consumption), hence θ and λ_2 are allowed to vary with x.[16] The expectation of $v(\cdot)$ is taken with respect to the random variable $\tilde{k}_2$, which is defined by (2); δ is the annual discount factor. Each choice o_2 is associated with an i.i.d. payoff shock $\epsilon_2(o_2)$, drawn from the standard Type I extreme value distribution, scaled by the

[11] Consider adding unobserved ability (a) to the model, such that the distribution of household characteristics in state s is given by $F_s(x, a) = F_s(a \mid x)F_s(x)$. Assume that the distribution of a conditional on (x, η_s) is common across states, that is, $F_s(a \mid x) = F_0(a \mid x, \eta_s)$. Then, η_s can reflect differences in $F_s(a \mid x)$ across states; moreover, the difference across s arises from differences in $F_s(x)$, z_s, and η_s, instead of household-level a.

[12] Details are in the online appendix.

[13] Since the distribution of private schools may vary with urbanicity levels, we have explored the role of urbanicity in the same set of achievement regressions. Controlling for household characteristics (x in our model), the coefficient of private school attendance is unaffected by the inclusion of the urbanicity variable.

[14] In order to ease notation, we present the model as if the length of each decision stage (K-12, college) is 1 period; in the empirical application, we explicitly account for the fact that the number of periods vary between K-12 and college stages and between two-year and four-year colleges. Details are in Appendix A.1.1.

[15] As such, our model allows for frictions that households face with respect to borrowing. However, we cannot distinguish the role of borrowing limit from, say, debt aversion, which is a limitation.

[16] Note that although we have rich microdata on household choices, these choices are not affected by g, because household preferences are assumed to be additively separable. As will be explained below, we can nevertheless identify this aspect of household preferences indirectly, using information on choices made by governments in different states on behalf of their constituent households. Since we have data for only a relatively small number of governments, we cannot hope to obtain useful estimates of preferences for g unless we restrict the specification of these preferences so that it involves few unknown parameters.

parameter σ_2.[17] The first constraint is the household's budget, where $C(\cdot) - A(\cdot)$ is the net cost of college, and $y(\tau, \tau_0, x_1)$ is after-tax income, given the state tax schedule τ and federal tax schedule τ_0:

$$y(\tau, \tau_0, x_1) = x_1(1 - \tau(x_1) - \tau_0(x_1)).$$

The constraint on d means that loans are available only for college students. Denote the optimal choice as $(o_2^*(x, k_1, \epsilon_2; \psi, z, \eta), d^*(x, k_1, \epsilon_2; \psi, z, \eta))$.

2.2.2. *Decision 1: K-12.* At the K-12 level, the household's problem is

$$V_1(x, \epsilon_1; \psi, z, \eta) = \theta(x, z)\ln(g) + \max_{o_1 \in \{0,1\}} \left\{ \ln(c_1) + \lambda_1(o_1, x) + \delta \mathbb{E} V_2\big(x, \tilde{k}_1(o_1), \tilde{\epsilon}_2; \psi, z, \eta\big) + \sigma_1 \epsilon_1(o_1) \right\}$$

$$\text{s.t.} \quad c_1 + p_1 o_1 = y(\tau, \tau_0, x_1)$$

$$\tilde{k}_1(o_1) \text{ follows (1)},$$

where the term $\lambda_1(o_1, x)$ allows the preference for private relative to public schools to depend on x. Each choice is associated with an i.i.d. payoff shock $\epsilon_1(o_1)$, drawn from the standard Type I extreme value distribution, scaled by the parameter σ_1. The expectation of $V_2(\cdot)$ is taken with respect to $(\tilde{k}_1, \tilde{\epsilon}_2)$. Denote the optimal choice as $o_1^*(x, \epsilon_1; \psi, z, \eta)$.

2.2.3. *Households without children.* Households without children make no decisions in this model. The value function is given by

$$V^0(x; \psi) = (1 + \delta)[\theta(x, z)\ln(g) + \ln(y(\tau, \tau_0, x_1))] + \delta^2 v(x, 0, 0, 0).$$

2.2.4. *Aggregate choices and outcomes.* Given government policy, enrollments in public K-12 education (N_1), two-year colleges (N_{21}), four-year public colleges (N_{22}), and four-year private colleges (N_{23}) are given by

$$(4) \quad N_1 = \sum_x F(x)q(x)\Pr(o_1^*(x, \tilde{\epsilon}; \psi, z, \eta) = 0),$$

$$N_{2j} = \sum_x F(x)q(x)\left[\sum_{o_1 \in \{0,1\}} \Pr(o_1^*(\cdot) = o_1) \sum_{k'} \Pr\big(\tilde{k}_1 = k' \mid x, o_1\big) \Pr\big(o_2^*(x, k', \tilde{\epsilon}; \psi, z, \eta) = j\big)\right], \ j \in \{1, 2, 3\},$$

N_1 is the expected number of households who have children and choose $o_1^*(\cdot) = 0$ (the probability expression here refers to the probability that the realization of the random variable $\tilde{\epsilon}$ is such that public education is the optimal choice). In order to calculate N_{21}, we take the probability that the two-year public college is optimal, given the high school outcome, and integrate over the possible high school outcomes and the K-12 choices (governed by (1), and then aggregate over the distribution of household types. N_{22} and N_{23} are calculated in the same way, and we write $N_2 = (N_{21}, N_{22}, N_{23})$. Similarly, the expected numbers of college graduates are given by

$$K_{21} = \sum_x F(x)q(x)\left[\sum_{o_1 \in \{0,1\}} \Pr(o_1^*(\cdot) = o_1) \sum_{k'} \Pr\big(\tilde{k}_1 = k' \mid x, o_1\big) \Pr\big(o_2^*(\cdot, k', \cdot) = 1\big) \Pr\big(\tilde{k}_2 = 1 \mid k', o_2 = 1\big)\right],$$

$$K_{2j} = \sum_x F(x)q(x)\left[\sum_{o_1 \in \{0,1\}} \Pr(o_1^*(\cdot) = o_1) \sum_{k'} \Pr\big(\tilde{k}_1 = k' \mid x, o_1\big) \Pr\big(o_2^*(\cdot, k', \cdot) = j\big) \Pr\big(\tilde{k}_2 = 2 \mid k', o_2 = j\big)\right], \ j \in \{2, 3\},$$

[17] With this preference shock specification (in contrast to, say, nested logit), we assume common substitutability between public four-year, private four-year, and two-year colleges. This is a simplification, but in Subsection 5.2, we confirm that the estimated model predicts an empirically reasonable substitution pattern.

where $\tilde{k}_2 = 1$ denotes a two-year and $\tilde{k}_2 = 2$ a four-year degree, and we write $K_2 = (K_{21}, K_{22,} K_{23})$.

2.3. *Government Problem.* A government cares about a weighted average of household expected welfare and may also directly care about aggregate educational attainment. Household expected welfare is calculated before the fertility outcome is realized, and is given by[18]

$$V(x; \psi, z, \eta) = q(x) EV_1(x, \epsilon_1; \psi, z, \eta) + (1 - q(x))V^0(x; \psi). \tag{6}$$

Let Ψ be the finite set of policy options, including the zero tuition option.[19] The government solves the following problem:

$$\begin{aligned} \pi(F, z, \eta, \varepsilon) \quad &= \max_{\psi \in \Psi} \left\{ \textstyle\sum_x \omega_x F(x) V(x; \psi, z, \eta) + W(N_2, K_2) + \varepsilon(\psi) \right\} \\ &\text{s.t.} \;\; z_1 + \textstyle\sum_x F(x) \mathcal{T}(x_1) + N_{21} \underline{t} + N_{22} t = e_1 N_1 + e_2(\varphi N_{21} + N_{22}) + g, \end{aligned} \tag{7}$$

where aggregate enrollments and college outcomes are determined by (4) and (5). Here, ω_x is the welfare weight given to households with characteristics x, which is applied to the average welfare of households with and without children. The government's direct preference for aggregate educational outcomes is captured by $W(\cdot)$. Finally, $\varepsilon(\psi)$ is a random shock associated with choosing policy vector ψ; this is drawn from a generalized extreme value distribution detailed in Appendix A.1.5.

The government faces a budget constraint, where revenue includes state income tax $\mathcal{T}(x_1) = \tau(x_1)x_1$, and tuition revenue that depends on government choices, as well as non-tax revenue z_1, which is taken as given. We define z_1 and $\mathcal{T}(x_1)$ as per-household revenue throughout the K-12 and college education periods.[20] In our model, each cohort makes choices over a 16-year period, and what happens after that is summarized in a terminal value function. There is no interaction between this cohort and any other cohort—it is as if each cohort lives in its own closed economy.[21] Government revenue is used to fund public K-12 and college education, as well as other public goods (g).[22] A government's optimal choice is denoted by $\psi^*(F, z, \eta, \varepsilon)$.

Focusing on state governments' choices, we model the state tax schedule τ as an equilibrium object while taking the observed federal tax schedule τ_0 as given. For state tax schedules, we follow the tradition in the public finance literature (e.g., Feldstein, 1969),[23] and model the state tax rate faced by a household with income x_1 as

$$\tau(x_1) = 1 - \tau^a x_1^{-\tau^b}, \tag{8}$$

[18] Notice that public education provides an option value to all households in expectation, regardless of whether they use it ex post.

[19] See Appendix A.1.5 for details of these options.

[20] In our static equilibrium model, we do not allow the state government to borrow against future tax revenue. This assumption is in line with the fact that virtually all states are required to balance the budget in each fiscal period—see National Conference of State Legislatures (2010).

[21] Thus, we need to know how much outside revenue the state governments would get if in fact the state economy contained only the cohorts we are analyzing. So we count the total number of households in the state, and the number of households in our cohorts, and we allocate a fraction of total outside revenue to our cohorts, where the fraction is the number of households in our cohorts divided by the total number of households.

[22] The parameter φ is set at 0.5, to account for the different lengths of two-year versus four-year education. Tuition rates $(\underline{t}, t)$ and per-student expenditure (e_1, e_2) represent total amounts paid by or spent on each student, not per-year amounts. For ease of interpretation, we express them in annualized amounts in the empirical application, accounting for the actual duration of K-12 and college education periods. See Appendix A.1.6 for details.

[23] See Heathcote et al. (2017) for a recent example .

which is governed by two policy parameters τ^a and τ^b. This state tax schedule is progressive if $\tau^b > 0$, regressive if $\tau^b < 0$, and flat with a rate of $1 - \tau^a$ if $\tau^b = 0$.[24]

REMARK. Instead of a political economy framework, we model a state government as a maximizer that cares about various factors. Welfare weights ω_x can reflect how strongly a state government seeks redistribution. The direct preference $W(\cdot)$ for aggregate educational outcomes may reflect two factors: a government's political concerns, as well as spillover effects of education that individual households do not internalize. We estimate the parameters governing the objective function (7) from the data, without distinguishing the underlying forces.

2.4. *Equilibrium.* DEFINITION. An equilibrium is a set of choice functions $\{o_1^*(\cdot), o_2^*(\cdot), d^*(\cdot), \psi^*(\cdot)\}$ such that

1. Given (ψ, z, η), $o_1^*(x, \epsilon_1; \psi, z, \eta)$ is an optimal K-12 choice for every (x, ϵ_1), and $o_2^*(x, k_1, \epsilon_2; \psi, z, \eta)$ and $d^*(x, k_1, \epsilon_2; \psi, z, \eta)$ are optimal college and loan choices for every (x, k_1, ϵ_2).
2. Given $(F, z, \eta, \varepsilon)$, $\psi^*(F, z, \eta, \varepsilon)$ solves the government problem (7).

2.5. *Discussion.* Some aspects of the model warrant further discussion. First, we treat each state in isolation. A household's choice depends on the equilibrium quality of public education in its home state but not on the quality of public education in other states; we also abstract from migration and treat the distribution of households $F_s(x)$ as policy invariant.[25] We thereby avoid having to model strategic interactions among state governments. We model each state government as a Stackelberg leader, which sets policies to maximize its own objective, accounting for equilibrium responses from households in the state. Were we to consider migration (or other cross-state spillovers), we would have to model strategic interactions among state governments. Estimation of such an equilibrium model is a very challenging problem.[26]

Second, we view government decisions as being static, thereby abstracting from complications such as time consistency and government commitment issues in dynamic policy-making settings.[27] Similarly, our model does not consider the impact of policy choices on labor market equilibrium in the long run. One setting in which labor market equilibrium could be considered would be overlapping-generations models. Examples related to our study include Abbott et al. (2019) and Becker et al. (2018). Complementary to these papers, we adopt a different approach and focus on government choices instead.

Third, we model public investments in both K-12 and college education as being determined at the state level. We do allow for the possibility that state expenditure may be differentially productive for different households within the same state via interaction terms between expenditure and household income levels in our educational production functions. These interaction terms may matter partly because of the complementarity between state inputs and household inputs and partly because state education expenditure can be disproportionately "captured" by richer households, especially at the K-12 level. Indeed, K-12 educational funding tends to be higher in richer school districts; we do not model this within-state

[24] In our implementation, we model a state's choices of $\tau(x_1)$ for middle-income households and τ^b, which is equivalent to specifying (τ^a, τ^b).

[25] Kennan (2020) analyzes higher education policies in an individual decision model that allows for interstate migration, but with no consideration of the main focus of this article, that is, the government choices and the interaction between higher education and K-12 education.

[26] For example, multiple equilibria may exist in such a setting. In our current model without cross-state interactions, the Stackelberg leader game in each state has a unique equilibrium.

[27] In particular, we do not explicitly consider the possibility that governments may borrow against the future. Instead, we count all other components of the government budget, including noneducation expenditure and possibly a debt component, in "other expenditure" (g).

funding difference. We make this choice for both tractability and data reasons.[28] The current model nevertheless captures the essential message of this article: To design an effective educational policy, regardless of the level at which it is determined, one needs to recognize that human capital development is a cumulative process and that resources are to be allocated across different public goods, including different educational stages.

Fourth, we model household educational investments as a set of choices between different types of schools and colleges, while abstracting from more detailed choices, such as investment in terms of parental time, books, and tutoring services. Incorporating such choices in the model would make the predictions in our counterfactual policy analysis more precise, but it would require much richer data.

Finally, our model also assumes that households have perfect foresight of government's educational policies as they make educational investment decisions for their children at the K-12 stage. In Online Appendix Section G, we confirm that this assumption is not far-fetched: Despite the volatility of aggregate economic conditions across time, state governments' educational policies (per-student expenditure on K-12 and college education and college tuition levels) are highly correlated across time. Our sensitivity analysis in Online Appendix H shows that households' choices are very similar to their baseline choices were they myopic about college tuition and government college expenditure.

3. ESTIMATION

We estimate parameters governing the college financial aid function $A(C, x, k_1)$ outside of the model. All the other model parameters (Θ) are estimated via indirect inference, which consists of two steps. The first step estimates a set of "auxiliary models" that summarize the patterns in the data to be targeted for the structural estimation. The second step involves repeatedly simulating data with the structural model, computing corresponding auxiliary models using the simulated data, and searching for the parameter values such that the auxiliary model estimates computed from the simulated data and from the true data match as closely as possible. Let $\overline{\beta}$ denote our chosen set of auxiliary model parameters estimated from data. Let $\widehat{\beta}(\Theta)$ denote the corresponding estimates of the auxiliary model parameters obtained using data generated by the model (parameterized by a particular vector Θ). The structural parameter estimator then solves

$$\widehat{\Theta} = \text{argmin}_{\Theta}\left[\widehat{\beta}(\Theta) - \overline{\beta}\right]' \mathcal{W}\left[\widehat{\beta}(\Theta) - \overline{\beta}\right],$$

where $\mathcal{W}$ is a weighting matrix (which is described in Appendix A.1.7). We obtain standard errors for $\widehat{\Theta}$ by applying the delta method based on the variance matrix of $\overline{\beta}$, with $\frac{\partial \widehat{\Theta}}{\partial \overline{\beta}}$ computed numerically.

3.1. *Identification.* We discuss identification of the three categories of parameters in our model, governing household preferences, education production technologies, and the government objective. First, the observed distribution of household choices conditional on x identifies the relative value of each option for these households. The option-specific value depends on both the value households attach to educational outcomes and their direct tastes for enrollment in different types of schools. We rely on two assumptions that allow us to separate these two components: (A1) conditional on x and region, the distribution of household preferences is common across states,[29] (A2) there are no unobserved ability differences across

[28] Otherwise we would need to model interactions across local governments and we would need local-level data on government expenditure, household characteristics, choices, and outcomes.

[29] We include a Northeast region dummy in household preference for private colleges to absorb some possible regional differences in the distribution of private colleges.

households.[30] Given A2, the expected achievement gap between private and public schools for given x within each state is observed. Given A1, for households with characteristics x, the cross-state covariation of public–private achievement gaps and household choices identifies how much the households value achievement. The remaining unexplained part of household choices arises from direct preferences over different types of schools. The dispersion of taste shocks is identified from the sensitivity of school choices to tuition levels, given that utility is measured as the log of household consumption.

Identification of the education production technology needs to deal with a standard endogeneity problem: Education productivity (η_s) affects government investment in education but is unobserved. Other factors affecting expenditure policies include state-level observables z_s and the distribution of households $F_s(x)$. We allow η_s to be correlated with some but not all of these factors: Specifically, we allow η_s to be correlated with a state's income and (parental) education distribution, but exclude state racial composition and the government's nontax revenue from the η_s distribution.[31] These excluded variables then serve as model-consistent instruments for education expenditure. Thus, regressions of education outcomes on x and instrumented expenditure identify the productivity of these inputs. Contrasting the expenditure effect with state fixed effect regressions informs us of the distribution and importance of η_s.

Finally, we must identify the government objective function, and household preferences for g. For $W(.)$, we assume that the government cares about the total college enrollment rate ($N_2 = \sum_j N_{2j}$) and the total fractions of two-year graduates (K_{21}) and four-year graduates ($K_{22} + K_{23}$). Let ψ_{-g} be the policy vector excluding g. Rewrite the deterministic part of the government objective (7) as

$$(9)\quad \max_{\psi_{-g}} \left\{ \sum_x \omega_x F(x) \Big(\widetilde{V}(x; \psi_{-g}, z, \eta) + \theta(x, z) \ln(g) \Big) + \gamma_1 N_2 + \gamma_2 K_{21} + \gamma_3 (K_{22} + K_{23}) \right\}$$

with the understanding that g is determined from the government budget constraint. Notice that $\widetilde{V}$ is the part of a household's utility that varies with its choice and hence this is identified from household choices; the household's utility from g does not vary with its choice and hence preferences with respect to g must be identified from government choices.

Given the parameters governing household preferences and education technologies, including the unobserved productivity distribution, everything in (9) is a known function of ψ, except for the parameters $\omega_x, \theta(x, z), \gamma_1, \gamma_2, \gamma_3$. Since each feasible choice for the government maps into an equilibrium that determines the value of the government's objective function, the identification of these parameters follows a standard revealed preference argument. In particular, the estimated parameters have to explain the correlation between government choices and state-level characteristics, including nontax revenue and the state-specific household distribution $F_s(x)$, with the unexplained part attributed to the random policy choice shocks $\varepsilon(\psi)$. However (as was pointed out in footnote), with one state being an observation, data limitations restrict the flexibility in our specification. For this reason, we have assumed that ω_x varies only with income, instead of all dimensions of x, whereas $\theta(x, z)$ varies only with income and the federal transfer component of nontax revenue (as specified in Appendix A.4).

These identification arguments guide our choice of auxiliary models, which are described in the next section.

[30] These assumptions are strong, yet as discussed in the "Model" section, within-x variation is not the focus of the article.

[31] By controlling for income and education composition in a state, we seek to minimize the potential impact of a violation of our exclusion restriction assumption, which is untestable given that η_s is unobserved. As we will show in Section 5, our estimated effect of expenditure on educational outcomes is reasonable.

4. DATA AND AUXILIARY MODELS

For our empirical analysis, we combine information from the ELS of 2002, the ACS of 2002, the Census of Population (CP) of 2000, the Census of Governments (CG) of 2002, and the National Center for Education Statistics (NCES).

ELS interviewed 15,244 individuals from a representative sample of 10th graders in 2002, with follow-ups in 2004, 2006, and 2012. It provides a wide range of information on household characteristics, education choices, and outcomes at high school and college levels. We use the base-year (2002) interview data to determine household income and other characteristics (x), as well as high school choices (private vs. public). We measure K-12 achievement k_1 by the standardized math test score in 2004 and the eventual high school dropout status. We use the college attendance history in the 2006 and 2012 interviews to determine college choice o_2, the outstanding college loan level in 2006 to measure d, and degree completion status in 2012 for the college outcome k_2. ELS also contains administrative Pell grant information, which we use along with self-reported aid information to estimate the college financial aid function $A(\cdot)$.

Since primary school choice information is not available in ELS, we use primary school students in ACS to measure the private primary school attendance rate given state and household characteristics (z, x). We also use pairs of siblings at different stages of K-12 (primary and high school) in ACS to get private high school attendance rates conditional on primary school choices.

Our sample from CP consists of all households whose members include a woman aged 35–40 (whether single or married) and all single-male households aged 37–42. The age range of women is chosen such that the binary fertility outcome in our model is likely to have been realized for the household, with the child still living in the household (and thus observable in CP). The age range of single men is chosen such that they were in approximately the same marriage market as the women. As such, the sample is chosen to represent an entire five-year birth cohort of women, together with the husbands of the married women, and an estimate of the set of potential husbands of the single women.[32] We use this sample to estimate the state-specific demographic distribution $F_s(x)$ and the fertility rate $q_s(x)$. Combined with ELS and ACS, this allows us to obtain state-level household choices and outcomes. We also combine this sample with the NBER TAXSIM program to estimate the federal tax schedule $\tau_0(x_1)$ and to infer tax policy variables chosen by each state in the observed equilibrium, including the state-specific tax rate for middle-income households and state-specific progressivity τ^b.

From NCES, we obtain information on private college tuition, state-specific public college tuition, and region-specific private K-12 tuition.[33] Data counterparts are still needed for state-specific nontax revenue z_1, K-12 expenditure e_1, and college expenditure e_2; these we obtain from CG, using the combined budgets of state and local governments of the 48 contiguous U.S. states. The online appendix contains details of the data construction.

4.1. *Empirical Definitions of Model Variables.* The components of the household characteristics vector x include income quintile, demographic group, and whether or not any adult in the household went to college.[34] State observables z include state nontax revenue (z_1) and a dummy for the Northeast Census Region. We consider the discrete probability distribution

[32] If it were the case that people only marry within the same birth cohort, we could just use an actual five-year birth cohort, including both men and women. Or if it were the case that women only marry men who are two years older, we could just use actual five-year cohorts, with the birth-years of men and women offset by two years. Marriage patterns in the data are of course more complicated, but since the modal age difference is about two years, our sample selection rule gives a reasonable approximation of an entire cohort.

[33] NCES does not provide reliable state-specific private K-12 tuition information due to small sample sizes. We assume a common private K-12 tuition within each region.

[34] Income in the ELS is recorded in 13 categories. We define our income groups by collapsing these categories so that each group corresponds approximately to one quintile of the national income distribution. The resulting group cutoff levels are \$20,000, \$35,000, \$50,000 and \$75,000. Within each income group, household income is approximated by the within-group median. We divide households into two demographic groups, one including Whites and Asians,

over households' education choices and outcomes, as well as the amount of college loans. Government choices ψ_s to be matched include six variables: $\tau(x_1)$ for middle-income households, tax progressivity parameter τ^b, government expenditure on K-12 and on college, and two-year and four-year public college tuition levels.

4.2. *Auxiliary Models.* We target the following auxiliary models, guided by our identification argument.

(1) At the household level, we match coefficients from regressions of choices and outcomes on household characteristics x_{is} and other relevant observables w_{is}.
  (a) For primary school choice and high school choice, we use linear probability regressions, where w_{is} consists of log per-student K-12 expenditure and private tuition.
  (b) For loans taken by students attending each type of college, we use OLS regressions, where w_{is} is college tuition net of financial aid.
  (c) For college choice, we use a multinomial logit regression with the latent utility being

$$\begin{cases} u_{0is} = \epsilon_{0is} \\ u_{jis} = \alpha_0 w_{jis} + x'_{is}\alpha_{1j} + \epsilon_{jis} \quad j = 1, 2, 3 \end{cases},$$

  where w_{jis} is the net tuition for each college option j, x_{is} consists of household characteristics, high school outcome dummies, a private high school dummy, log per-student college expenditure, and a Northeast state dummy.[35]
  (d) We map the five K-12 outcome categories to numerical scores, assigning the median score in each outcome group as the test score for all students in that group.[36] We treat these scores as the dependent variable in an OLS regression, where w_{is} is log per-student K-12 expenditure for public schools and private tuition for private schools.
  (e) For graduation among students attending each type of college, we use linear probability regressions, where w_{is} includes high school outcome dummies, a private high school dummy, and in the case of public colleges, w_{is} also includes log per-student college expenditure.

(2) In order to identify the distribution of education productivity levels (η_{s1}, η_{s2}) as specified in (3), we run state fixed effect variants of the regressions in $1(d)$ and $1(e)$ and target the standard deviations of state fixed effects at both education levels, covariance of the two fixed effects, and the fraction of each fixed effect above its mean. We also include the following targets:
  (a) OLS regression coefficients of each of the two fixed effects on log per-student expenditure and the fraction of college-educated adults, controlling for log average income.
  (b) IV variants of the regressions above (2(a)), in which log per-student expenditure is replaced by its predicted value from the regression described in (3) below. We target coefficients associated with the predicted log expenditure.

the other including Blacks and Hispanics and all others. For convenience, we refer to the second group as the "minority" group.

[35] We use the derivatives of the log likelihood as targets instead of the coefficient vector to reduce computational time. In particular, let $p_j(x, w; \hat{\phi})$ be the choice probability evaluated at the $\hat{\phi}$ coefficient estimated using the actual data. We match $E[\sum_{j=1,2,3} w_{jis}(d_{jis} - p_j(x_{is}, w_{is}; \hat{\phi}))]$ and the regression coefficients of $d_{jis} - p_j(x_{is}, w_{is}; \hat{\phi})$ on x_{is} between the actual data and the model. These auxiliary statistics are zero in the data due to the first-order conditions of the multinomial logit.

[36] The structural production function is ordered logit and logit for K12 and college outcomes, respectively. In order to summarize the data, we use linear regressions in auxiliary models, because IV and fixed effect analyses are better suited in a linear setting and linear regressions are computationally more economical.

TABLE 1
HOUSEHOLD CHOICES

%	HS Private	College Enrollment: Public Two-year	Public Four-year	Private Four-year	HS Score >median	College $\frac{Graduates}{Enrollment}$ Two-year	Four-year	Observations (ELS)
All	7.5	27.6	31.2	24.4	47.3	43.7	61.9	15,058
Nonollege Parents	2.8	34.9	22.1	14.5	28.3	47.5	49.2	3,918
Minority	3.9	34.7	24.5	20.5	26.2	41.8	47.2	5,000
Income Quintile 1	2.4	36.3	20.1	15.6	23.5	40.7	46.1	2,211
Income Quintile 2	3.4	33.4	25.6	17.9	32.4	43.3	49.6	2,692
Income Quintile 3	5.1	29.7	30.6	20.1	43.8	45.3	56.3	2,831
Income Quintile 4	7.3	27.4	35.1	24.3	53.5	42.9	62.1	3,080
Income Quintile 5	15.6	17.9	38.2	36.5	69.7	46.2	72.4	4,244

NOTE: The counts in the last column refer to ELS respondents in the 48 contiguous U.S. states.

TABLE 2
SUMMARY OF STATE-SPECIFIC COMPOSITION OF HOUSEHOLDS

%	Income Quintiles: 1(low)	2	3	4	5(high)	Minority	College
Mean	17.9	18.7	17.5	22.3	23.6	20.2	56.3
Std dev.	4.4	2.5	1.5	1.9	6.4	12.5	6.1

NOTES: Statistics for the 48 contiguous U.S. states. "Minority": not White or Asian.
"College": at least one adult in the household has some college education.

(3) We run OLS regressions of government policy choices ψ_s on state-level observables, and we treat the regression coefficients from these regressions and the cross-state variance of ψ as targets to be matched. The regressors in each case include the mean and standard deviation of log income across households, the fraction of households with college-educated adults, the fraction of minority households, (log) nontax revenue z_1, and a Northeast dummy.

4.3. *Summary Statistics.* Table 1 summarizes the distribution of choices and outcomes by household characteristics. Students from lower educated, minority, and low-income households are less likely to attend private high schools and four-year colleges (especially private colleges), but are more likely to attend two-year colleges. Cross-group differences in achievement are also substantial. In standardized high school tests, 70% of students from the highest income group score above the median, compared with 24% from the lowest income group. Conditional on enrolling in a four-year college, the graduation rate is 72% for the highest income group and 46% for the lowest income group.

Table 2 summarizes the marginal distribution of household characteristics across states. We calculate, for each state, the fraction of households with each characteristic and report the mean and standard deviation of these fractions across states. For example, states vary in the fractions of households belonging to the lowest income group: The average fraction is 17.9%, with a standard deviation of 4.4%. The most noticeable difference across states is in the fraction of minority households.

Table 3 summarizes state government policies. The greatest disparity across states is in college tuition levels, per-student expenditure on college education, and tax progressivity. The rightmost columns show coefficients from regressions of each policy variable on the six state-level characteristics (Auxiliary Model 3). For example, controlling for the other characteristics, per-student K-12 and college expenditures are positively correlated with average

TABLE 3
GOVERNMENT POLICIES

			Regression Coefficients					
		Std	Log Income		Household Fractions		Nontax	
	Mean	Dev	Mean	Std	College	Minority	Rev (log)	Northeast
Expenditure ($1,000/Enrollment)								
K-12	7.50	1.46	1.28	0.06	−0.81	−0.16	0.34	0.22
College	15.78	2.45	0.91	−2.29	−1.02	0.20	0.22	0.09
Tuition ($1,000/Year)								
Two-year	2.28	0.99	0.67	−12.69	−1.16	−0.49	−0.33	0.99
Four-year	4.14	1.29	3.78	−20.97	−6.90	0.77	0.53	1.85
Tax rate (%, middle income)	9.88	0.89	−0.46	6.57	−0.60	−2.34	0.49	0.02
Tax progressivity τ^b ($\times$100)	1.31	0.76	−0.91	−2.53	0.63	0.37	0.56	0.24

NOTE: K-12 and college expenditures are log-transformed in computing regression coefficients.

household income and a state's nontax revenue and negatively correlated with the fraction of college-educated households. [37]

5. ESTIMATION RESULTS

5.1. *Parameter Estimates.* We present estimates of selected parameters in Table 4 (with more detail in Appendix A.3); standard errors are shown in parentheses. Panels A and B show the estimated education production parameters associated with expenditure, school type, and previous achievement. There are two notable observations. First, all else equal, the effect of government educational expenditure is slightly stronger for higher income groups at both K-12 and four-year college levels. Our estimates imply that the marginal effect of a 10% increase in e_2 (evaluated at the average graduation rate of 61.9%) is approximately a 3 percentage point increase in the four-year graduation rate, which is comparable to the effect implied by the estimates in Deming and Walters (2018). For two-year college outcomes, the public expenditure is negligible for the higher income group. Second, high school test scores contribute positively to four-year college graduation probabilities.[38]

Panel C shows the estimated parameters for the educational productivity distribution. The fraction of college-educated adults is positively correlated with a state's (unobserved) college productivity but negatively correlated with its K-12 productivity. The two productivity levels are not significantly correlated. Given these estimates, we report the support of the productivity distribution (the mean is normalized to zero), and the joint distribution $\Pr(\eta_{s1}, \eta_{s2})$; we find that 18% of states have low productivity at both K-12 and college levels, and 28% have high productivity at both levels.

Panel D reports parameter estimates of the government's objective function. The welfare weights are strongly tilted toward high-income households, which would mean that the government cares more about such households. But household utilities are concave in consumption, which increases the sensitivity of the government's objective with respect to the welfare of low-income households. Together with other factors, these two opposite forces jointly determine the relative importance of various income groups in the government's optimization problem. The last three columns in Panel D show that the government directly cares about aggregate education outcomes, which is necessary to rationalize the observed government policies.

[37] Conditional on the other regressors, there is a negative relationship between per-student expenditures and the fraction of college-educated households, but the unconditional regression coefficients are 0.80 for K-12, and 0.42 for college expenditures.

[38] The high school outcome is ordinal, but to save on parameters, we assign numerical values to the outcome based on test score percentiles, and we assume that the latent logit functions are quadratic in these values.

TABLE 4
SELECTED PARAMETER ESTIMATES

A. High School Achievement (Ordered Logit)*

	Gov Expenditure ($\ln(e_1)$)			
	Low Income	High Income	Private Tuition	Public HS
HS k_1	0.42 (0.14)	0.68 (0.13)	0.04 (0.03)	−2.02 (0.25)

B. College Graduation (Logit)*

	Gov Expenditure ($\ln(e_2)$)		HS score	(HS score)^2	Private HS
	Low Income	High Income			
Two-year college	0.30 (0.05)	0.09(0.07)	−1.22(0.55)	0.52 (0.53)	0.14 (0.13)
Four-year public	1.15 (0.10)	1.23 (0.10)	1.42 (0.79)	0.92 (0.78)	0.12 (0.10)
Four-year private	-	-	3.22 (0.79)	−0.48 (0.71)	0.47 (0.11)

C. Educational Productivity Distribution Parameters

	Constant	F(college HH)	ρ_2		std σ_η
K-12 η_{s1}	0.21 (0.69)	−5.54 (4.71)	-		0.21 (0.03)
College η_{s2}	0.21 (0.19)	7.50 (4.18)	−0.19(1.57)		0.64 (0.10)
Implied values of η			$\Pr(\eta_{s1}, \eta_{s2})$ across states		
	Low	High	$\Pr(\eta_{s1}, \eta_{s2})$	$\underline{\eta}_1$	$\overline{\eta}_1$
K-12	$\underline{\eta}_1$ =−0.23	$\overline{\eta}_1$ =0.19	$\underline{\eta}_2$	0.18	0.27
College	$\underline{\eta}_2$ =−0.71	$\overline{\eta}_2$ =0.58	$\overline{\eta}_2$	0.27	0.28

D. Government Objective Function

Welfare Weights ω			Aggregate Education Outcome		
Low Income	Middle Income	High Income	Col. Enrollment	2-year Grads	4-year Grads
0.32 (0.11)	1.0 (normalized)	1.86 (0.42)	1.00 (0.23)	3.90 (0.41)	3.68 (0.30)

NOTES: Low Income refers to the first two income quintiles; High Income refers to the top two income quintiles.
*Estimates of the effects of other inputs are in Table A.2 in Appendix A.3.

5.2. *Effects of Tuition Changes.* Our model explicitly considers how tuition levels are determined endogenously. Nevertheless, identification of tuition impacts relies on the exogeneity of nontax revenue and can also be influenced by assumptions on functional forms. In order to confirm that our model can replicate the tuition impacts found in quasi-experimental studies, we simulate the impact of financial aid programs investigated by Goodman (2008) and Castleman and Long (2016). Cohorts of students analyzed in these papers are comparable to our sample from the ELS2002. Goodman (2008) studies the Adams Scholarship, which gives high-performing students in Massachusetts a $740 subsidy for attending community colleges and a $1,575 subsidy for attending state universities. He finds that the program increased the public four-year attendance rate by about 6 percentage points but had no impact on the overall college attendance rate. Simulating the same amount of aid for a comparable student group ($k_1 = 5$), our model predicts a 5.6 percentage point increase in the public four-year attendance rate and a 0.6 percentage point increase in the overall college attendance rate. Castleman and Long (2016) studied the Florida Student Access Grant, which awards low-income students a $1,300 subsidy for attending any public college in Florida. They find the program increased the college attendance rate by 2.5 percentage points for students with parental income around $28,000, with a slightly larger impact on immediate enrollment. Our simulation using a comparable group ($x_1 = 2$) predicts a 2.8 percentage point increase in the college attendance rate.

5.3. *Model Fit.* Model fit results are shown in Tables 5 and 6. Table 5 shows results for household choices and outcomes. The first two columns of Table 6 show the fit for the mean

TABLE 5
MODEL FIT: HOUSEHOLD CHOICES AND OUTCOMES

%		Enrollment Choices					Education Outcomes		
		Priv HS	Two-Year col	Four-Year pub	Four-Year Pri	HS > Median	Graduation / two-year Enroll	Graduation / Four-year Pub	Graduation / Four-year Priv
All	Data	7.5	27.6	31.2	24.4	47.3	43.7	61.1	62.9
	Model	7.3	27.9	31.1	23.7	47.3	43.2	61.5	61.9
Low Edu	Data	2.8	34.9	22.1	14.5	28.3	47.5	53.0	43.3
	Model	3.3*	35.2	22.6	14.3	28.1	46.6	46.5*	48.3
Minority	Data	3.9	34.7	24.5	20.5	26.2	41.8	51.6	41.9
	Model	4.4*	34.4	24.5	20.3	27.5	39.9	52.1	41.5
Low Inc	Data	3.0	34.6	23.2	16.9	28.5	42.1	52.4	42.5
	Model	4.1*	33.8	24.0	17.0	29.1	40.7	52.9	42.8
High Inc	Data	11.9	22.1	36.8	31.1	62.5	44.4	66.1	71.2
	Model	10.2*	23.3	35.9	30.0	63.0	44.4	66.3	72.1

NOTES: *Predictions that are the 95% confidence interval for the corresponding statistic in the data.
Low Income refers to the first two income quintiles; High Income refers to the top two quintiles. Low education means that no adult in the household went to college.

TABLE 6
MODEL FIT: GOVERNMENT POLICIES

				Regression Coefficients					
			Std	Income (log)		Household fractions		Nontax	
		Mean	dev	Mean	Std dev	college	minority	Rev (log)	Northeast
K-12 expenditure	Data	7.50	1.46	1.28	0.06	−0.81	−0.16	0.34	0.22
($1,000/Enrollment)	Model	7.49	1.14	1.41	−0.47	−0.15*	−0.01	0.03*	−0.03*
College expenditure	Data	15.78	2.45	0.91	−2.29	−1.02	0.20	0.22	0.09
($1,000/Enrollment)	Model	15.74	1.69*	0.89	−0.52	0.05*	0.13	0.02*	−0.06*
Two-year tuition	Data	2.28	0.99	0.67	−12.69	−1.16	−0.49	−0.33	0.99
($1,000/Year)	Model	2.27	1.15	0.99	−11.30	1.61	−0.20	−0.11	0.34
Four-year tuition	Data	4.14	1.29	3.78	−20.97	−6.90	0.77	0.53	1.85
($1,000/Year)	Model	4.23	1.37	2.35	−9.41	−4.67	1.85	−0.02	1.75
Tax rate	Data	9.88	0.89	−0.46	6.57	−0.60	−2.34	0.49	0.02
(%, middle income)	Model	9.74	1.12*	−3.51	3.93	−1.98	−2.52	−0.98*	0.21
Tax progressivity τ^b	Data	1.31	0.76	−0.91	−2.53	0.63	0.37	0.56	0.24
(×100)	Model	1.31	0.85	1.75	2.60	−1.05	−0.28	0.04	0.17

*Outside the 95% confidence interval.
NOTES: K-12 and college expenditures are log-transformed in computing regression coefficients.

and standard deviation of each of the government policy variables, whereas the other columns show the fit of auxiliary regression models, which summarize the correlation between the state policy choices and the observed state characteristics. In these tables, asterisks indicate predictions that are outside the 95% confidence interval for the corresponding statistic in the data. With a few exceptions, the equilibrium model predictions closely match the data.

6. COUNTERFACTUAL EXPERIMENTS

We use the estimated model to evaluate equilibrium impacts of free public college policies, implemented in two different ways.[39] In the first set of experiments, free public college policies are mandatory; in the second, the federal government offers subsidies to induce state governments to charge zero college tuition. Our estimated government preference parameters indicate that a state government's objective differs from that of a benevolent social planner. Therefore, as we discussed in Remark 2.3, the equity-efficiency implication is theoretically ambiguous when state governments' choices are distorted, for example, by a free-college mandate. We study these implications empirically in the following counterfactual policy simulations.

6.1. *Free Public Colleges (Mandatory).* Under a mandatory free-college policy, the choice set of a state government is restricted to be $\Psi^c \subset \Psi$, such that for all $\psi \in \Psi^c$, $\underline{t} = 0$, and t is no greater than the baseline four-year college tuition if two-year colleges are required to be free, and $\underline{t} = t = 0$ if all public colleges are required to be free. Table 7 shows the policy impacts. The state government decreases per-student expenditure at both levels of education, and increases tax levels while reducing tax progressivity. When two-year tuition is zero, in many cases the state government reoptimizes by reducing four-year college tuition, which helps to reduce enrollment shifts from four-year public colleges to free two-year colleges. Overall, government and household reactions to the counterfactual policy are stronger at the college stage than at the K-12 stage, which seems reasonable.

Panel B of Table 7 shows the impact on the college enrollment rate, the graduation rate, and the fraction of all students with a college degree.[40] For example, when two-year colleges

[39] We treat parameters governing fertility and household terminal value functions as invariant to our counterfactual policies.

[40] The baseline data here are not conditional on high school graduation, and for this reason they are not quite the same as the corresponding numbers in Table 5.

TABLE 7
FREE PUBLIC COLLEGES (MANDATORY)

A. Government Policy (Mean)

	Per student e(\$1, 000)		State Tax		Tuition (\$1, 000)	
	K12	College	(MidInc) (%)	τ^b ($\times$100)	2year	4year
Baseline	7.49	15.74	9.74	1.34	2.27	4.23
Free four-year	7.47	15.48	9.80	1.33	0	4.03
Free two- and four-year	7.39	14.45	10.42	1.22	0	0

B. College Enrollment and Graduation

	Enrollment				$\frac{Graduates}{Enrollment}$		Graduates	
%	None	2year	4year pub	4yr pri	2year	4year pub	2year	4year (pub+pri)
Baseline	21.2	26.6	29.7	22.6	43.2	61.5	11.5	32.3
Free two-year	20.6	28.0	29.3	22.1	42.6	61.3	11.9	31.7
Free two- and four-year	16.7	22.7	43.3	17.3	43.6	56.7	9.9	35.5

C. Welfare

			Welfare Changes (% CEV)					
		Winners	Income Group					
			All	1 (low)	2	3	4	5 (high)
V only	Free two-year	19.4%	−0.03	0.03	−0.02	−0.02	−0.04	−0.07
	Free two- and four-year	17.5%	−0.57	−0.26	−0.50	−0.54	−0.71	−0.76
V and W	Free two-year	30.1%	−0.01	0.04	0.00	−0.00	−0.02	−0.04
	Free two- and four-year	31.4%	−0.23	0.02	−0.20	−0.21	−0.33	−0.37

D. Welfare Changes (% CEV)

	Income Group					
	All	1 (low)	2	3	4	5 (high)
Free two- and four-year (V)	−0.57	−0.26	−0.50	−0.54	−0.71	−0.76
Tuition	0.54	0.97	0.59	0.47	0.43	0.32
Education expenditure	−0.13	−0.04	−0.04	−0.04	−0.24	−0.23
Tax	−0.84	−0.90	−0.86	−0.83	−0.80	−0.82
Public expenditure (g)	−0.14	−0.29	−0.19	−0.14	−0.09	−0.03

NOTE: Welfare changes are measured by consumption equivalent variation in percentage terms. Panel D decomposes welfare changes by sequentially changing each policy variable from the baseline level to the new equilibrium level.

alone are made free, some students would switch to two-year enrollment, mostly from the outside option and some from four-year enrollment.[41] When both two-year and four-year public colleges are free, enrollment in four-year public colleges increases, whereas it decreases in private four-year colleges. The proportion of graduates (unconditional on enrollment) increases, although the large increase in enrollments is offset to a substantial extent by a decrease in graduation rates.

Notice that in the main text, we hold private college tuition fixed at its baseline level. In Appendix A.2, we allow private tuition to adjust to maintain the baseline enrollment level. The results are similar. See Bound and Simon (2021) for an analysis of how private colleges would respond to changes in funding of public colleges.

The government objective (7) includes a direct preference $W(\cdot)$ over aggregate education outcomes, which may capture factors such as political concerns of the government and educational externalities. We present our welfare analysis using two measures of welfare based on

[41] Previous studies focusing on individual decisions also find four-year to two-year switches when two-year colleges are free, but to a larger extent (e.g., Liu, 2016). There is less switching in our model because state governments adjust their policies in other dimensions: In particular, we find that they would reduce tuition in four-year colleges to reduce the flow from four-year to two-year colleges.

two different interpretations of $W(\cdot)$. The first measure reflects only household preferences, represented by the ex ante value $V(\cdot)$, defined in equation (6), with $W(\cdot)$ interpreted purely as the government's political value. Alternatively, we use a second welfare measure that views $W(\cdot)$ as capturing a positive externality where having more college-educated workers would benefit the entire cohort, each of whom would get an additional value of $W(\cdot)$.[42] Our overall findings, as shown below, are similar for these two measures.

Panel C of Table 7 shows the fraction of households whose welfare is improved and also the average changes in welfare, according to either of the two welfare measures. The welfare numbers in this and later tables are stated in terms of equivalent percentage variations in lifetime consumption (% CEV).[43] Holding state policies fixed, any individual household would gain under zero-tuition policies, but these gains may vanish when the resource constraint and the government's policy choices are taken into account. Indeed, our results show that most households would lose from the free-tuition policy. For example, when all public colleges are free, based on the V-only measure, the fraction of winners is 18%; based on the broader measure, this fraction is 31%. The average welfare cost of implementing the policy is equivalent to a 0.57% decline in consumption based on the V-only measure, ranging from 0.26% for the lowest-income group to 0.76% for the highest-income group. Welfare losses are smaller under the broader measure, which takes improved aggregate education achievement into account.

Panel D provides details regarding the sources of these results, by showing the breakdown of the welfare changes resulting from the separate components of the governments' policy responses.[44] In the naive free-tuition case, average welfare increases for all households, and the gain is larger for lower-income households. It is true that the poorest households are more likely to receive financial aid,[45] but even so, their marginal utility of consumption is relatively high and they are more likely to respond to the cost of college. The welfare effects of expenditure changes are relatively minor on average but heterogeneous: the effect of educational expenditures is larger for higher-income groups and that of other public spending is larger for lower-income groups. The fourth row of Panel D shows the average welfare changes resulting from the change in tax rates, where losses are similar across income groups.

6.2. *Free Public Colleges (Subsidized).* In this experiment, we implement an intervention that induces state governments to make their public colleges free. Unlike a mandate, such interventions can be implemented in many different ways. As an illustration, we design a federal subsidy policy with a relatively simple structure. This subsidy policy is essentially a voluntary cost-sharing mechanism between the state government and the federal government; thus it is similar in spirit to many other policies (e.g., the expansion of Medicaid). Under this policy, states that set tuition to zero in all public colleges qualify for a federal subsidy. Although the free-college policy is not mandated, it is funded by a mandatory federal tax surcharge, which is levied on households in all states.

To be specific, a complying state obtains, for each enrolled student in the new equilibrium, a subsidy that is a fraction r of its original tuition level. In order to balance the federal budget, the surcharge rate κ is such that the increased federal tax revenue $\mathcal{K}(\kappa)$ equals the total tuition subsidy $\mathcal{S}(\kappa, r)$ from the federal government to the states. The surcharge revenue is

[42] The second welfare measure is $V(\cdot) + q(x)W(\cdot)$. That is, ex post, all households with children enjoy the same W from having more college educated workers in their child's cohort; ex ante, every household benefits from W.

[43] If consumption increases by 1% in every period in the model, the lifetime value of the household would increase by $0.01 \cdot \sum_{t=1}^{16} \delta^{t-1} \approx 0.112$. Therefore, we divide the raw welfare numbers by 0.112.

[44] We start from the naive "free" scenario where tuition is zero but all other state government policies are fixed at their baseline levels, then, we adjust education expenditure to its level in the new equilibrium, while keeping tuition at zero, then we adjust tax rates, and finally other public expenditure. In each step, the previous adjustments are maintained, and households respond optimally, and the last step brings us to the full new equilibrium, shown in row 1. We show results for the case where both two-year and four-year colleges are free, based on the V measure. The decomposition for other cases gives similar results. Moreover, the order in which the policy variables are changed makes virtually no difference.

[45] Financial aid can exceed tuition for some students, and it does not go to zero when tuition is zero.

given by[46]

$$\mathcal{K}(\kappa) = \kappa \sum_s \sum_{x_1} \mathcal{N}_s(x_1) \max(\tau_0(x_1)x_1, 0),$$

where $\mathcal{N}_s(x_1)$ is the number of households in income group x_1 in state s (that is, the number of such households in our CP sample, as described in Section 4).

In order to calculate $\mathcal{S}(\kappa, r)$, we need to solve the state's problem first. Given the federal policy (κ, r), the government problem for state s is modified as

$$\tilde{\pi}_s(\kappa, r) = \max\left\{\pi_s(\kappa), \pi_s'(\kappa, r)\right\}.$$

A state chooses between not complying, with value $\pi_s(\kappa)$ and complying, with value $\pi_s'(\kappa, r)$. Here, $\pi_s(\kappa)$ is the optimal value from a modified version of (7), reflecting the effects of the surcharge on household value functions and optimal choices, and the implications of these choices for aggregate enrollments and college outcomes, as determined by (4) and (5). The value of complying is given by

$$\text{(10)}\quad \pi_s'(\kappa, r) = \max_{\psi^c \in \Psi^c} \left\{ \sum_x \omega_x F_s(x) V_\kappa(x; \psi^c, z_s, \eta_s) + W(N_{s2}, K_{s2}) + \varepsilon_s(\psi) \right\}$$

$$\text{s.t. } z_{s1} + \sum_x F_s(x)\mathcal{T}_s(x_1) + r(N_{s21}\underline{t}_s^* + N_{s22}t_s^*) = e_{s1}N_{s1} + e_{s2}(\varphi N_{s21} + N_{s22}) + g_s,$$

where V_κ is the household value function as described in Subsection 2.2 given that income $y(\tau, \tau_0, x_1)$ is reduced by the amount of the tax surcharge. Aggregate enrollments and college outcomes are again determined by (4) and (5), given optimal household choices at the new after-tax income and tuition and educational expenditure levels, and $\underline{t}_s^*$ and t_s^* are the original optimal tuition choices associated with (7) in the baseline. Compared with (7), (10) requires that the government policy be chosen from the constrained choice set Ψ^c with $\underline{t} = t = 0$; in return, the state receives a subsidy of $r(\underline{t}_s^* N_{s21} + t_s^* N_{s22})$.

The total federal subsidy can be written as

$$\mathcal{S}(\kappa, r) = r \sum_s \mathcal{N}_s \mathbb{E}_{\eta_s, \varepsilon_s}[\mathbb{I}(\pi_s(\kappa) < \pi_s'(\kappa, r))(N_{s21}\underline{t}_s^* + N_{s22}t_s^*)],$$

where $\mathcal{N}_s$ is the total number of households in state s, and the expectation is taken over the distribution of a state's unobserved education productivity η_s and policy shocks ε_s. This subsidy is an equilibrium outcome that depends on how many state governments take the subsidy, how they change their own policies and how many students attend public colleges in the new equilibrium in these states. State governments' and households' decisions in turn depend on the subsidy rate and the federal tax surcharge. At different subsidy rates r, we calculate the compliance rates and changes in outcomes and welfare, solving for κ to satisfy the constraint $\mathcal{S}(\kappa, r) = \mathcal{K}(\kappa)$. In order to illustrate, we show the equilibrium effects of subsidizing at rates of $r = 0.1, 0.2$, and 0.3.

The first column of Table 8 shows the fraction of subsidy-taking states: At $r = 0.1$, about 8% of states would comply, whereas over 98% of states would comply at $r = 0.3$.[47] Using the case of $r = 0.2$ (with a compliance rate of 74%) as an example, a comparison of the last two

[46] No surcharge is applied if the federal tax is negative in the baseline (which is the case for the lowest income group). Thus, for a household with income x_1, the surcharge is $\kappa \max(\tau_0(x_1)x_1, 0)$.

[47] States are quite responsive to the federal cost-sharing policy in our counterfactuals. This arises partly from the fact that college tuition revenue is only a small fraction of a state's overall budget, and hence the distortion introduced by the subsidized free-tuition policy is limited.

TABLE 8
COMPLIANCE RATE AND STATE CHARACTERISTICS

	Compliance Rate (%)	State Characteristics by Complying Status under $r = 0.2$	Complying States (73.9%)	Non Complying States
$r = 0.1$	7.8	Low Inc Fraction	0.36	0.38
		High Inc Fraction	0.47	0.44
$r = 0.2$	73.9	Frac. High-Edu Parents	0.57	0.55
		$\Pr(\eta_{s1} = \overline{\eta}_1)$	0.55	0.56
$r = 0.3$	98.4	$\Pr(\eta_{s2} = \overline{\eta}_2)$	0.58	0.47
		Non-tax Rev. z_1 (\$1,000)	4.11	4.17

TABLE 9
FREE TWO-YEAR AND FOUR-YEAR PUBLIC COLLEGES (SUBSIDIZED)

A. Policy & Outcomes

	Per student e (\$1,000)		State Tax		College Graduates %	
			%	×100		
	K12	College	(MidInc)	τ^b	Two-year	Four-Year (pub+pri)
Baseline	7.49	15.74	9.74	1.34	11.5	32.3
Subsidy $r = 0.1$	7.49	15.71	9.82	1.33	11.4	32.6
Subsidy $r = 0.2$	7.43	15.07	10.25	1.23	10.4	34.9
Subsidy $r = 0.3$	7.42	14.89	10.34	1.19	9.9	35.8
Mandatory Free Two and &Four-year	7.39	14.45	10.42	1.22	9.9	35.5

B. Benefit & Cost

	Winners %	Welfare Changes (% CEV) All	Complying	Noncomplying	Cost Subsidy	κ
B1. V only					\$ per HH	
Subsidy $r = 0.1$	1.7	−0.04	−0.43	−0.00	40	0.04
Subsidy $r = 0.2$	13.0	−0.42	−0.53	−0.08	767	0.71
Subsidy $r = 0.3$	15.3	−0.60	−0.60	−0.15	1,514	1.41
Mandatory Free Two− and Four−year	17.5	−0.57	−0.57	-	-	-
B2. V and W						
Subsidy $r = 0.1$	2.9	−0.01	−0.05	−0.00	40	0.04
Subsidy $r = 0.2$	23.5	−0.14	−0.15	−0.08	767	0.71
Subsidy $r = 0.3$	24.8	−0.20	−0.21	−0.16	1,514	1.41
Mandatory Free Two- and Four-year	31.4	−0.23	−0.23	-	-	-

NOTE: Welfare changes are measured by consumption equivalent variation in percentage terms. Costs are measured by the federal subsidy per household (\$ per HH) and the federal tax surcharge rate (κ).

columns in Table 8 shows how state-level characteristics differ between complying and noncomplying states. Complying states appear to have slightly more high-income households and are more likely to have high unobserved productivity in college education.

Panel A of Table 9 shows the equilibrium outcomes across all states in the baseline, in each of the three subsidy cases, and in the mandatory policy case for comparison. Panel B of Table 9 shows the benefit and cost of each subsidy policy.[48] Using the alternative welfare measures discussed in Subsection 6.1, we report the fraction of winners among all households, and welfare changes for households overall and for those in complying and noncomplying states separately. The fraction of winners increases with the subsidy rate but is always small: At the

[48] Note that the subsidy policy provides not only a direct incentive for eliminating tuition fees but also, *relative to the mandatory free-tuition policy*, an indirect incentive for increasing enrollment (partly through higher per-student expenditure), because the subsidy amount depends on enrollment in the new equilibrium. In addition, the progressive federal tax surcharge induces a small transfer from high-income states to low-income states.

subsidy rate of 0.3, the fraction of winners among all households is 15% according to the narrower welfare measure, and 25% according to the broader measure. Recall that households in all states are affected by the subsidized free-tuition policy due to the federal tax surcharge, which implies a flow of resources from noncomplying to complying states. As the federal tax surcharge is small, so is the average welfare loss for households in non-complying states. Using the narrower welfare measure, average welfare loss is larger in complying states than in noncomplying states; using the broader welfare measure, average welfare loss in complying states is closer to that in noncomplying states. The last two columns show the cost of subsidies in terms of dollars per household, and the federal tax surcharge. For example, to fund the subsidy with $r = 0.3$ requires a 1.41% surcharge, with the cost being \$1, 514 per household.

7. CONCLUSION

The idea of "free" public colleges is politically seductive. But of course a college education cannot actually be free—someone must pay for it. We develop a model that can be used to systematically analyze some of the implications of this simple observation. We emphasize that since education is a cumulative process, allocating additional resources to the college stage may be self-defeating if this entails a reduction of public expenditure in the earlier stages. As has been stressed by Cunha and Heckman (2007), this is not just a question of the overall level of investment in public education, since investments at earlier stages enhance the returns to later investments.

Our analysis interprets data on government tuition and expenditure policies, household enrollment choices, and educational achievement, as the equilibrium outcome of a game in which the government chooses a policy to maximize its objective, anticipating the best responses of households. We treat each state in isolation, and use the cross-state variation in the data to estimate the underlying parameters governing household and government preferences and educational technologies, and we then use the estimated model to predict the consequences of free-college policies introduced at the federal level. Our main finding is that such policies would lead to lower per-student expenditure on K-12 and college education, and would have negative welfare effects for a large majority of households.

It should be noted that we have assumed away some potentially important frictions in deriving our policy implications. For example, we do not account for the possibility that households may overestimate the (net) cost of college, nor do we consider the possibility that procedural barriers such as financial aid forms can discourage students from applying. A recent field experiment study by Dynarski et al. (2021) suggests that these frictions can be nontrivial for high-achieving low-income students.[49] As such, a free-college policy would serve to reduce these frictions in addition to reducing the financial cost.

In addition, our framework has some other important yet challenging extensions worth pursuing. The first is to allow for migration, with state governments responding optimally to each others' policy choices. This extension would help us better understand the ripple effects of policies implemented in some but not all states.[50] The second extension is to expand the model to better fit the U.S. educational system, where K-12 education is funded mainly via local property taxes. This extension would better address issues such as cross-district inequality within a state, which, however, requires local-level data on government expenditure, household characteristics and outcomes. Finally, we allow states to differ in their unobserved educational productivities; taking them as given, we model governments' decisions in a static setting. It is important to recognize that unobserved educational productivities evolve and government policies change over time. In order to understand such evolution, a third extension would add dynamics into the government problem.

[49] Earlier studies (e.g., Hoxby and Avery, 2013) find that even among well-prepared students, there are substantial gaps in college enrollment and the quality of college attended.

[50] For example, New York state recently launched the Excelsior Scholarship to make four-year colleges free for those with annual family income below \$125,000.

DATA AVAILABILITY STATEMENT. Four parts of the data that support the findings of this study are publicly available from the American Community Survey (ACS), the Census of Population (CP), the Census of Governments (CG), and the National Center for Education Statistics (NCES). The fifth part of the data is the Education Longitudinal Study (ELS). Restrictions apply to the availability of this data, which was used under license for this study; the access to this data is available to researchers via application from the National Center for Education Statistics. Code for data cleaning and analysis is available in openICPSR at https://doi.org/10.3886/E192482V1.

APPENDIX

A.1 *Empirical specification details.* Household characteristics x consist of income x_1, with five levels, an indicator x_2 for the presence of at least one adult with some college education, and an indicator x_3 signifying that a student is not White or Asian.

A.1.1 *K-12 education.* We adjust the utility function and the budget constraint to reflect the actual length of each schooling stage in the empirical version of the model. Private K-12 choice is now denoted by $o_1 = (o_{1L}, o_{1H})$, a pair of indicators referring to private primary school (o_{1L}), and high school (o_{1H}). Taking the typical durations of primary and high school education into account, the utility from consumption during the K-12 stage is specified as

$$\sum_{t=1}^{8} \delta^{t-1} \ln \left(y(\tau, \tau_0, x_1) - p_1 o_{1L}\right) + \sum_{t=9}^{12} \delta^{t-1} \ln \left(y(\tau, \tau_0, x_1) - p_1 o_{1H}\right).$$

We set $\delta = 0.95$. The taste function for K-12 choice is specified as

$$\lambda_1(o_1, x) = o_{1L}\lambda_{1L} + o_{1H}\lambda_{1H} + \frac{1}{12}(8o_{1L} + 4o_{1H})\big(\lambda_{1P}^1(x_1) + \lambda_{1P}^2 x_2 + \lambda_{1P}^3 x_3\big) + \lambda_{1S}\mathbb{I}(o_{1L} \neq o_{1H}),$$

where taste heterogeneity across x is restricted to be proportional to private enrollment intensity $\frac{2}{3}o_{1L} + \frac{1}{3}o_{1H}$. The parameter λ_{1S} represents the cost of switching between public and private schools when moving from primary to high school. The K-12 outcome k_1 is generated from an ordered logit model with latent outcome function

$$\ell_1(o_1, x, e_1, \eta_1, p_1) = \mu_1^1(x_1) + \mu_1^2 x_2 + \mu_1^3 x_3 + \left(\frac{2}{3}o_{1L} + \frac{1}{3}o_{1H}\right)\mu_1^4 p_1 + \left(\frac{2}{3}(1 - o_{1L}) + \frac{1}{3}(1 - o_{1H})\right)\big(\mu_1^5 + \mu_1^6(x_1)\ln e_1 + \eta_1\big).$$

The primary and high school stages are assumed to affect the final K-12 education outcome proportionally to their durations.

A.1.2 *College education.* We specify the utility from consumption in the college period as

$$\begin{cases} \sum_{t=1}^{4} \delta^{t-1} \ln y(\tau, \tau_0, x_1) & \text{if } o_2 = 0 \\ \sum_{t=1}^{2} \delta^{t-1} \ln\Big(y(\tau, \tau_0, x_1) + d + A_{o_2}(C, x, k_1) - C\Big) + \sum_{t=3}^{4} \delta^{t-1} \ln y(\tau, \tau_0, x_1) & \text{if } o_2 = 1 \\ \sum_{t=1}^{4} \delta^{t-1} \ln\Big(y(\tau, \tau_0, x_1) + d + A_{o_2}(C, x, k_1) - C\Big) & \text{if } o_2 \in \{2, 3\}. \end{cases}$$

For each college type o_2, we use the conditional mean of an estimated Tobit model as the aid function:[51]

$$A_{o_2}(C,x,k_1) = \mu^A_{o_2}(C,x,k_1)\Phi\left(\frac{\mu^A_{o_2}(C,x,k_1)}{\sigma^A_{o_2}}\right) + \sigma^A_{o_2}\phi\left(\frac{\mu^A_{o_2}(C,x,k_1)}{\sigma^A_{o_2}}\right).$$

The taste for college education is given by

$$\lambda_{2o_2}(x,k_1,o_1,z) = \lambda^1_{2o_2}(x_1) + \lambda^2_{2o_2}x_2 + \lambda^3_{2o_2}x_3 + \lambda^4_{2o_2}k_1 + \lambda^5_{2o_2}o_{1H} + \lambda^6_{2o_2}\mathbb{I}(o_2=3)z_3,\ \ o_2 \in \{1,2,3\},$$

where z_3 is an indicator for states in the Northeast region, to reflect the fact that this region has more private college options.

The (binary) college outcomes are generated by the following logit models:

$$\text{(A.1)}\quad \Pr(k_2=1 \mid o_2=1) = \mathbb{L}\big(\mu^1_{21}(x_1) + \mu^2_{21}x_2 + \mu^3_{21}x_3 + \mu^4_{21}(k_1) + \mu^5_{21}o_{1H} + \mu^6_{21}(x_1)\ln e_2 + \eta_2\big),$$

$$\text{(A.2)}\quad \Pr(k_2=2 \mid o_2=2) = \mathbb{L}\big(\mu^1_{22}(x_1) + \mu^2_{22}x_2 + \mu^3_{22}x_3 + \mu^4_{22}(k_1) + \mu^5_{22}o_{1H} + \mu^6_{22}(x_1)\ln e_2 + \mu^7_{22}\eta_2\big),$$

$$\text{(A.3)}\quad \Pr(k_2=2 \mid o_2=3) = \mathbb{L}\big(\mu^1_{23}(x_1) + \mu^2_{23}x_2 + \mu^3_{23}x_3 + \mu^4_{23}(k_1) + \mu^5_{23}o_{1H}\big).$$

A.1.3 *Terminal value.* We assume that the terminal value function is additively separable in debt, K-12 outcome, and college outcome, such that

$$v(x,k_1,k_2,d) = f(d,x_1) + b_1(x_1)k_1 + b_2(x_1)\mathbb{I}(k_2=1) + b_3(x_1)\mathbb{I}(k_2=2),$$

where each of the $b_n(x_1)$ $(n=1,2,3)$ parameters takes two values, for lower and higher income households, respectively. The borrowing cost function is given by

$$f(d,x_1) = \gamma_1(x_1)\ln\big(1 - \gamma_2(x_1)\cdot R_{o_2}\cdot\big(d + \gamma_3\max\{0, d-(C-A(C,x,k_1))\}\big)\big).$$

Note that $f(d,x_1)=0$ if $d=0$. The parameter γ_3 allows for an extra cost associated with borrowing more than the net tuition $(C-A(C,x,k_1))$, which helps to fit the borrowing statistics in the data. R_{o_2} is the ratio of the final outstanding debt to the annual borrowing d, which is set to

$$R_{o_2} = \sum_{t=1}^{2}(1+r)^{4-t+1} + \mathbb{I}(o_2 \in \{2,3\})\sum_{t=3}^{4}(1+r)^{4-t+1}.$$

The annual gross interest rate $1+r$ is set to the inverse of the annual discount factor.

A.1.4 *Preference for other public expenditures.* We specify the household's preference for other public expenditure g as $\theta(x,z)\ln(g)$, where

$$\theta(x,z) = (\theta_0 + \theta_1\ln(x_1))\exp\left(\theta_2\ln\left(z^f_1\right)\right).$$

The preference for g differs across income groups if $\theta_1 \neq 0$ (e.g., low-income households are more likely to benefit from welfare programs). We also allow for a systematic correlation between the federal transfer component of nontax revenue (z^f_1) and the "preference" for g, because federal transfers may reflect a state's need to spend on public goods other than education. The exponential function is used to guarantee a positive preference for g given that $\ln z^f_1$ varies substantially across states. For ease of interpretation, instead of θ_0 we present $\theta(x,z)$ for the middle income households with $\ln z^f_1$ being the average across 48 states in Table A.3 below, in addition to (θ_1,θ_2).

[51] Details of the Tobit model specification and the estimated coefficients are given in Online Appendix Section E.

A.1.5 *Government policies.* Letting $\tau(x_1 \mid x_1 = mid)$ denote the tax rate for the middle income group, the grid for state choices $\psi = [\tau(x_1 \mid x_1 = mid), \tau^b, e_1, e_2, \underline{t}, t]$ has $7 \times 5 \times 8 \times 8 \times 7 \times 8 = 125{,}440$ points. In each dimension of the policy choices, the grid points are assigned to provide good coverage of the empirical policy distribution, but the grid is wider than the support of the observed distribution to allow for the possibility that government choices may be outside the empirical range in counterfactual scenarios (see Online Appendix Section D.2).

We assume that the government policy shocks $\varepsilon(\psi)$ follow a generalized extreme value distribution with a nested logit structure. Let $\bar{V}(\psi)$ be the deterministic part of the government value function. Split the policy vector as $\psi = (\psi_1, \psi_2)$, where $\psi_1 = (\tau(x_1 \mid x_1 = mid), \tau^b)$ corresponds to the tax schedules and $\psi_2 = (e_1, e_2, \underline{t}, t)$ refers to the education-related choices. The probability of choosing the vector ψ is

$$P(\psi) = \frac{\exp\left(\frac{\bar{V}(\psi_1,\psi_2)}{\sigma^P \cdot \sigma^N}\right)}{\sum_t \exp\left(\frac{\bar{V}(\psi_1,t)}{\sigma^P \cdot \sigma^N}\right)} \frac{\left[\sum_t \exp\left(\frac{\bar{V}(\psi_1,t)}{\sigma^P \cdot \sigma^N}\right)\right]^{\sigma^N}}{\sum_s \left[\sum_t \exp\left(\frac{\bar{V}(s,t)}{\sigma^P \cdot \sigma^N}\right)\right]^{\sigma^N}}, \tag{A.4}$$

where $\sigma^P > 0$ is the scale parameter and $\sigma^N \in (0, 1)$ is the nesting parameter. The model collapses to the standard multinomial logit model as $\sigma^N \to 1$.

Using the results from Cardell (1997) and Stephenson (2003), $\varepsilon(\psi)$ can be expressed as

$$\frac{\varepsilon(\psi)}{\sigma^P} = \sigma^N \varepsilon_0(\psi) + \varepsilon_1(\psi_1),$$

where $\varepsilon_0(\psi)$ follows a standard Type I extreme value distribution and $\varepsilon_1(\psi_1)$ follows a distribution parameterized by σ^N. In this expression, $\varepsilon_0(\psi)$ is specific to each possible policy choice ψ and i.i.d. across ψ, whereas $\varepsilon_1(\psi_1)$ is specific to each possible tax schedule ψ_1 and i.i.d. across ψ_1. Thus, for each tax schedule ψ_1, $\varepsilon_1(\psi_1)$ takes on the same value across policy choices $\psi = (\psi_1, \psi_2)$ with different education-related choices ψ_2. Our estimate of σ^N (in Table A.3 below) indicates that random shocks are far more important for explaining tax policies than for explaining education-related policies. We follow Stephenson (2003) to simulate random draws of $\varepsilon(\psi)$, which are kept the same throughout counterfactual simulations to ensure that each state faces the same shocks across different scenarios.

A.1.6 *Government budget.* As in (2.7), a budget constraint of a local government is

$$z_1 + \sum_x F(x)\mathcal{T}(x_1) + N_{21}\underline{t} + N_{22}t = e_1 N_1 + e_2(\varphi N_{21} + N_{22}) + g. \tag{A.5}$$

Recall that we model one cohort of households for periods of length equal to the duration of K-12 and college education. The government budget constraint is expressed in terms of per-household total revenue and expenditure throughout these periods. In the empirical implementation of our model, a K-12 period lasts for 12 years and a college period lasts for four years. As seen in A.4 and A.5, a household pays taxes every year. Therefore, in calculating the total revenue, we compute the tax revenue $\mathcal{T}(x_1)$ as the 16-year total tax revenue collected from a household with income x_1, $N_{21}\underline{t}$ as the total two years of tuition revenue from two-year college enrollees, and $N_{22}t$ as the total four years of tuition revenue from four-year public college enrollees. Similarly, for total expenditure, we calculate $e_1 N_1$ as the total K-12 expenditure on students for the total number of years they are enrolled in public schools (recall that we allow households to switch between private and public schools in the primary–secondary transition), and we calculate $e_2(\varphi N_{21} + N_{22})$ as the total college expenditure throughout college years. The government policy variables $(e_1, e_2, \underline{t}, t)$ we present are all annual numbers.

The per-household subsidy presented in Subsection 6.2 is the total instead of the annualized amount.

A.1.7 *The weighting matrix.* The optimal choice of the weighting matrix $\mathcal{W}$ used in the indirect inference criterion is the inverse of the variance matrix V_β of the auxiliary statistics $\hat{\beta}$. However, the variance matrix has to be estimated in practice, which is known to cause finite sample problems when the number of the auxiliary statistics is large. For this reason we ignore covariances and give each statistic a weight that is proportional to the inverse of the estimated variance. Since the number of observations for the household-level data far exceeds the number of observations for the state-level data, we attach an importance weight w_k to each statistic, since otherwise the weighting scheme would put much lower weight on the auxiliary statistics from the state-level data, despite their economic importance. Thus, the criterion function is given by

$$\left[\widehat{\beta}(\Theta)-\overline{\beta}\right]'\mathcal{W}\left[\widehat{\beta}(\Theta)-\overline{\beta}\right]=\sum_k \frac{w_k}{\widehat{Var}\left(\overline{\beta}_k\right)}\left(\widehat{\beta}_k(\Theta)-\overline{\beta}_k\right)^2,$$

where $\overline{\beta}_k$ is one of the auxiliary statistics from the data and $\widehat{\beta}_k(\Theta)$ is the corresponding statistic from the model simulation, given structural parameter Θ. The government-level regression coefficients, state fixed effect–related statistics, and coefficients of state-level variables such as tuition and per-student expenditure in household-level regressions are assigned an importance weight $w_k = 10$, whereas all the other auxiliary statistics have importance weight $w_k = 1$.

A.2 *Counterfactual Policy: A Robustness Check.* In conducting our counterfactual analyses, we have kept private college tuition fixed at its baseline level. Although it is beyond the scope of this article to predict how private colleges might respond to free public college policies, as a robustness check we consider one arguably reasonable scenario: when all public colleges are made free, private tuition adjusts such that the private college enrollment rate is maintained at its baseline level. We consider the most extreme counterfactual experiment in the text, that is, a mandatory zero tuition policy for all public colleges. We find that private tuition would need to decrease by 7.5% to maintain the baseline level enrollment in the new equilibrium, labeled as (P) in Table A.1. State governments respond to the reduction in private tuition by cutting college expenditure even further, while increasing K-12 expenditure and changing taxes toward the baseline levels. The final fractions of college graduates in the population are similar in these two cases. A slightly higher fraction of households would gain under the free-college policy when private tuition adjusts.

When private colleges reduce their tuition, it may negatively affect the quality of their education. In the baseline, private tuition does not directly enter the production function (A.3) because in our model there is one representative private college option, meaning that the effect of tuition is not separately identified from the private–specific constant term. As a robustness check, we assume that the production in private colleges can be viewed as

$$\text{(A.6)}\quad \Pr\left(k_2=2 \mid o_2=3\right)=\mathbb{L}\left(\mu_{23}^1\left(x_1\right)+\mu_{23}^2 x_2+\mu_{23}^3 x_3+\mu_{23}^4\left(k_1\right)+\mu_{23}^5 o_{1H}+\mu_{22}^6\left(x_1\right)\ln\left(1-\triangle\right)\right),$$

where the productivity of tuition is governed by the same parameter vector as that in public colleges $\mu_{22}^6(x_1)$. As private tuition decreases by $\triangle$%, we shift the productivity of private colleges down if the tuition decreases by $\triangle$% as in (A.6). Notice that given the fact that we are unable to pin down the productivity of tuition in private colleges in our estimation, this exercise is not a rigorous prediction. Nevertheless, it can serve as a robustness check. When quality decreases with tuition, private colleges have to decrease tuition by 9.6% to maintain the baseline level enrollment in the new equilibrium, labeled as (Q) in Table A.1. Again, the model-predicted outcomes and welfare implications are robust.

Table A.1
free public colleges (mandatory)

A. Government Policy (Mean)

	Per student e ($1,000)		State Tax		Tuition ($1,000)	
	K12	College	(MidInc) (%)	$\tau^b(\times 100)$	Two-year	Four-year
Free two- and four-year	7.39	14.45	10.42	1.22	0	0
Free two- and four-year (P)	7.44	13.86	10.19	1.33	0	0
Free two- and four-year (Q)	7.43	14.33	10.26	1.35	0	0

B. College Enrollment and Graduation

	Enrollment				$\frac{College\ Grad}{College\ Enroll}$		College Grad	
%	None	Two-year	Four-year pub	Four-year pri	Two-year	Four-year pub	Two-year	Four-year (pub+pri)
Free two- and four-year	16.7	22.7	43.3	17.3	43.6	56.7	9.9	35.5
Free two- and four-year (P)	16.1	21.8	39.5	22.6	43.7	55.8	9.5	35.6
Free two- and four-year (Q)	15.9	21.7	39.9	22.6	43.9	56.9	9.5	35.3

C. Welfare

	Winners	Welfare Changes (% CEV)					
		Income Group					
		All	1 (low)	2	3	4	5 (high)
Free two- and four-year	17.5%	−0.57	−0.26	−0.50	−0.54	−0.71	−0.76
Free two- and four-year (P)	32.1%	−0.15	0.39	−0.05	−0.16	−0.35	−0.45
Free two- and four-year (Q)	27.7%	−0.22	0.42	−0.11	−0.23	−0.45	−0.59

Note: In each panel, the first row reproduces the results in Table 7, which assumes that private colleges do not respond; the second row shows the results when private colleges cut tuition so as to keep private-college enrollment at the baseline level; the third row shows the results when private colleges' tuition cut would reduce its quality as governed by function (B.1).

A.3 *Other Parameter Estimates.*

TABLE A.2
OTHER PARAMETER ESTIMATES: PRODUCTION

A. High School Achievement (Ordered Logit, Latent Outcome)						
	Linear income*	$\mathbb{I}(inc \geq 4)$	College	Minority	K-12 TFP η_1	
HS k_1	1.40 (0.11)	−0.45 (0.15)	0.66 (0.04)	−1.00 (0.04)	1.0 (normalized)	
B. High School Achievement (Ordered Logit, Cutoffs)						
	dropout-1q	1q-2q	2q-3q	3q-4q		
HS k_1	−3.58 (0.22)	−1.23 (0.22)	0.01 (0.22)	1.33 (0.21)		
C. College Graduation (Logit)						
	Linear income*	$\mathbb{I}(inc \geq 4)$	College	Minority	College TFP η_2	Intercept
Two-year college	1.01 (0.30)	0.14 (0.33)	−0.26 (0.11)	−0.26 (0.11)	1.0 (normalized)	−1.26 (0.19)
Four-year public	−0.04 (0.35)	−0.38 (0.42)	0.50 (0.13)	−0.16 (0.10)	0.52 (0.10)	−4.24 (0.29)
Four-year private	1.06 (0.39)	−0.02 (0.26)	0.10 (0.16)	−0.58 (0.12)	-	−1.90 (0.28)

*The income unit is $100,000.

TABLE A.3
OTHER PARAMETER ESTIMATES: PREFERENCES

A. Scale of Household Preference Shock			B. Household Preference for Private K-12			
K-12	College			Primary	High School	Switching Cost
7.14 (1.26)	0.55 (0.05)		Private K-12	−6.69 (2.31)	−15.52 (3.18)	−12.10 (2.18)
C. Household College Preference						
	intercept	HS score	HS score^2	Private HS	Northeast	
Two-year college	−2.93 (0.40)	2.42 (0.76)	−1.16 (0.74)	0.17 (0.23)	-	
Four-year public	−0.97 (0.18)	2.29 (0.55)	−0.93 (0.51)	0.62 (0.10)	-	
Four-year private	3.11 (0.19)	−0.64 (0.47)	1.12 (0.40)	0.85 (0.12)	0.20 (0.06)	
D. Household Preference Interaction with x						
	inc=2	inc=3	inc=4	inc=5	College	Minority
private K-12	−3.12 (0.59)	−2.31 (0.82)	−4.20 (1.20)	−0.16 (1.71)	7.34 (1.33)	−4.85 (0.93)
Two-year college	−0.14 (0.10)	−0.36 (0.16)	−0.38 (0.54)	−1.21 (0.68)	0.47 (0.18)	0.50 (0.16)
Four-year public	0.05 (0.07)	0.11 (0.08)	−0.83 (0.21)	−0.89 (0.25)	0.17 (0.08)	0.03 (0.06)
Four-year private	−2.11 (0.17)	−2.72 (0.19)	−3.89 (0.28)	−4.12 (0.39)	0.33 (0.08)	0.17 (0.07)
E. Public Good					**F. Terminal Values**	
Const. (inc=3)	$\ln x_1$	$\ln z_1^f$			$\mathbb{I}(inc \leq 3)$	$\mathbb{I}(inc \geq 4)$
0.20 (0.02)	−0.17 (0.04)	0.88 (0.11)		HS score	0.03 (8.78)	42.69 (9.66)
				Two-year grad	7.23 (0.93)	9.41 (1.66)
				Four-year grad	0.96 (0.43)	3.48 (0.50)
G. Borrowing Cost: $\ln \gamma_1(x_1) = \gamma_{11} + \gamma_{12} \ln x_1$ and $\ln \gamma_2(x_1) = \gamma_{21} + \gamma_{22} \ln x_1$.						
γ_{11}	γ_{12}	γ_{21}	γ_{22}	γ_3		
0.28 (0.13)	0.09 (0.10)	−4.58 (0.12)	−0.74 (0.09)	0.25 (0.06)		
F. Government Policy Shocks						
Scale (σ^P)	0.004 (0.002)		Nesting (σ^N)	0.0002 (0.09)		

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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