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COLLEGE CHOICE, PRIVATE OPTIONS, AND THE INCIDENCE OF PUBLIC  
INVESTMENT IN HIGHER EDUCATION

John Bound  
Andrew Simon

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College Choice, Private Options, and The Incidence of Public Investment in Higher Education  
John Bound and Andrew Simon  
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**ABSTRACT**

Previous measures of the incidence of public investment in higher education focus on the transfer to public college students. This implies that the net benefits to students who do not attend public colleges is negative. However, they miss potential general equilibrium effects on the private college and labor markets. Changes in the public college market affect who private colleges admit, what prices they charge, and the number of students who enroll in any college. We show that capturing these spillovers is important for characterizing incidence using a model of higher education that we validate with quasi-experimental variation in state spending. Unlike previous measures, we find that high-income-modest-ability students especially benefit since they are only admitted to high-quality private colleges when state spending is high, and the public colleges create sufficient competitive pressure. Decreased investment also reduces educational attainment, raising the college wage premium. This exacerbates private college market power.

John Bound  
Department of Economics  
University of Michigan  
Ann Arbor, MI 48109-1220  
and NBER  
jbound@umich.edu

Andrew Simon  
University of Chicago, Department of Economics  
1126 E. 59th St  
Chicago, IL 60637  
United States  
andrewsimon@uchicago.edu

## 1. Introduction

Understanding who benefits and who bears the burden of public investment in higher education is increasingly important for state and federal policy. Some states are greatly reducing support, while many Democrats and the Biden administration call for tuition-free public college and an expanded Pell Grant. However, since the controversial findings of Hansen and Weisbrod (1969), the merits of public higher education as a redistributive tool have been called into question. They found that while higher education is mainly financed through progressive income taxes, take-up is predominately by higher income households.<sup>1</sup> Pechman (1970, 1972), using the same data as Hansen and Weisbrod, and more recently William Johnson (2006) using a nationally representative survey, argue that Hansen and Weisbrod misinterpret their findings. When stratifying by income, Pechman and Johnson show that net subsidies flow from high income families whose children often attend private colleges to the moderate income whose children often attend the publics.

The previous approaches to measuring incidence implicitly ignore general equilibrium considerations. Pechman and Johnson's method uses an accounting-style approach that sums the amount of money spent on an individual student from instructional expenditure and capital costs at public institutions and subtracts the amount paid in public college tuition and taxes. As Johnson acknowledges, these calculations leave out possible general equilibrium effects of state subsidies to public colleges.<sup>2</sup> In particular, it is plausible that competition from public colleges affects who the private colleges admit and the tuition they charge. States' investments in public colleges have indirect effects on those who, in equilibrium, attend private colleges. Public investment in higher education also increases the size of the college educated workforce, affecting the relative wages of college and high school graduates.

How important are the general equilibrium implications of public investment for char-

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<sup>1</sup>This result was supported by subsequent work in Wisconsin (Hansen 1970) and Florida (Windham 1970).

<sup>2</sup>Conlisk (1977) develops a simple intergenerational model to show that net benefits measured here are not a good indicator of the intergenerational equity implications. However, the focus of this paper is on the distribution of benefits across households at a given point in time.

acterizing who benefits and who bears the burden? For what types of students do these effects matter the most? We build on the previous approaches to understand the redistributive implications of state divestment within the context of a general equilibrium model of higher education based on Epple et al. (2006, 2017, 2019) using a compensating variation (CV) framework. This stylized setting allows us to study the role of college choice and market power for overall incidence. More specifically, the model allows us to consider the extent to which the private market responds to changes in public funding, especially who private colleges admit and how they set their (sticker) prices, and on the effect that such changes have on relative wages.<sup>3</sup> We calibrate the model to match national college attendance patterns and prices, which replicates the main findings from the accounting-style approach. We additionally build on the previous models<sup>4</sup> by endogenizing sticker prices, which is important for measuring changes in private college market power because changes in sticker prices affect revenue and the extent to which they can price discriminate.

While the mechanisms captured by our calibrated model seem plausible, any such model involves a number of assumption. We use state level variation over time in public higher education expenditure to empirically test and validate this class of economic models of higher education. After a decrease in state spending per student at public colleges, the model predicts that all students, but especially the low-income-high-ability, will increase their demand for the private sector. This has two implications for the private colleges. First, tuition will increase for all students, and increase more for the low income. Second, selectivity at the highest quality private college will increase and create negative downstream effects on the selectivity of the lower quality private colleges. The model also predicts that the magnitude of these effects are functions of the extent to which private colleges can increase their sticker prices and therefore their market power. We provide empirical support for these

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<sup>3</sup>We abstract from other relevant features like the importance of within and across state heterogeneity in the college market. We plan to explore the implications of cross border externalities in future work.

<sup>4</sup>Rothschild and White (1995); Epple et al. (2006, 2017, 2019); Chade et al. (2014); Fu (2014); and Fu et al. (2019). Gordon and Hedlund (2018) also adapted this class of models to study changes in tuition. Winston (1999) also studies these supply side issues for higher education although without a formal structural model.

predictions, validating these key mechanisms.

Our framework addresses the previous concerns about the accounting approach by comparing the baseline college market equilibrium to one with lower levels of public investment in higher education. CV therefore measures how much additional income a household would need to be given, in excess of taxes, to be just as well off after a state spending decrease. Like the accounting approach, this method measures the direct effect of public investment on the value of enrolling in a public college. Our approach additionally captures the value of changes in price, quality, admissions decisions, and the changes in the labor market— the benefits are not only for those who attend.

We measure CV in two steps. First, we decrease state appropriations per student by 10 percent and hold private college sticker prices fixed. This exercise puts a lower bound on the extent to which private market power increases because the colleges can only raise their prices to a limited extent and not at all on students who pay the sticker price before the shock to state spending. However, with more aggregate demand, we expect the privates to increase their maximum prices as well. We then allow the sticker prices to adjust to highlight the importance of private market power for incidence.

While our results imply that public investment is weakly progressive, we find that the accounting approach mischaracterizes incidence because the general equilibrium responses are large. In our framework, high-income-modest-ability students benefit the most from public investment because they are only admitted to the highest quality private college when state spending is sufficiently high. As state spending decreases, public colleges charge higher tuition and become lower quality, which leads the low-income-high-ability students to switch sectors. The change in enrollment patterns from the spending cut crowds out the modest-ability students. However, since the high-income-modest-ability are very likely to attend the privates under the current spending level and pay high taxes, the accounting approach implies that they subsidize the system, rather than benefit.

Our results for the high-income-modest-ability students are driven by private college price setting behavior. The sticker prices imply that there is a minimum ability required for admission. These students are crowded out of the private market unless they are able to sufficiently compensate the colleges for their negative effects on peer quality.<sup>5</sup> This is only possible if the sticker price is high enough. As private market power and (sticker) prices increase, the minimum ability thresholds fall for two reasons. First, students can pay more in tuition to increase instructional expenditure and offset the negative peer effects. Additionally, at higher prices, fewer low-income-high-ability students enroll in the privates. Average peer quality does not increase as much and therefore neither do the negative peer externalities. Since we find that private sticker prices only minimally increase when state support falls, these students bear much of the burden of divestment.

In aggregate, changes in these enrollment patterns affect the labor market returns to college as well. When state support decreases, the public colleges become more expensive and lower quality, while the privates restrict access through admission and prices. This makes college human capital scarce, driving up the college wage premium. When the privates increase their sticker prices, even more students are priced out of the private market. This pushes up the college wage premium further. As college wages rise, so does private college market power and vice versa. Therefore, even students who never attend a public or private college benefit from the effects of public investment on the private market.

The increases in private market power and the college wage premium from decreases in state support have the largest benefit for high-income-high-ability students. These students are always admitted to the high quality privates and pay the full sticker price. When state support falls, their colleges become higher quality at a time when the labor market returns to quality are higher but pay nearly the same tuition and less in taxes. These students look very similar to high-income-modest-ability students based on the accounting approach, but

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<sup>5</sup>In the model, college quality is partially determined by average student ability, or SAT scores. Students with ability above the college's average therefore create positive peer effects, while those below create negative.

the frameworks provide starkly different estimates of the welfare implications for these two groups. This is because the general equilibrium effects are large in magnitude, but the sign varies with income and ability. Appropriately accounting for these effects is necessary to measure incidence and the progressivity of public investment in higher education.

Overall, our findings contribute to our understanding of who benefits from public investment of higher education. Recent empirical work has shown that higher levels of state support increase student achievement because it reduces crowding, increases resources per student (Bound and Turner 2007; Bound et al. 2010), and increases persistence and graduation (Deming and Walters 2018). State funding also has important implications for public college admission decision and pricing (Bound et al. 2019, 2020). These results focus on students who enroll in public colleges. While those results are consistent with our model, we additionally show that the equilibrium effects from spillovers onto the private college and labor markets are important for welfare. By focusing on the direct effects, previous work does not fully characterize the full distribution of benefits and costs.

## 2. Measuring Incidence

Much of the previous empirical literature on the incidence of public investment in higher education (e.g. William Johnson 2006) uses an accounting approach. The net benefit captures a transfer to those who attend, measured by the sum of subsidies received from instructional and capital expenditure at public institutions less public tuition and tax payments. State appropriations directly affect this transfer value of public college attendance because it affects expenditure, tuition, and tax rates.

The accounting exercise misses important general equilibrium effects summarized by Figure 1. It only considers the farthest left arrow— a decrease in state appropriations creates a smaller transfer for those who attend public colleges. When the transfer value decreases, fewer students enroll. Instead, the lower in-kind subsidy leads some switch to the private sector (Peltzman 1973), while others do not enroll in any college. With increased relative

demand, private colleges have more market power; they charge tuition even further above marginal cost. A high quality, well-funded public college puts competitive pressure on privates, which creates benefits for those students. When fewer students enroll in any college after divestment, college-educated human capital becomes scarce and the college wage premium rises.

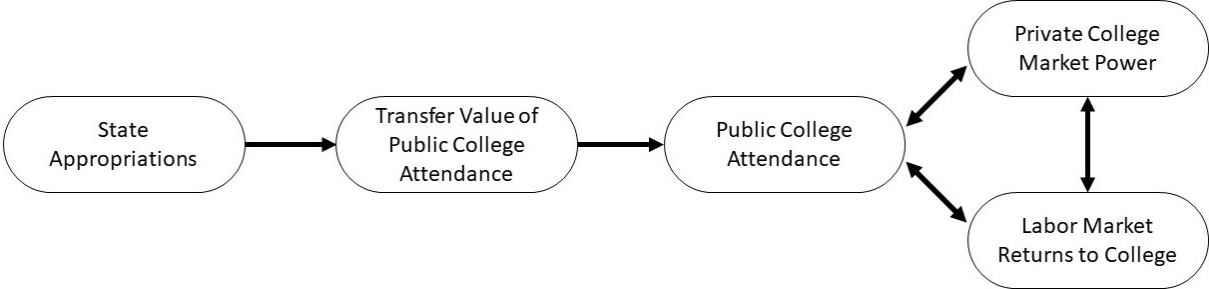


Figure 1: General Equilibrium Implications of State Appropriations

These mechanisms on college choice, private college market power, and the labor market returns to college importantly interact with each other, as indicated by the double sided arrows in Figure 1. For example, changes in enrollment patterns from state divestment affect college quality through peer effects, which further determines who the privates admit and how much they charge. Some students are crowded out of the private sector, further altering enrollment decisions. Implications in the college market then spill over to the labor market. Increased relative wages for college workers increase demand for higher education and therefore feed back onto private college market power. This compounds the effects on enrollment patterns and restarts the cycle.

This paper proposes a framework to incorporate the general equilibrium implications of state investment in public higher education to measure incidence. We first build on the model of the higher education market from Epple et al. (2017). We then implement a compensating variation (CV) measure in the model that captures the amount of money one would need to give a household, in excess of tax and tuition revenue, so that it is indifferent

between the current state spending per student levels and a 10 percent decrease.<sup>6</sup> From the observed baseline setting, we simulate the general equilibrium effects of the divestment on the college and labor markets, as well as student enrollment choices. CV then computes the welfare effects by comparing these two equilibria.

Building on the accounting approach, the objective here is to measure the value inclusive of the general equilibrium effects,  $\nu$ , in dollars, of higher education appropriations rather than just the direct transfer to those who attend. Let  $U(y, b; z)$  denote the utility of student with parental income  $y$  and ability  $b$  when states spend  $z$  in appropriations per student. CV for counterfactual spending  $0.9z$  compared to the baseline level is then

$$CV = \nu - (t(z) - t(0.9z))y - (T(z) - T(0.9z)) \quad (1)$$

$$\text{such that } U(y, b; z) = U(y + \nu, b; 0.9z)$$

where  $t(z)$  and  $T(z)$  are taxes and tuition paid to public colleges as a function of the state spending, respectively.<sup>7</sup> Our analysis is similar to Epple et al. (2019) who measure the welfare effect of moving from a state with only the lowest quality public college to a state with four different levels of quality. However, their analysis does not capture the general equilibrium effects on the college and labor markets that are the focus of our analysis.<sup>8</sup>

### 3. The Higher Education Market

We build on the general equilibrium model of higher education from Epple et al. (2017) with two main extensions that highlight the importance of private college market power and the

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<sup>6</sup>A 10 percent decrease is similar to the observed decreases. From the peak in 2001 to the trough in 2012, spending per student decreased by 31.6 percent. Since 2001, the average year-on-year decrease is about 1.3 percent.

<sup>7</sup>In our model presented in the next section, all state income taxes support the public colleges, but only the fraction of federal income taxes used to finance financial aid at the public colleges does. Tuition paid equals the sticker price minus federal financial aid received.

<sup>8</sup>Kasman and Guyot (2019) also investigate the implications of college subsidies using an agent-based model, although their main interest is enrollment and their framework does not consider private college market power. Our analysis is also complementary to Fu et al. (2021) who measure the effects of college locations and tuition, but do not consider the effects of state spending.

labor market returns to college to measure incidence. First, we endogenize sticker prices. In doing so, private colleges are better able to adjust their prices and admissions decisions with changes in government policy to further increase their market power. Second, we model the value of college as a function of the size of the college educated workforce. Changes in aggregate enrollment affect an individual’s demand for higher education through its impact on the college wage premium.<sup>9</sup> We additionally specify a more flexible parameterization of the model that is better able to match attendance by income and ability.

The market consists of three private colleges, one public college in each of two states, a unit mass of households, and state and federal governments. The college market is stylized, but allows us to highlight the mechanisms in Figure 1. At a minimum, the model must include at least one public and one private college to investigate the general equilibrium effects of public investment on the private market power. We include two additional private colleges because competition within the private college sector is itself a function of state investment. That is, who the highest quality private chooses to admit has implications for the lower quality colleges. Finally, having an in-state and out-of-state public college allows us to better compare our results to the accounting exercise since wealthy households who attend the out-of-state public colleges help subsidize less wealthy in-state students.

### 3.1 Households

There is a unit mass of households living in two identical states. Households are characterized by their state of residence,  $s$ , parental income<sup>10</sup>,  $y$ , and student ability,  $b$ , which are drawn from a joint distribution  $f(b, y_p)$ . Students make college enrollment decisions based on the wage adjusted value of human capital  $y_{sj}$  from enrolling in  $j$  with quality  $q_j$  and the household’s income net of college cost,  $y_p$ . College  $j$  costs  $p_{sj}(b, y)$  in tuition, and  $L$  in living expenses. Federal financial aid of  $A_{sj}$  is available to offset college costs. Households attend

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<sup>9</sup>George Johnson (1984) shows that this general equilibrium effect can be so strong that non-college enrollees prefer more government investment in public colleges than those who directly benefit.

<sup>10</sup>All dollar amounts are measured in tens of thousands.

the option that maximizes their utility  $U_j(s, b, y, \epsilon_j) = \ln(y_{pj}^{\alpha_p} y_{sj}^{\alpha_s}) + \epsilon_j$ , where

$$y_{pj} = (1 - t_s - t_f)y - p_{sj} - L_j + A_{sj} \quad (2)$$

$$\text{and } y_{sj} = \begin{cases} w_c \beta_1^c (\beta_2^c b^{\beta_3^c} + (1 - \beta_2^c) q_j^{\beta_3^c})^{1/\beta_3^c} & \text{if attends college } j \\ w_h \beta_1^h b^{\beta_2^h} y^{\beta_3^h} & \text{if does not attend college} \end{cases} \quad (3)$$

where  $\alpha_p$  and  $\alpha_s$  are weighting parameters that reflect the relative values of college costs and future student earnings,  $t_s$ , and  $t_f$  are state and federal taxes,  $w$  is the wage value of college or non-college human capital, and the disturbances  $\epsilon_j$  are i.i.d. Type I Extreme Value preference shocks for college  $j$ . The value of attending college depends on a student's ability and college quality, while the value of the outside option depends on ability and parental income. Under standard regularity conditions on  $\epsilon_j$ , as in McFadden (1974), we can recover the probability that a student of type  $(b, y)$  attends college  $j$ ,  $r_{sj}$ , given the set of admitted colleges  $J$  and the outside option of not attending college  $O$ .<sup>11</sup>

The labor market value of college human capital,  $w_c$ , and non-college human capital,  $w_h$ , are determined by a CES production function in aggregate college and non-college educated labor. The college wage premium for a unit of human capital is:

$$\frac{w_c}{w_h} = \frac{s}{(1 - s)} \left( \frac{C}{H} \right)^{\rho - 1} \quad (4)$$

where  $s$  is the share on college human capital,  $\rho$  determines the elasticity of substitution,  $C$  and  $H$  are the aggregate amounts of college and high school human capital in the economy, respectively.

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<sup>11</sup>  $r_{sj} = \frac{y_{pj}^{\alpha_p} y_{sj}^{\alpha_s}}{\sum_{k \in J \cup O} y_{pk}^{\alpha_p} y_{sk}^{\alpha_s}}$ . If a student does not attend college,  $L$ ,  $A$  and  $p$  are 0.

### 3.2 Private Colleges

The three private colleges admit students and choose individual prices to maximize quality,  $q_j$ , subject to a budget constraint and a maximum or sticker price  $P_j^c$ . College quality is a function of mean student ability,  $\theta_j$ , and instructional expenditure,  $I_j$ .

$$q_j = \phi_j \theta_j^\gamma I_j^\omega, \quad \gamma, \omega > 0 \quad (5)$$

Mean student ability and instructional expenditures per student are important inputs to the education production function and common proxies for quality (Black and Smith 2006). The colleges' objective function is similar to prestige maximization, where each wants to enroll high test score students that raise its national profile, while also collecting revenue to improve instructional quality or increase merit aid to attract more high test score students. Blair and Smetters (2021) provides evidence for the prestige assumption based on falling admission rates at elite colleges.

All colleges, public and private, have the same cost function,

$$C(k, I) = F + v_1 k + v_2 k^2 + kI \quad (6)$$

where  $F$  are fixed costs,  $k$  is the number of enrolled students, and  $v$  are parameters to be calibrated that capture the marginal cost of enrolling more students. Private college  $j$  has exogenous endowment  $E_j$ . A student with ability  $b$  and income  $y$  faces price  $p_{sj}$  that depends on her effective marginal cost,

$$EMC_j = v_1 + 2v_2 k + I_j + \frac{\partial q_j / \partial \theta}{\partial q_j / \partial I} (\theta_j - b) \quad (7)$$

and the conditional choice probability  $r_{sj}$  that a student of her type  $(b, y)$  attends college  $j$

$$p_{sj}(b, y) + \frac{r_{sj}(b, y)}{\partial r_{sj}(b, y) / \partial p_{sj}(b, y)} = EMC_j(b) \quad (8)$$

but must not exceed sticker price,  $P_j^c(z_s)$ , which is a function of state appropriations,  $z_s$ .  $EMC$  depends on ability through peer effects. Private colleges want to charge high ability students lower prices so that they are more likely to attend and raise  $\theta$ . A student is admitted if her marginal revenue (the minimum of the left hand side of (8) and the sticker price) is greater than effective marginal cost. Colleges must satisfy their budget constraint. They spend tuition and endowment income to cover custodial and instructional costs.

### 3.3 Public Colleges

Each state operates a public college. The public college in state  $s$  maximizes expected future income of its state's residents,  $y_{sj}$ , subject to a budget constraint.

Public colleges also take appropriations,  $z_s$ , to be exogenous. Given  $z_s$ , the public college in state  $s$  charges  $T_s$  to residents and  $T_{so}$  to non-residents. In order to raise sufficient funds for instruction, colleges adjust tuition based on changes to  $z_s$ . Colleges may also change the relative proportion of residents and non-residents admitted. We assume tuition is a function of appropriations such that

$$\begin{aligned} T_s &= \left[ 1 + \kappa_s \left( \frac{z_s - \bar{z}_s}{\bar{z}_s} \right) \right] \bar{T}_s \\ T_{so} &= \left[ 1 + \kappa_{so} \left( \frac{z_s - \bar{z}_s}{\bar{z}_s} \right) \right] \bar{T}_{so} \end{aligned} \quad (9)$$

where  $\kappa$  is the elasticity of tuition with respect to appropriations, and  $\bar{T}$  represents base-line equilibrium tuition. This equation is only locally valid and is therefore only used to understand tuition setting under small changes in appropriations. All students of the same residency type at a public college face the same sticker price, although students with differ-

ent incomes pay different amounts due to differences in federal financial aid. Tuition and appropriations per student fund instructional expenditure per student and custodial costs.

Epple et al. (2017) show that the public college  $j$  admits all students with ability above a residency specific threshold for residents,  $b_{min}^s$ , and non-residents,  $b_{min}^o$  respectively implicitly defined by:

$$y_{sj}(q_j, b_{min}^s)/\lambda + T_s + z_s - EMC_j(b_{min}^s) = 0 \quad (10)$$

$$T_{so} + z_s - EMC_j(b_{min}^o) = 0 \quad (11)$$

where  $\lambda$  is the multiplier on the budget constraint. The non-resident threshold is a function of tuition and the appropriations level, while the resident threshold also accounts for how educating student with ability  $b$  changes the total stock of in-state human capital.

### 3.4 Federal and State Governments

The federal government distributes financial aid,  $A_{sj}$  through a Pell Grant type program, that takes into account expected family contribution as a function of income  $EFC(y)$ . A student can receive at most  $\bar{A}$  in aid.

$$A_{sj} = \min\{\max[0, P_j^c + L - EFC(y)], \bar{A}\}$$

The state and federal governments must balance their budgets. Let  $Y_s$  be pre-tax aggregate income in state  $s$ .

$$t_s Y_s = z_s k_s, \quad s = \{1, 2\}; \quad t_f \sum_s Y_s = \sum_s \int \sum_j r_{sj} A_{sj} f_s(b, y) db dy$$

where  $k_s$  is the number of students who attend the public college in state  $s$ , regardless of each student's state of residence. State colleges can give admission and tuition preference to residents but do not treat students differently after enrolling.

### 3.5 Equilibrium Definition

An equilibrium consists of a price and quality vector with corresponding college characteristics  $(\theta_j, I_j, k_j)$  for all  $j \in J \setminus O$ ; state admission criteria for all states for residents and non-residents; state of residence  $s$  for all households, which gives  $f_s(b, y)$ ; and a set of student choices for all  $(s, b, y)$  and  $j \in J$  and choice probabilities  $r_{sj}(b, y)$  such that:

1. Private colleges choose who to admit and what prices to charge to maximize quality, taking the prices and qualities of the other colleges, the student choice probability functions, and public policies as given.
2. Public colleges choose who to admit to maximize in-state achievement, taking the prices and qualities of the other colleges, the student characteristics, and public policies as given.
3. Household  $(b, y)$  pick where to attend to maximize utility, taking college prices and qualities, public policies, and the decisions of other households as given.
4. State and federal budgets are balanced.

### 3.6 Brief Discussion of Model Limitations

The model is highly stylized, but the general equilibrium structure allows us to shed light on the importance of private college market power and the labor market for measuring the incidence of public investment in higher education. Before discussing how the model is calibrated and the results, it is important to understand some of the model's key simplifications.

First, the public sector only consists of one college per state while states have several colleges of varying quality. Including additional public colleges would provide more competitive pressure on the private sector and therefore strengthen the mechanisms we highlight. Similarly, public colleges do not offer institutional aid in the model, which also understates the competitive pressure they provide. Cook and Turner (2021) show that public research

universities have progressive pricing policies, although that is not the case for non-research universities. If the public universities could attract more high-ability students away from the privates with subsidies, then the privates would have less market power. However, the opposite is true for the size of private sector— including more privates would increase the competitiveness of market and therefore lower the value of public competition.<sup>12</sup>

Related to our assumptions on the size of the market, we also assume colleges do not face capacity constraints. With capacity constraints, public colleges have less resources to spend on instruction but also no longer enroll the lower ability students who lower peer effects but whose education raises average state achievement. This leads to an ambiguous quality change and therefore an unknown change in public value and competitive pressure. Private college capacity constraints also have an ambiguous effect on market power because it restricts access but also lowers quality and therefore decreases both demand and supply.<sup>13</sup> Most importantly for incidence, when private college demand increases after a state funding cut, capacity constraints would lead fewer total students to enroll. A constraint would lead to larger negative welfare effects on the baseline ( $z = \bar{z}$ ) marginal ability students who have high effective marginal costs, strengthening our overall findings.

Our simplifications on the household side of the market are also important for incidence. Households are only able to pay for college out of current income and so some low-income households may be financially rationed out of the private market, especially when the returns to college are high. We may therefore overstate the value of public colleges to the modest-income-high-ability students who are always admitted to the privates but can only afford to attend in our model with public competitive pressure.<sup>14</sup> However, a loan market weakly increases households' willingness-to-pay for college and therefore also

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<sup>12</sup>We will additionally assume, for simplicity, that the public colleges are of the same quality. This implies that students will only attend the out-of-state public if they have a high idiosyncratic preference for that school. This is likely the case for some students who care about non-educational amenities (e.g. sports) or if they want to move to that state after graduating.

<sup>13</sup>Since the privates maximize quality in the model, a constraint necessarily would weakly lower quality.

<sup>14</sup>Our framework does not capture the impact of liquidity constraints and household borrowing for college, which are likely important (see Lochner and Monge-Naranjo 2012) and vary across the income distribution.

increases private college prices and market power. Overall, we find that changes in private market power from decreases in public investment mainly affect high-income-modest-ability students who are always able to afford college without loans. A loan market would therefore give greater college access to low-income-higher-ability students, exacerbating the main mechanisms we study in this paper.

#### 4. Private Colleges and Incidence

Public investment in higher education creates general equilibrium implications for the private college market, in addition to the direct effects on public colleges previously considered in the literature. To measure the role private colleges play for measuring incidence, first consider how appropriations,  $z_s$ , affect their prices. For the purposes of this illustration, we hold the labor market fixed. Given the model's parametrization and Equation 8, private college  $j$  net tuition after institutional aid is

$$p_{sj} = \frac{(1 - r_{sj})\alpha_p}{1 + (1 - r_{sj})\alpha_p} EMC_j(b) + \frac{y - L_j + A_{sj}}{1 + (1 - r_{sj})\alpha_p} \quad \text{and therefore} \quad (12)$$

$$\frac{\partial p_{sj}}{\partial z_s} = \underbrace{\frac{\alpha_p(y - L_j + A_{sj} - EMC_j(b))}{(1 + (1 - r_{sj})\alpha_p)^2} \left( \frac{\partial r_{sj}}{\partial z_s} \right)}_{\text{change in relative value of private college}} + \underbrace{\frac{(1 - r_{sj})\alpha_p}{1 + (1 - r_{sj})\alpha_p} \left( \frac{\partial EMC_j(b)}{\partial z_s} \right)}_{\text{change in cost to college of enrolling}} \quad (13)$$

$$\text{where } \frac{\partial EMC_j(b)}{\partial z_s} = \underbrace{2\nu_2 \frac{\partial k_j}{\partial z_s}}_{\text{custodial costs change}} + \underbrace{\left( 1 + \frac{\gamma}{\omega} \left( 1 - \frac{b}{\theta_j} \right) \right) \frac{\partial I_j}{\partial z_s}}_{\text{expenditure costs change}} + \underbrace{\frac{\gamma I_j b}{\omega \theta_j^2} \frac{\partial \theta_j}{\partial z_s}}_{\text{peer externality change}} \quad (14)$$

and  $\partial r_{sj}/\partial z_s$  is determined by the household's utility function.<sup>15</sup> When appropriations fall, instructional expenditure at the public colleges falls as well and tuition increases. Households are more likely to enroll in the privates as a result. This implies  $\partial r_{sj}/\partial z_s < 0$  and  $\partial k_j/\partial z_s <$

<sup>15</sup>The derivate is only defined for students who attend college  $j$  in the baseline. For those students,  $y - L + A_{sj} - EMC_j(b)$  is positive since price is less than or equal to  $EMC_j(b)$  and students only attend if they can afford to.

0. The first term in Equation 13 captures the first order effect of changes in the value of a student's other options on private college prices. When the value of the public colleges decreases and they provide less competitive pressure, the privates gain market power.

The market level changes also create general equilibrium effects from student sorting, reflected in the second term of Equation 13 and broken down into three components in Equation 14. First, decreases in public college appropriations increase custodial or operating costs as long as the college has increasing marginal costs, or when  $v_2 > 0$ . The middle term reflects changes in instructional costs. If decreases in appropriations allow the college to charge higher prices because  $\partial r_{sj}/\partial z_s < 0$ , it will have more revenue to increase instructional expenditure. The direct financial cost of enrolling students increases. The impact of changes in expenditure on prices is weighted by a function of student ability since instruction and average ability are linked through the quality production function. Since expenditure and average ability are complements, the value to the college of enrolling high-ability students or cost of enrolling low-ability students is larger when expenditure is higher.

The final term in Equation 14 captures how general equilibrium sorting of students affects relative college quality from changes in peer effects. The sign of  $\partial \theta_j/\partial z_s$  and the final term therefore depends on who the marginal students to private colleges are. When the public colleges become lower quality, low-income-high-ability students may then find it worthwhile to pay for the more expensive privates. In that case,  $\theta_j$  will increase. The opposite is true if high-income-modest-ability students are on the margin. When  $\theta_j$  is larger,  $\theta_j - b$  is also larger and low-ability students produce more negative peer externalities. They must pay higher prices to compensate, although colleges are unable to raise tuition above a maximum  $P_j^c$ . Overall, this discussion implies that the sign of  $\partial p_{sj}/\partial z_s$  is theoretically ambiguous and potentially varies across the income and ability distribution. However, in our calibrated model, we find that both  $\partial p_{sj}/\partial z_s$  and  $\partial EMC_j(b)/\partial z_s$  are negative for all.

State investment in public higher education additionally affects who the privates admit. Each private admits a student if her effective marginal cost is less than the minimum

of the optimal price given by Equation 8 and the sticker price, that is if  $\min(P_j^c, p_{sj}(b, y)) \geq EMC_j(b)$ . Students that pay more than their effective marginal cost but less than the sticker price before a small appropriations decrease will still be admitted afterwards. The spending shock has an ambiguous effect on welfare for these students since they now face higher prices, but also benefit from higher quality private colleges.

The students most impacted by decreases in state spending are those who are no longer admitted to the privates. The sticker price and effective marginal cost together imply a minimum ability threshold at each college defined by  $EMC_j(b) = P_j^c$ . Who is still admitted after the state spending change depends on how both pieces respond. Holding the sticker prices fixed, a decrease in appropriations will increase the minimum ability threshold if  $\partial EMC_j(b)/\partial z_s < 0$  for the marginal ability student. Students who can no longer attend their best option face a potentially large welfare loss. How many students are affected depends on the private college sticker price responses. If the privates also raise their maximum prices when appropriations fall,  $\partial P_j^c/\partial z_s < 0$ , then more low-ability students can compensate the privates for their high effective marginal costs. In the remainder of the paper, we calibrate the model and present counterfactual simulations to understand the importance of these mechanisms for incidence.

## 5. Calibration and Equilibrium Description

We calibrate the model to match the college going behavior across the income distribution and previous estimates from the literature that describe how students and institutions respond to different higher education policies. The estimates are presented in Table 1. First, using information on the joint income-ability distribution from the High School Longitudinal Study of 2009 (HSLs), we estimate the income distribution and the correlation between income and ability, assuming that they are jointly log-normally distributed. Following Epple et al. (2017), we assume that the ability distribution has a mean of 1 and a standard

deviation of 0.15.<sup>16</sup> We truncate the income distribution at the lowest bin we observe in the data (\$15K) so that all households can afford the in-state college option as well as \$300K.

Many baseline parameters, specifically government policies, sticker prices, and endowments, are directly observed in the data. The calibration uses the 2013-2014 academic year to align with the HSLs. The Delta Cost Project has data on institution-level resident and non-resident tuition, state appropriations, and private college sticker prices. We compute the enrollment-weighted average for public four-year colleges and private not-for-profit four-year colleges, divided into three groups by SAT scores. Living Expenses are from the National Center for Education Statistics (NCES). Federal financial aid policies and private college endowments follow Epple et al. (2017)<sup>17</sup>.

We calibrate the remaining household and college parameters,  $\alpha_s, w\beta_s, \phi_s, \gamma, \omega, F$ , and  $vs$ , to minimize the sum of squared percent deviations of: (1) average private college tuition of \$27220 (National Postsecondary Student Aid Study 2012, Epple et al. 2019 scaled to 2013-2014 dollars); (2) private school enrollment as percent of total enrollment of 28.5 (HSLs); (3) enrollment elasticity of institutional aid of 0.7 (Van der Klaauw 2002); (4-5) estimates of the elasticity of aid with respect to ability and income from Epple et al. (2019); (6) the 20 percent earnings increase for the marginal-ability student from attending a public college (Hoesktra 2009 and Zimmerman 2014)<sup>18</sup>; (7) public college instructional expenditure per student of \$10463 (Delta Cost Project); (8-13) the percent of students from each of 6 income bins who enroll in any 4 year college weighted by the percent of students in each bin<sup>19</sup>; and (14-18) the percent of students from each ability quintile who enroll in any 4 year

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<sup>16</sup>Using the PowerStat tool from the National Center for Education Statistics, data is available by the following income bins: less than \$15K; in increments of \$20K up to \$235K; more than \$235K. We measure ability using the mathematics quintile score. Income is scaled to 2013-2014 using the Consumer Price Index.

<sup>17</sup>The maximum federal aid is set to \$4K to match estimates from the 2011-12 National Postsecondary Student Aid Study for those who applied for federal aid.

<sup>18</sup>The model implies a minimum-ability threshold at public colleges. This creates a regression-discontinuity, where students just above the threshold have access to the public colleges, but those below do not. We match the model implied earnings gain from college attendance for these students, based on  $\beta$ , to the RD estimates.

<sup>19</sup>We combine the highest income bins to create \$95K to \$135K and more than \$135K so that all bins have at least 10 percent of the population. We exclude the lowest income bin of less than \$15K since we truncate the income distribution at that point.

college weighted by the percent of students. We additionally set  $v_1$  to 0, based on previous results from Epple et al. (2006, 2017). Appendix A presents the model fit.

From the calibrated equilibrium, the returns to college quality and ability,  $\beta s$ , and the labor market returns to human capital,  $w_s$ , are not separately identified. While  $\beta s$  are structural parameters,  $w_s$  are equilibrium parameters and functions of public investment in higher education. Assuming that the labor market value of human capital is determined by a CES production function in college and non-college educated labor, we set  $\rho$  to 1.7 (Autor 2014). We then recover the share parameter,  $s$ , assuming that the entire baseline earnings difference between workers is because of human capital differences or that  $w_c/w_h = 1$ .<sup>20</sup> Under these assumptions, we recover  $\beta s$ ,  $w_c$  and  $w_h$  for the baseline equilibrium.

Finally, we calibrate how public and private college tuition respond to changes in public investment in higher education. We set  $\kappa_s = -0.263$  and  $\kappa_{so} = -0.066$  based on Bound et al. (2020).<sup>21</sup> In the next subsection, we estimate the private college sticker price elasticity with respect to state appropriations,  $\kappa_p$ .

## 5.1 Sticker Price Response to Public Investment

The model implied incidence of public investment in higher education depends on the responsiveness of private college sticker prices to changes in state funding. The progressivity of public investment is a function of the magnitude of the elasticity since a larger price response implies a smaller change in the minimum ability thresholds at the private colleges. We estimate the elasticity of private college sticker prices with respect to state appropriations,  $\kappa_p$ ,

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<sup>20</sup>From the model’s calibrated equilibrium, we cannot recover both  $s$  and the college wage (per unit of human capital) gap. However, since college educated labor is a scarce resource, we expect  $w_c \geq w_h$ . From calibration moment (6), the marginal student’s earnings gains also imply that  $w_c \leq 1.2w_h$  if college weakly increases human capital. We therefore choose  $w_c/w_h = 1$  as a normalization. For a small policy change, like in our counterfactuals to measure incidence, the equilibrium wage ratio is mainly determined by  $\rho$ .

<sup>21</sup>Rizzo and Ehrenberg (2004) find that for a \$1000 increase in appropriations, resident tuition decreases by \$60, while non-resident decreases by about \$222. Webber (2017) finds larger elasticities, especially for more recent years, but does not differentiate between resident and non-resident tuition.

Table 1: Calibration Parameters

Parameter	Name	Value
<b>Households:</b>		
$\alpha_p$	Parent Utility Shifter	20.832
$\alpha_s$	Student Utility Shifter	25.320
$w\beta_1^c$	College Wage Shifter	2.614
$w\beta_2^c$	College Wage Ability Share	0.505
$w\beta_3^c$	College Wage Substitution Parameter	-0.936
$w\beta_1^h$	Non-college Wage Shifter	2.359
$w\beta_2^h$	Non-college Return to Ability	0.111
$w\beta_3^h$	Non-college Return to Parental Income	0.138
$L$	Living expenses	\$5479
$b$	Ability Distribution	$\ln(b) \sim N(1.0, 0.0225)$
$y$	Income Distribution	$\ln(y + 42470) \sim N(11.500, 0.298)$
$\text{corr}(b, y)$		0.359
<b>Governments:</b>		
$\bar{T}_s$	Resident; Non-Resident Tuition	\$7113; 19345
$\bar{z}_s$	Per Student Subsidy	\$7062
$EFC$	Effective Family Contribution	$\max\{0, .48y - 10300, .69y - 22500\}$
$\bar{A}$	Maximum federal aid	\$4000
$\kappa_s; \kappa_{so}$	In-state; Out-of-state Tuition Elasticity	-0.263; -.066
<b>Colleges:</b>		
$\phi$	Private Productivities	1.089;1.118;1.182
$\gamma$	Return on Peer Quality	0.049
$\omega$	Return on Instruction	0.065
$E_j/k_j$	Baseline Endowments Per Student	\$221, 603, 3850
$P_j^c$	Baseline Sticker Prices	\$24082; 31724; 34118
$\kappa_p$	Sticker Price Elasticity	-0.126
<b>Costs:</b>		
$F$	Fixed Cost	\$231
$v_1; v_2$	Custodial cost parameters	\$0; 18057
<b>Labor Market:</b>		
$\rho$	CES Substitution Parameter	0.412
$s$	CES College Share	0.461

from the following specification:

$$\log(P_{j(s)t}^c) = \kappa_p \log(z_{j(s)t}) + \pi_{j(s)} + \psi_{st} + u_{jt} \quad (15)$$

$$\text{where } z_{j(s)t} = \sum_i z_{it} \frac{k_{ij,1998}}{k_{j,1998}} \quad (16)$$

where  $P_{j(s)t}^c$  is the sticker price of private college  $j$  in state  $s$  in year  $t$ ,  $z_{it}$  is the average appropriations in state  $i$  and year  $t$ ,  $z_{j(s)t}$  computes the relevant state appropriations for college  $j$  by weighting  $z_{it}$  by the fraction of  $j$ 's students from  $i$  in the baseline year 1998, and  $\pi_{j(s)}$  and  $\psi_{st}$  are institution and state-by-year fixed effects, respectively.

Equation 15 is similar to a shift-share design where  $z_{it}$  captures yearly variation in the effective treatment for college  $j$  and  $k_{ij,1998}/k_{j,1998}$  captures  $j$ 's dependence on students from  $i$ . As appropriations and public college quality in  $i$  decrease, the demand for private options increases, allowing those colleges to raise prices. The importance of a spending shock in  $i$  to college  $j$  depends on how many students from that state tend to enroll.<sup>22</sup> This strategy exploits within state variation based on where private colleges draw their students.

McDuff (2006) provides empirical support for these mechanism where students respond to changes in public investment in higher education. He finds that a 1 standard deviation increase in public college quality, which is measured as a combination of mean SAT scores, freshman retention, and spending per student at the flagship, increases the percentage of scores sent to in-state public schools by about 6 percentage points and the likelihood of enrolling in an in-state public school by 5 percentage points. Increased demand in one sector implies relative decreases in others, the private market or no college. McDuff also finds that lower income households are more price sensitive, while the higher income are more quality sensitive. This evidence is consistent with our calibrated model and we highlight its implications for enrollment and incidence in the next section.<sup>23</sup>

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<sup>22</sup>Contemporaneous measures of the share of students from each state would lead to an upward bias since enrollments are also a function of the sticker prices. We therefore use 1998 as a base year.

<sup>23</sup>Bound et al. (2009) provide additional suggestive evidence that students responded to the decrease in public college quality over time.

We estimate Equation 15 using a balanced panel of Bachelor’s, Master’s and Doctoral private colleges from 2000 to 2017. For each institution, the Integrated Postsecondary Education Data System (IPEDS) reports the college’s sticker price in a given year, as well as the number of students from each US state who attend. Grapevine, an annual compilation of data on state fiscal support for higher education, from the Center for the Study of Education Policy at Illinois State University and the State Higher Education Executive Officers (SHEEO) report the state-level average appropriations per student at public colleges. We allow  $\kappa_p$  to vary by quartile of SAT scores since our model predicts that the elasticity depends on how close substitutes the public and private colleges are.<sup>24</sup> The results are reported in Table 2. Our preferred specification is column (3) with state-by-year fixed effects. We present specifications with only year fixed effects, and both year fixed effects and state linear time trends to show the importance of capturing business cycle fluctuations. When the economy is doing well, states have more resources to spend on appropriations, but so do households to spend on education, which would lead  $\kappa_p$  to be biased upwards.

Our results suggest that private colleges adjust their maximum prices to further increase market power when state appropriations fall, but the effect is small in magnitude. A 10 percent decrease in appropriations would lead to less than a 1.3 percent increase in private college sticker prices. The effect also appears to be concentrated in the upper-middle quartile of selectivity, at institutions like Northeastern University. Colleges at this level of selectivity are likely close substitutes for the public colleges. The student-weighted average SAT scores at public colleges is at the boundary of the lower-middle and upper-middle quartiles and well within the upper-middle for flagships. Our results may understate the effects at less selective institutions since many draw students locally, which makes it difficult to detect a response in our framework with state-by-year fixed effects. Some of these institutions are also horizontally differentiated, religious colleges for example, and therefore may also not

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<sup>24</sup>IPEDS reports the 25th and 75th percentiles of the math and verbal section of the SAT. We measure the institution’s SAT scores as the average of all four components in Fall 2001, the first year available in the data.

Table 2: The Effect of State Appropriations on Private College Sticker Prices

	(1)	(2)	(3)
	Log Price	Log Price	Log Price
Lower quartile	-0.003 (0.035)	-0.015 (0.035)	-0.042 (0.054)
Lower-middle quartile	0.020 (0.025)	-0.002 (0.026)	-0.031 (0.049)
Upper-middle quartile	-0.069* (0.038)	-0.093*** (0.036)	-0.126** (0.057)
Upper quartile	0.033 (0.028)	0.011 (0.025)	-0.024 (0.052)
Observations	14705	14705	14705
Year FE	Yes	Yes	No
State Linear Time Trend	No	Yes	No
State-by-Year FE	No	No	Yes
Institution FE	Yes	Yes	Yes

Note: Each column presents the coefficients from a regression of the log of institution relevant appropriations interacted with quartiles of SAT scores on the log of private college sticker prices using a balanced panel of institutions from 2000 to 2017 with various institution and time controls. Standard errors clustered by institution. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

directly compete with publics. Highly selective institutions compete less with the public sector and respond less as well, based on our estimates.

Based on the results, we set  $\kappa_p = -0.126$  for all private colleges in the model. This subtle response may be consistent with quality-maximizing private colleges if high-ability-low-income students' application decisions are sensitive to the sticker price, as has been well-documented (e.g. see Bettinger et al. (2012), Hoxby and Avery (2013), Hoxby and Turner (2015), and Dynarski et al. (2021)). Some private colleges have recently lowered their sticker prices in hopes of attracting more students (Anderson 2019). Colleges may also have a different objective function for setting their maximum prices. Epple et al. (2006) suggest that lower than quality-maximizing prices would reduce the number of low-ability students who harm the college's reputation, limit the private incentives of administrators to admit students of wealthy households for personal gain, and lead to higher alumni giving.

Our results are also consistent with previous evidence on average prices, as in Fillmore (2016). Using the National Postsecondary Student Aid Study, he finds that, all else equal, colleges offer lower prices to students when they believe they face stiffer competition. Every additional school listed on a student’s FAFSA is associated with a \$373 increase in institutional aid. This effect is primarily driven by private colleges and the estimated association for very selective privates is more than \$900 per additional school listed. Large changes in the market that affect every student’s application portfolio should then have general equilibrium consequences for the entire tuition distribution, pushing up sticker prices as well.

## 5.2 State Investment and The Higher Education Market

State investment in public higher education has important implications for the entire college market and the labor market. Using the baseline calibrated model with state spending  $\bar{z}$  and private sticker prices,  $P_j^c$ , we simulate the effects of a 10 percent decrease in public support with and without endogenous sticker prices. Table 3 includes key features of the equilibria to highlight the general equilibrium consequences of state divestment. Figure 2 additionally presents how the enrollment decisions of different types of students, based on their income and ability, are affected when sticker prices endogenously adjust. Appendix B similarly shows the distributional enrollment changes when sticker prices are fixed to their baseline levels. The next section then quantifies the welfare effects of these different impacts to understand who benefits and who bears the burden of public investment.

Based on our calibration (column 1), the market consists of an open-access public college in each state, two nearly open-access private colleges, and one selective private college. We refer to the privates as LP, MP, and HP for low-quality, middle-quality, and high-quality private colleges. When state appropriations fall to  $0.9\bar{z}$  (column 2), the public colleges charge higher tuition to recover lost revenue, but spend less on instruction. These two changes depress aggregate public college demand and have two implications for private market. First, the privates charge higher prices to increase instructional expenditure and quality, further

driving up their own demand for most. However, prices increase too much for the low-income, leading some to substitute to the in-state public where prices did not increase as much, raising its average student ability.<sup>25</sup> The general equilibrium effects of state investment on the private market therefore feedback onto the public colleges.

Second, some baseline public college students now enroll in the privates. In particular, modest-income-very high-ability students, who receive substantial private institutional aid, switch sectors. The change in enrollments increases the average student ability at the highest quality private, which raises the minimum ability threshold. Those between the 60th and 62nd percentiles of the ability distribution can no longer sufficiently compensate the HP college at the baseline sticker prices, and are crowded out.

Increased selectivity at the highest-quality private college creates negative spillovers on the other privates. The modest-ability students, or those just above the 60th percentile, no longer admitted after the state funding decrease are now likely to enroll in one of the other privates, lowering their average student ability. This effect outweighs the increased demand from the modest-income-high-ability students who attend the public colleges when state support is high. Overall quality at LP and MP still increases because the colleges enroll more high-income students and can charge higher prices from the change in demand.

Based on the implications for student sorting and college quality, state divestment decreases total college human capital accumulation. The implied college wage gap increase by 0.4 percent induces some baseline non-college workers to enroll. Even though enrollment goes up, most attend the now lower quality publics. Although more students would want to enroll in the private sector, since the returns to any college and college quality increased, the privates limit access through their admissions decisions and prices.

When private colleges increase their sticker prices slightly after the decrease in state funding (column 3), more modest-ability students can sufficiently compensate the highest

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<sup>25</sup>The shift of more lower income households to the the less expensive public sector or to no college also decreases total federal financial aid.

Table 3: State Investment and the Higher Education Market

	(1) $\bar{z}_s$ with $P_j^c$	(2) $0.9\bar{z}_s$ with $P_j^c$	(3) $0.9\bar{z}_s$ with $(1 - 0.1\kappa_p)P_j^c$
Enrollment:			
Publics	0.131	0.129	0.130
LP	0.041	0.041	0.040
MP	0.032	0.032	0.032
HP	0.031	0.032	0.031
Expenditure per Student $I_j$ (\$10K):			
Publics	1.044	0.993	0.993
LP	1.551	1.619	1.630
MP	2.023	2.086	2.098
HP	2.988	2.995	3.032
Mean Student Ability $\theta_j$ (percentile):			
Publics	65.017	65.099	65.147
LP	79.838	79.560	79.765
MP	83.184	83.012	83.182
HP	89.965	90.139	90.007
Quality $q_j$ :			
Publics	1.056	1.052	1.052
LP	1.181	1.184	1.185
MP	1.237	1.240	1.240
HP	1.346	1.346	1.347
Minimum Ability Enrolled (percentile):			
Public Resident	0	0	0
Public Non-resident	0	0	0
LP	0.008	0.008	0.008
MP	0.008	0.008	0.016
HP	60.061	62.331	61.443
Average Tuition (\$10K):			
Publics	0.751	0.769	0.769
LP	2.153	2.233	2.251
MP	2.728	2.799	2.817
HP	3.393	3.400	3.443
Percent Increase in Baseline Wages Per Unit Human Capital			
$w_c$	-	0.239	0.253
$w_h$	-	-0.178	-0.188
Tax rates			
$t_s$	0.025	0.022	0.022
$t_f$	0.005	0.005	0.005

Each column presents equilibrium summary statistics for the two public colleges and the three privates of varying quality. Column (1) describes the baseline calibrated equilibrium. Column (2) simulates the new equilibrium, including student attendance choices and the labor market changes, after a 10 percent decrease in state appropriations per student holding private college sticker prices fixed. Finally, Column (3) additionally allows the sticker prices to endogenously adjust.

quality private for their effect on  $\theta_{HP}$ , and are now admitted. The minimum ability threshold falls slightly but is still above the baseline. The threshold also falls because, at higher prices, low-income-high-ability students are less likely to enroll. Fewer students are crowded out on the admissions margin from the policy change, but more choose not to attend because it is not worth the cost.<sup>26</sup> From the enrollment and price changes, the college raises more revenue for instruction, improving quality and thereby increasing demand and the entire distribution of prices further. Moreover, with less crowd out of high-income-low-ability students, the spillovers on the other privates are smaller.

The change in attendance patterns and quality from increases in private college sticker prices has an ambiguous effect on the labor market. More students are admitted to the highest quality college and the privates collect more tuition revenue to improve quality but fewer choose to enroll at higher prices. We find that increases in private sticker prices decrease total human capital in the economy. Therefore, the college wage premium rises with private market power.

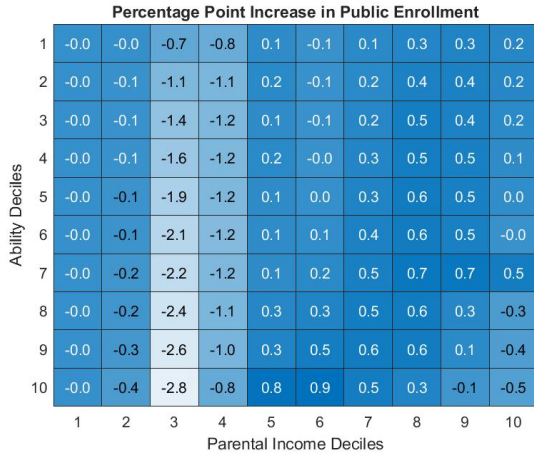
### 5.3 Equilibrium Impacts of Sticker Price Increases

As highlighted in Section 4, the sticker price elasticity's effect on private college admission has important implications for who benefits and who bears the burden of public investment in higher education. The more the sticker prices increase, the more the privates can increase their market power and modest-ability students can compensate for their negative peer effects. The elasticity therefore determines who has access to the highest quality private after a 10 percent decrease in appropriations per student ( $z = 0.9\bar{z}$ ).

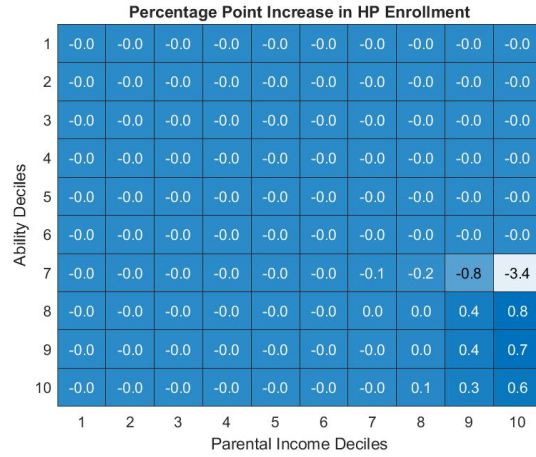
Panel (a) of Figure 3 plots the change in HP college's minimum ability threshold as a function of the sticker price elasticity. As it increases in magnitude, the minimum ability threshold falls. However, the elasticity would need to be less than -0.325 for the admission

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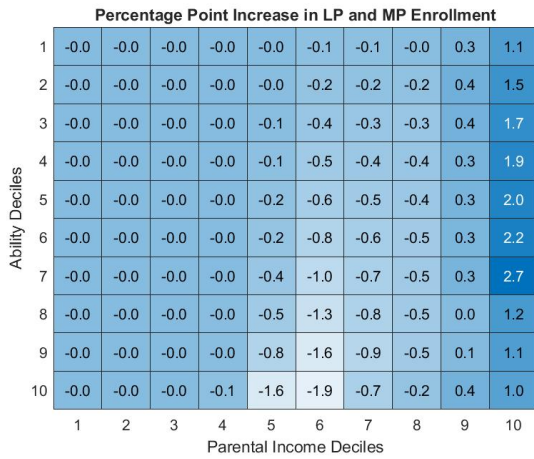
<sup>26</sup>Panel (b) of Figure 2 shows that when sticker prices increase after a decrease in funding, the net impact for middle income households on the highest quality private enrollment is negative for even the top decile of ability students. The net impact is positive but small for these households when sticker prices are fixed (Appendix B).



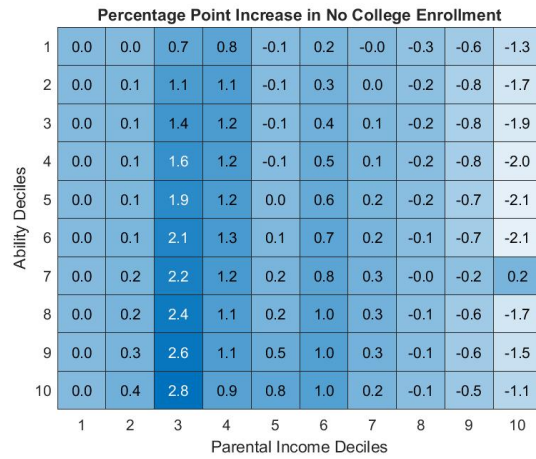
(a) Public College Enrollment



(b) Highest Quality Private Enrollment



(c) Low and Middle Quality Private Enrollment



(d) No College Enrollment

Figure 2: Public Investment and Enrollment with Endogenous Sticker Prices

Note: Each panel of the figure is a heat map of the percentage point increase in enrollment after a 10 percent decrease in state spending per student, when allowing private college sticker prices to endogenously adjust up. A darker shade denotes that enrollment increases by more after appropriations decrease.

threshold to be lower than the baseline, which is well outside the confidence interval of our estimate from Table 2, shown by the virtual dotted lines. After the decrease in public investment, the highest quality private becomes more selective and some modest-ability students are crowded out, although the number depends on the sticker price elasticity.

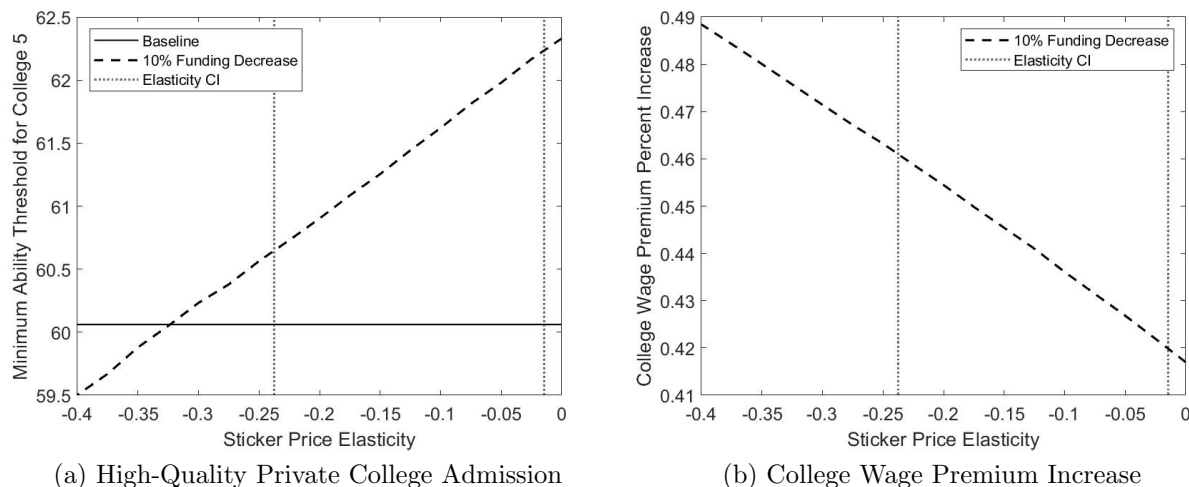


Figure 3: Equilibrium Impacts of Sticker Price Increases

Note: Panel (a) plots the relationship between the sticker price elasticity and HP college’s minimum ability threshold for a 10 percent decrease in appropriations per student. The horizontal solid line shows the baseline admission’s threshold for reference. Panel (b) plots the college wage premium,  $w_c/w_h$ , for the same decrease in funding as a function of the elasticity. In both panels, the vertical dotted lines show the upper and lower bounds of the elasticity’s confidence interval from Table 2.

Increases in private college sticker prices also affect attendance by pricing lower income households out of the market. Those students either choose to enroll in the lower quality public colleges or do not attend any. Although the privates use the extra revenue to improve their own quality and increase their students’ human capital, Panel (b) of Figure 3 implies that aggregate college human capital decreases after the cut to state spending and is decreasing with the magnitude of elasticity. Increases in private college prices, and therefore market power, exacerbate the college wage premium. Increases in the college wage premium also drive up demand for the privates, allowing them to charge higher tuition, although they are limited by their sticker prices. These two effects build on one another, but the extent to

which they do depends on the elasticity.

#### 5.4 Empirical Tests of the Model

The model provides several predictions for the equilibrium impact of state divestment in higher education, which we now test. Our empirical approach to validate the model follows the same identification strategy as Section 5.1— it leverages quasi-experimental variation from changes in state appropriations across space and time as well as private colleges’ historical dependence on students from each state. However, unlike Section 5.1, the results here allow us to evaluate the model by comparing it to data that were not used for calibration.

After a decrease in state funding per student, the model predicts that all students will see a weak increase in their tuition after institutional aid since the value of the public college and no-college options decrease. Based on Equation (8), prices should also increase more for the low-income because they value the less expensive public college more; since their best option becomes worse, private college market power increases more for them. Additionally, when holding sticker prices fixed, net tuition should increase by less (Table 3) because private college market power does not fully adjust. Beginning in the 2008-2009 academic year, IPEDS has collected data on the average net tuition paid for several income-bins<sup>27</sup> which lets us compare the model to the data.

We estimate the effect of a change in private college  $j$ ’s relevant state appropriations,  $z_{j(s)t}$ , on net tuition by income bin  $b$  from:

$$\log(p_{jbt}) = \sum_{b=1}^5 \kappa_b \mathbb{1}_b \log(z_{j(s)t}) + \pi_{j(s)b} + \psi_{st} + u_{jbt} \quad (17)$$

where  $p_{jbt}$  is the average net tuition for students enrolled in college  $j$  in income bin  $b$  in year  $t$ ,  $\mathbb{1}_b$  is an indicator for income bin  $b$ ,  $\pi_{j(s),b}$  are institution-by-income bin fixed effects, and  $\psi_{st}$  are state-by-year fixed effects. We additionally estimate a version of Equation (17)

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<sup>27</sup>Less than \$30K; \$30K to \$48K; \$48K to \$75K; \$75K to \$110K; and more than \$110K

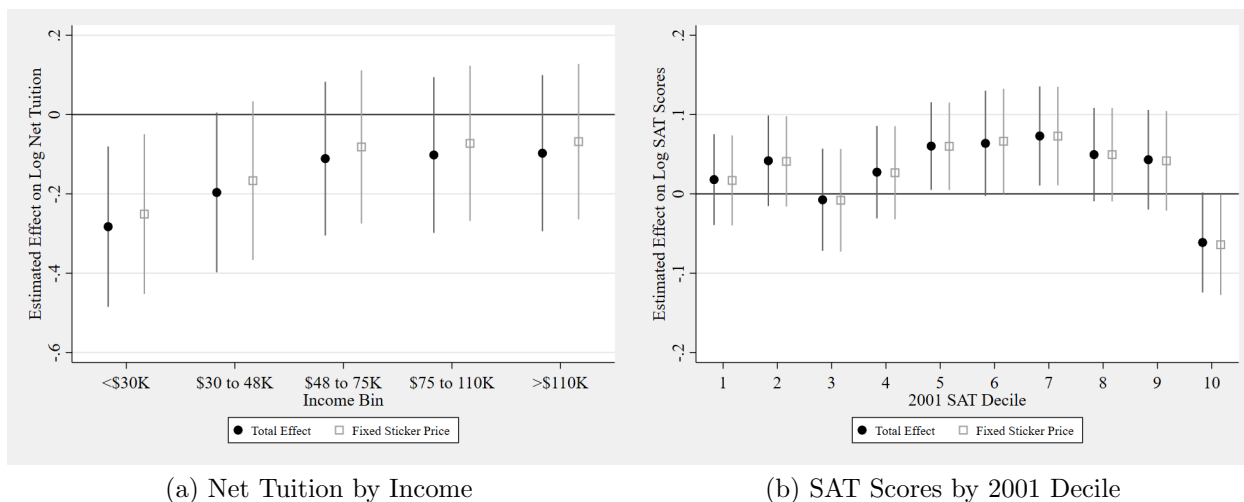


Figure 4: Tests of the Model

Note: Panel (a) presents elasticity estimates and 95 percent confidence intervals of the effect of changes in college  $j$ 's relevant state appropriations on net tuition by income bin using data from IPEDS 2008 to 2017. The sample size is 38027 and standard errors are clustered by institution. Panel (b) presents elasticity estimates and 95 percent confidence intervals of the effect of changes in college  $j$ 's relevant state appropriations on SAT scores by 2001 SAT decile using data from IPEDS 2002 to 2017. The sample size is 7549 and standard errors are clustered by institution. In both panels, the solid circles show the total effect, while the open squares control for the log of the sticker price.

where we control for the log of the sticker price. The unconditional specification estimates the total effect in general equilibrium as in Column (3) of Table 3, while controlling for the log of the sticker price estimates a partial equilibrium effect where private college market power does not fully adjust as in Column (2).

Panel (a) of Figure 4 provides support for all three predictions about net tuition after a decrease in state funding: (1) tuition increases for all; (2) tuition increases the most for lower-income households; and (3) tuition increases by less when the sticker prices are held fixed. The magnitude of the model and estimated elasticities by income bin are also very similar. For example, our simulations imply an elasticity of -0.30 for those with income less than \$30K and -0.17 for those with income more than \$110K, while we estimate elasticities of -0.28 and -0.10 respectively from Equation 17.

As a set second tests, we investigate the prediction that the average student test

scores will increase at the highest quality private college after a decrease in state funding per student. Fewer modest-ability students are admitted and instead enroll in the lower quality privates, which also increases their average student test scores. The magnitude of the changes should be larger when sticker prices are fixed. We test the model’s predictions by estimating the following specification:

$$\log(SAT_{jt}) = \sum_{d=1}^{10} \kappa_d \mathbb{1}_{dj} \log(z_{j(s)t}) + \pi_{j(s)} + \psi_{st} + u_{jt} \quad (18)$$

where  $SAT_{jt}$  is the average of the 25th and 75th math and verbal SAT score percentiles for students enrolled in college  $j$  in year  $t$ ,  $\mathbb{1}_{dj}$  is an indicator that is 1 if college  $j$  is in decile  $d$  of private college Fall 2001 SAT scores,  $\pi_{j(s)}$  are institution fixed effects, and  $\psi_{st}$  are state-by-year fixed effects. Estimated elasticities are plotted in Panel (b) of Figure 4.

As in the model, our empirical test shows that after a decrease in state appropriations, SAT scores at the highest quality private colleges rise since the estimated elasticity for decile 10 is negative. The elasticity is also slightly larger in magnitude when sticker prices are held fixed. The data also supports the prediction that SAT scores fall at the slightly lower quality privates. We find mixed evidence on the model’s implications for the difference between the general equilibrium and fixed sticker price elasticities. The spillover effects appear to be concentrated in the top half of the SAT score distribution and we find no evidence of spillovers on the bottom half. Given the few colleges in our model, we were unable to fully capture these distributional effects. Appendix C conducts similar tests for the effect of state spending on public college selectivity, providing some additional support for the model.

## 6. The Incidence of Public Investment

We consider several different methods of measuring who benefits and who bears the burden of public investment in higher education. We begin by showing that the model replicates the main findings of the accounting approach. We then present the model implied CV measure

in two steps to illustrate the general equilibrium mechanisms. First, the private college sticker prices are held fixed. In this exercise, private college market power increases but only to a limited extent. Then, sticker prices adjust based on the results from the previous section to better understand the role of private college market power. In both CV exercises, the labor market returns to college endogenously adjusts as a function of public investment and private market power. Appendix E additionally presents comparative statics to further illustrate the key mechanisms of how changes in the college market affect incidence.

### 6.1 The Model Implied Accounting Approach

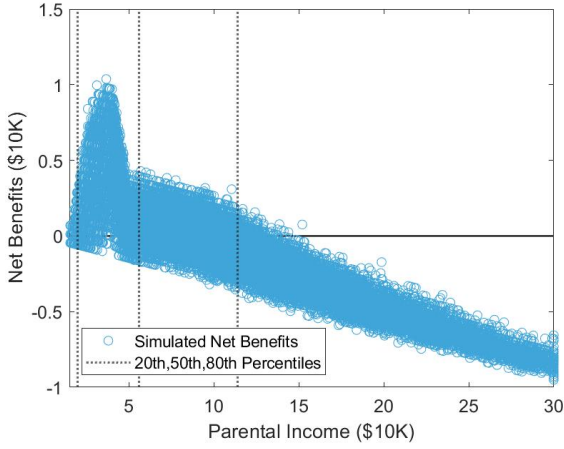
The model replicates Pechman's and William Johnson's accounting approach that spending is weakly progressive. Panel (a) of Figure 5 presents the distribution of net benefits by parental income, that is, instructional expenditure plus capital costs minus tuition and taxes paid. Each open circle represents the average net benefits for a household of type  $(b, y)$ .<sup>28</sup>

Based on the model implied accounting approach, the very low income do not benefit since they are unlikely to attend given the costs even with the maximum amount of federal financial aid. Slightly higher income households still receive the maximum federal aid at both public colleges but tuition is less of a financial burden, leading to large attendance rates and a positive mass around \$40,000. As income increases, aid for the in-state public falls while households still receive the maximum amount at the out-of-state option and the privates. Net benefits decrease sharply since they are less likely to attend their in-state public college. High income households have large negative net benefits since they are much more likely to attend the private colleges but pay high income taxes.

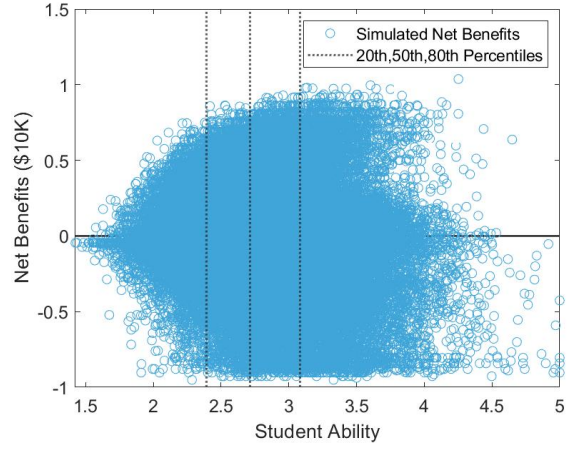
Panel (b) of Figure 5 shows a weak, but negative, association between ability and net benefits, or that lower ability students benefit more from public investment. The in-state public is the best option for these students since they are not admitted to the highest-

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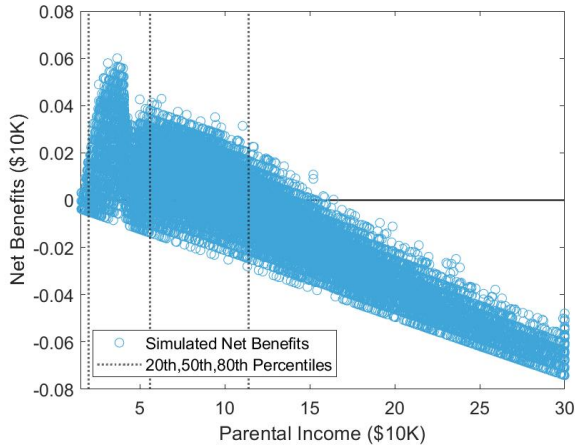
<sup>28</sup>The figures show the benefits by income and ability, averaging over 20 sets of idiosyncratic preference draws, to emphasize the distributional effects of public investment. Appendix D additionally presents the accounting approach for each household-enrollment decision  $(b, y, \epsilon)$ .



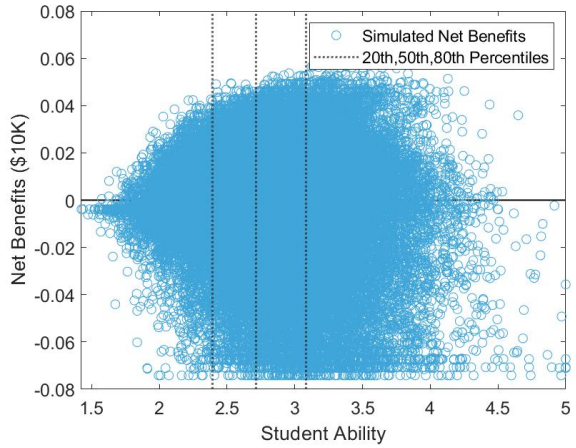
(a) Total net benefits by income



(b) Total net benefits by ability



(c) 10% decrease net benefits by income



(d) 10% decrease net benefits by ability

Figure 5: Net Benefits for Public Higher Education Investment

Note: Each open circle represents average net benefits for one draw from the joint distribution of income and ability using the accounting approach. For each household, we take 20 draws from the preference distribution, find the implied college enrollment decision, and then average over the corresponding net benefits. Panels (a) and (b) present the distribution for public colleges, while (c) and (d) for a 10 percent decrease in appropriations. The dotted vertical lines represent the 20th, 50th and 80th percentiles of the income and ability distribution. A positive value implies that the average household of type  $(b, y)$  receives more in college expenditure than it pays in tuition and taxes.

quality private college, and have relatively high effective marginal costs and prices at the others. Higher ability students receive merit aid at the privates, which makes those higher quality colleges more affordable. Since income and ability are positively correlated, average taxes paid are also increasing in ability. Taken together, there is a negative association between net benefits and ability for higher ability students.

We additionally calculate the accounting measure for a 10 percent decrease in state appropriations as the change in instructional expenditure minus the change in tuition and taxes paid to support the public colleges, holding college attendance decisions fixed:<sup>29</sup>

$$(I(z) - I(0.9z)) - (t(z) - t(0.9z))y - (T(z) - T(0.9z)) \quad (19)$$

The decrease in appropriations has a direct effect on the college and state budget constraints, affecting both instructional expenditure and tax rates. Public colleges also increase tuition to recover some of the lost revenue. Some lower income households also receive additional federal financial to offset the tuition increase. This equation is analogous to Equation 1, which allows us to compare the two approaches for measure incidence and understand the bias from ignoring the general equilibrium effects of public investment.

The distributional effects for a 10 percent decrease shown in Panels (c) and (d) are qualitatively similar to the total net benefits. However, the share of the net benefits that go to low income household shrinks because they now pay for a larger share of their lower quality education. Additionally, slightly higher income households see no change in relative net benefits because new federal financial aid largely offsets the increase in tuition. Higher income households also have a similar share of net benefits.

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<sup>29</sup>Note that since attendance decisions are fixed, so are capital costs.

## 6.2 The General Equilibrium Incidence of Public Investment

We now reexamine incidence using our model and the compensating variation framework described in Section 2, since the accounting approach misses important general equilibrium consequences of public investment in higher education. We first decrease state appropriations per student by 10 percent, or about \$700, holding private college sticker prices fixed. This counterfactual corresponds to the equilibrium presented in Column (2) of Table 3. Panels (a) and (b) of Figure 6 present the distribution of CV by income and ability, respectively. A positive number indicates that a household is better off when state spending is high; she would need to be given a positive amount of money to be just as well off after the decrease in appropriations per student. Each open circle represents the average CV for a household of type  $(b, y)$  based on 20 draws from the preference distribution. We focus on the average CV to highlight the distributional effects.<sup>30</sup>

Public investment in higher education is weakly progressive, but high-income-modest-ability students benefit the most. They are crowded out of the highest quality private since more low-income-high-ability students now enroll. The implied change in the minimum ability threshold generates the large positive spike in CVs in panel (b) near the 60th percentile of the ability distribution. Many of these students lose access to their preferred college and face a large welfare cost to move to their next best option. The negative welfare effects from changes in admission are especially concentrated among the high-income because low-income-modest-ability households are less likely to enroll in the high price privates where they are charged the full sticker price, and even those that do are not as harmed when moving to the lower price public colleges. That is, given relative prices and qualities, the publics and privates are closer substitutes for lower income households.

Most students who enroll in public colleges when state support is high are also negatively affected by the appropriations decrease, but the welfare effects are smaller in mag-

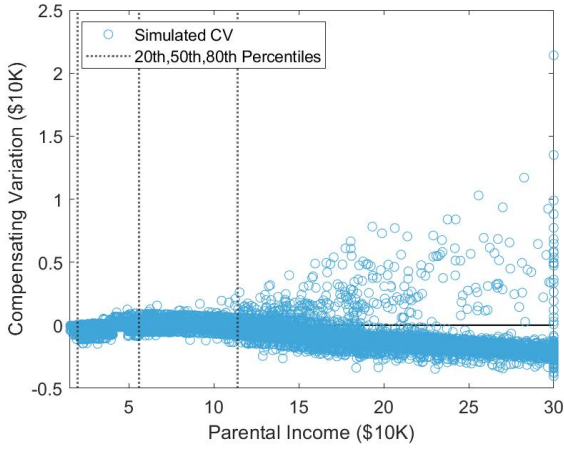
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<sup>30</sup>Appendix D presents the results conditional on a household's attendance decision based on the preference draws.

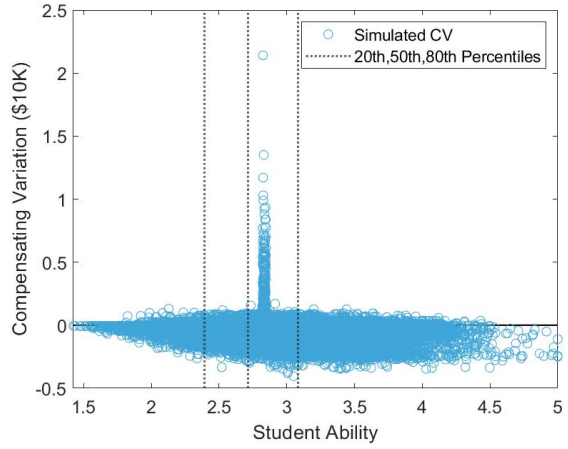
nitude than those on the high-income-modest-ability. This mainly affects above median income households who are the most likely to enroll in the in-state public, as seen in the small hump in panel (a) from \$50K to \$100K. Their preferred baseline ( $z = \bar{z}$ ) college option becomes lower quality and more expensive, implying a positive CV, especially for those that still enroll. They are not very mobile across sectors because the privates are too expensive and the returns to any college are high, and so they bear some of the burden of the policy change. However, based on our parameterization and calibration, some lower ability students who still enroll in the public colleges after the appropriations decrease are better off because the value of the increased returns to college outweighs the decrease in public quality. By missing the general equilibrium labor market effects, the accounting approach overstates the negative effects on these students. Slightly lower income households are less affected because their federal financial aid increases with prices.

Public college students can partially avoid the negative effects of higher tuition and lower college quality by enrolling in the privates or not enrolling in any college. However, when they leave the public sector after state divestment, they still face the general equilibrium effects on the private and labor markets. Changes in college choice, as a function of state funding, are important for assessing who benefits and who bears the burden. The accounting approach misses both of these margins. The low income are especially harmed because the price increases push some of them out of the college market, and they then see their wages fall from the decreases in both human capital and the returns to human capital as non-college workers. The higher income, who are less burdened by the private price increases, are more likely to shift to the higher quality colleges where they benefit from the increased returns to college. The overall welfare effect is ambiguous in sign for these students, but since they no longer pay public college tuition to help finance public expenditure, CV is often negative.

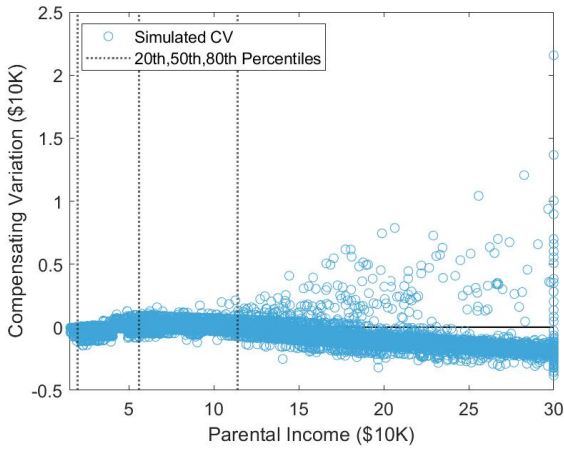
At the other extreme, high-income-high-ability students benefit the most from state divestment. As more high-ability students shift to the HP college and all privates charge higher average prices from the increased aggregate demand, the colleges become higher



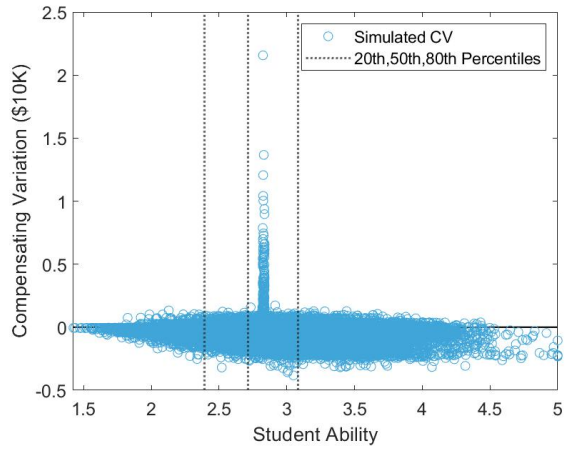
(a) CV by income with fixed sticker prices



(b) CV by ability with fixed sticker prices



(c) CV by income with endogenous sticker prices



(d) CV by ability with endogenous sticker prices

Figure 6: Compensating Variation for Public Higher Education Investment

Note: Each open circle represents average compensating variation (CV) for one draw from the joint distribution of income and ability. For each household, we take 20 sets of draws from the preference distribution, compute the corresponding CV based on equilibrium changes and the enrollment decisions, and then average over the 20 estimates. The dotted vertical lines represent the 20th, 50th and 80th percentiles of the income and ability distribution. A positive value in panels (a) and (b) denotes that the household is better off under the baseline than when appropriations decrease by 10 percent, holding private college sticker prices fixed. Panels (c) and (d) allow private colleges' sticker prices to endogenously adjust.

quality. However, since these households are high-income, they always pay the sticker price. They receive a higher quality education, when the returns to quality are higher, while paying the same tuition and lower taxes. Although missed by the accounting approach, the general equilibrium consequences of public investment have large and varied effects on the high-income. Overall, excluding these effects creates biases for incidence in both directions.

The equilibrium changes in the private and labor market from a decrease in state appropriations have an ambiguous welfare effect on lower income baseline private college students. The moderate income households value the increased quality and returns to college more than the added tuition costs, while the reverse is true for lowest income. The higher prices even lead some students to enroll in the less expensive and lower quality public colleges or not enroll in any college—increased private market power crowds out some low-income students.<sup>31</sup> For those who switch to the public sector from the privates, the welfare effect could be positive or negative, depending on the individual’s benefits from the increased returns to college. However, CV is shifted up because they only pay public college tuition when spending is low.<sup>32</sup>

Finally, the equilibrium labor market changes have a negative welfare effect on baseline non-college workers. Their wages decrease as college human capital becomes more scarce from the increased private college market power and decrease in public college value. Therefore, the changes in the college market spill over to non-college workers since the two are linked through the economy’s production function— with more public investment, non-college workers benefit from less competition in the labor market. While the accounting approach implies that these students have negative net benefits from paying taxes, our approach additionally captures the added value from labor market spillovers. Ignoring these general equilibrium effects leads the accounting approach to understate progressivity since these

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<sup>31</sup>Very few students are no longer able to afford college from the price change. However, price increases enough that the privates are no longer their best option.

<sup>32</sup>In practice, the difference between  $\nu$  and CV in Equation 1 is small because the low-income receive federal aid to cover their tuition expenses.

households are more likely to be low-income.

Inframarginal college attendees in the baseline enroll in college after the shock because of the decrease in relative earnings. The welfare effect is ambiguous in sign, similar to what we describe for several other cases above, because both price and the returns to college increase over the baseline. This trade-off is more likely to be a net benefit for the high-income baseline non-college workers, who shift to colleges LP and MP. Lower income, modest ability students switch to the publics to avoid the low non-college wages and are worse off but often have positive CVs because the policy change greatly increases how much they pay to help finance public expenditure with tuition.

With increased demand for private colleges after the negative shock to state appropriations, the privates will increase their sticker prices. Panels (c) and (d) of Figure 6 present the distribution of CV allowing the maximum prices to adjust based on our estimates from Table 2, as in Column (3) of Table 3. Since the sticker prices minimally increase, the results are qualitatively similar to the previous case. However, the mass of positive points for households in the top of the income distribution in Panel (c) is slightly smaller than in Panel (a). For example, in panel (c), 1.03 percent of households in the top 10 percent of the income distribution have positive average CV. In panel (a), the corresponding percent is 1.21. With higher sticker prices, more students are able to sufficiently compensate the high quality private for their modest ability. Public investment in higher education is still weakly progressive, but the largest benefits still go to modest ability students who only have access to high quality private when state spending is high.

Sticker price increases also create other equilibrium changes in college price and quality, the wage premium, and taxes that matter for incidence. Overall, these effects on individuals are much smaller in magnitude than changes in admission, but impact all households. The sign of these effects on welfare varies importantly with income and ability, but the implications for incidence are analogous to the fixed sticker price case because they all move in the same direction from the baseline. Compared with the fixed sticker price case, high-income-

high-ability students receive much of the new benefits because HP college's quality increases along with the returns to quality. Since they are high income, they always pay (nearly) the full sticker price so tuition only increases modestly. Most of the new burden from the sticker price increases falls on the lower income, who are more harmed by the increase in prices than the increase in private college quality or are even priced out of the private market.

Taking the results from the two counterfactuals together, we find that high-income-modest-ability students benefit the most from public investment in higher education because the general equilibrium effects on the private college and labor markets are large. The externalities on these students from changes in the private market are smaller when the privates raise their maximum tuition, but colleges only minimally do so after state divestment. Since these households are very likely to attend the privates under the current level of state appropriations,  $\bar{z}$ , the accounting approach would instead say that they do not benefit but pay high taxes. However, these households only have access to the highest quality private college when state spending is sufficiently high. By ignoring the impacts of public investments on other parts of the economy, the accounting approach mischaracterizes incidence.

### **6.3 The Bias from Ignoring Equilibrium Effects**

Since the accounting approach ignores the general equilibrium effects of public investment on college enrollment, and the private college and labor markets, it mischaracterizes who benefits and who bears the burden. To further highlight the distributional implications, we consider two policy relevant measures of the bias. First, in Panel (a) of Figure 7, for each income-ability decile, we present the average CV measure in dollars with endogenous sticker prices and labor market returns to college minus the accounting approach for a 10 percent decrease in state appropriations (Equation 1 - Equation 19). In Panel (b) we define the bias as the percent of households with a positive CV minus the percent with a positive accounting measure. More negative values are shaded lighter and indicate that the accounting approach overstates the benefits by more.

1	-13	-25	-132	-205	-101	-145	-158	-176	-238	-438
2	-14	-33	-183	-241	-122	-162	-191	-203	-287	-488
3	-14	-30	-212	-269	-137	-161	-201	-223	-298	-559
4	-14	-40	-241	-275	-152	-174	-215	-221	-302	-606
5	-16	-45	-260	-290	-154	-166	-206	-237	-301	-630
6	-18	-52	-264	-313	-157	-169	-207	-236	-327	-703
7	-17	-53	-284	-320	-160	-168	-205	-222	-197	-143
8	-14	-67	-300	-331	-170	-153	-207	-252	-338	-828
9	-16	-57	-321	-335	-157	-136	-212	-259	-363	-834
10	-21	-77	-347	-338	-111	-109	-212	-281	-402	-950
	1	2	3	4	5	6	7	8	9	10

(a) Average Benefits

1	-0	-0	-1	-4	-10	-8	-23	-23	-21	-13
2	-0	-0	-1	-4	-13	-9	-29	-31	-26	-16
3	-0	-0	-1	-3	-14	-9	-31	-33	-29	-18
4	-0	-0	-2	-3	-16	-8	-33	-36	-32	-19
5	-0	-0	-2	-1	-16	-8	-34	-39	-33	-20
6	-0	-0	-2	-1	-17	-5	-36	-41	-34	-20
7	-0	-0	-2	-1	-15	-5	-38	-42	-30	-12
8	-0	-1	-2	-1	-16	-0	-38	-43	-33	-15
9	-0	-0	-2	-1	-12	4	-40	-44	-33	-16
10	-0	-1	-2	0	-5	9	-41	-42	-32	-14
	1	2	3	4	5	6	7	8	9	10

(b) Percent Positive Benefits

Figure 7: Difference Between CV and Accounting Approaches

Note: Panel (a) shows the difference between CV and 10 percent of net benefits from the accounting approach in dollars by income-ability deciles. Panel (b) shows the difference in the percent of households with positive compensating variation minus percent with positive net benefits by income-ability deciles.

Overall, the accounting approach overstates both the average benefits and the number of households that benefit from public investment in higher education, but the magnitude varies importantly across the income and ability distribution because the general equilibrium effects are large and ambiguous in sign. The largest differences in magnitude in Panel (a) are for the highest income decile households. They benefit from the general equilibrium implications of state divestment on private college quality and the labor market returns to college. Ignoring these effects leads to substantial bias for measuring the average benefits. The bias is large enough that the accounting approach also gets the sign of the welfare effect wrong for about 16 percent of the highest income decile households.

The average net benefits and CV for the very high income households in the seventh ability decile (60th to 70th percentiles) are much closer in magnitude but only because the welfare effects from changes in private college market power vary in sign. The accounting approach misses several important equilibrium effects that act in opposite directions. High-income-modest-ability students between the 60th and 61st ability percentiles are crowded out of the highest quality private when state funding decreases and are much worse off, while

those above the 61st benefit from the increases in private quality and the returns to college.

Slightly lower income households in the seventh, eighth, and ninth income deciles, are similarly affected, although to a lesser extent, from the increase in private market power and the returns to college. Increased private college market power leads to price increases for these students since they are less likely to pay the full sticker price when state funding is high. These households additionally have more negative CV, on average, because they are especially likely to switch to the private colleges after the public funding decrease. This allows them to avoid the negative effects of divestment on the public colleges, and they no longer pay public college tuition. Those who remain at the public colleges also benefit from the increased returns to college human capital. The accounting approach misses these three equilibrium effects.

The difference between CV and the accounting measure is nearly uniformly decreasing in ability for the relatively high income, except for the high-income-modest ability who are crowded out of the highest quality private college. Both the human capital returns to college quality and the labor market returns to college are higher for higher ability students. However, the same pattern does not hold for the percent with positive benefits because public college enrollment and the likelihood of moving from a public to private college after state divestment are non-linear functions of ability, conditional on income.

The interaction between college choice, private college market power and the general equilibrium labor market affects of state divestment are especially important for households in the fifth and sixth income deciles. Many of these households only enroll in public colleges when state spending is low. The private colleges become too expensive, and non-college wages fall. The large changes in tuition from changes in college choice not captured by the accounting approach have a large impact on CV. The accounting approach therefore understates the percent of high-ability households in the sixth income decile who benefit from public investment.

These interaction effects are also important for slightly lower income households in the third and fourth deciles. Since the cost of college imposes a large financial burden, the public college price increases lead some of them to no longer enroll. They are made worse-off from the decrease in relatively wages and loss of human capital. However, they only pay public college tuition when state spending is high, which pushes CV down.

Finally, although the difference between the two approaches to measure incidence is small for households in the bottom two income deciles, the composition of the total effects are different. These households are mainly affected by the tax changes, which both approaches capture, as well as the general equilibrium labor market effects. Since fewer students enroll in the public colleges after the spending decrease, states and the federal governments collect less tax revenue. The accounting approach understates the corresponding decrease in equilibrium tax rates because student enrollment decisions are fixed. This alone would lead CV to be larger than the accounting measure. However, for these students, the accounting approach overstates the total benefits because it does not include the negative labor market externalities on mainly low-income non-college workers.

## 7. Conclusion

Previous measures of the incidence of public investment in higher education implicitly ignore general equilibrium effects. We use a compensating variation framework in a general equilibrium model of higher education to understand how responses in the private college and labor markets affect the distribution of benefits. We show that public investment puts competitive pressure on the privates and reduces the college wage premium, which creates benefits for students who do not attend public colleges. Unlike the previous approaches, our measures capture the effect of public investment on private college prices and admissions decisions, student enrollment decisions, and the aggregate implications for relative wages.

Building on a class of stylized models of higher education, we find that these general equilibrium effects are large in magnitude and vary importantly with both income and

ability. This makes signing the bias for overall progressivity from the accounting approach difficult. Students who look similar based on their income and college attendance decisions at the current level of state spending can face different consequences of state divestment that matter for incidence. For example, in our model, high-income-modest-ability students benefit the most from public investment because they are only admitted to the privates when the publics provide sufficient competitive pressure, that is, when state support is high. However, the high-income, slightly higher ability students are not crowded out after a negative appropriations shock. They retain access to the highest quality private colleges when increased private market power improves college quality and raises their wages.

While the role of private colleges and the labor market enhance our understanding of incidence in this setting, both approaches focus on the private returns and cost. Higher education impacts the distribution of human capital and therefore the tax base as well as the demand for other public expenditure, like assistance programs. If the social benefits mainly impact lower income households, then both measures understate the progressivity. If the increase in human capital leads to lower tax rates on the wealthy, then we would understate the regressivity. Further work is needed to understand how the social returns to public investment affect incidence.

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## A. Calibration Results

Table 4 shows that the model matches our target moments well. The college market moments are close to the data, although the private aid elasticities are just outside the boundary of the targeted ranges. The model also approximates the distribution of college attendance by income and ability. Our approach builds on Epple et al. (2017), but can better match these patterns. This is mostly because we allow the no 4-year college option to be a function of both income and ability, rather than fixed across the population. However, our parametrization is highly stylized<sup>33</sup> and the model understates enrollment for the high-income and high-ability. This likely biases our findings against the mechanisms we highlight because it implies that the model understates the value of college quality for the high-ability (weakens the general equilibrium sorting effects), while overstates the value of no college for the high-income (weakens the negative consequences of no longer being admitted to the privates).

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<sup>33</sup>For tractability, the value of college and utility are continuously differentiable in income and ability, where all households have the same preference parameters (e.g.  $\alpha$ s).

Table 4: Calibration Results

Moment	Data	Model
<b>College Market Moments:</b>		
Average Private Tuition	\$27220	\$26978
Private Enrollment as Percent of Total	28.5	28.6
Enrollment Elasticity of Aid	0.700	0.700
Additional Private Aid for 1 Std Increase in Ability	(920,1960)	918
Additional Private Aid for \$10000 Decrease in Income	(210, 510)	516
Earnings Percent Increase for Marginal-Ability Student	20.0	21.9
Public College Instructional Expenditure	\$10463	\$10436
<b>Percent Enrolled in College with 2011 Income between:</b>		
\$15k and \$35k	25.6	21.9
\$35k and \$55k	32.6	40.2
\$55k and \$75k	41.2	42.2
\$75k and \$95k	47.8	49.8
\$95k and \$135k	54.2	54.9
more than \$135k	65.5	62.9
<b>Percent Enrolled in College by Ability quintile:</b>		
First (Lowest)	13.7	12.4
Second	23.4	24.3
Third	32.2	34.2
Fourth	53.9	47.1
Fifth (Highest)	75.9	64.8

## B. Investment and Enrollment with Fixed Sticker Prices

Figure 8 shows how attendance changes by student income and ability after a 10 percent decrease in state appropriations per student, holding private college sticker prices fixed to their baseline levels.

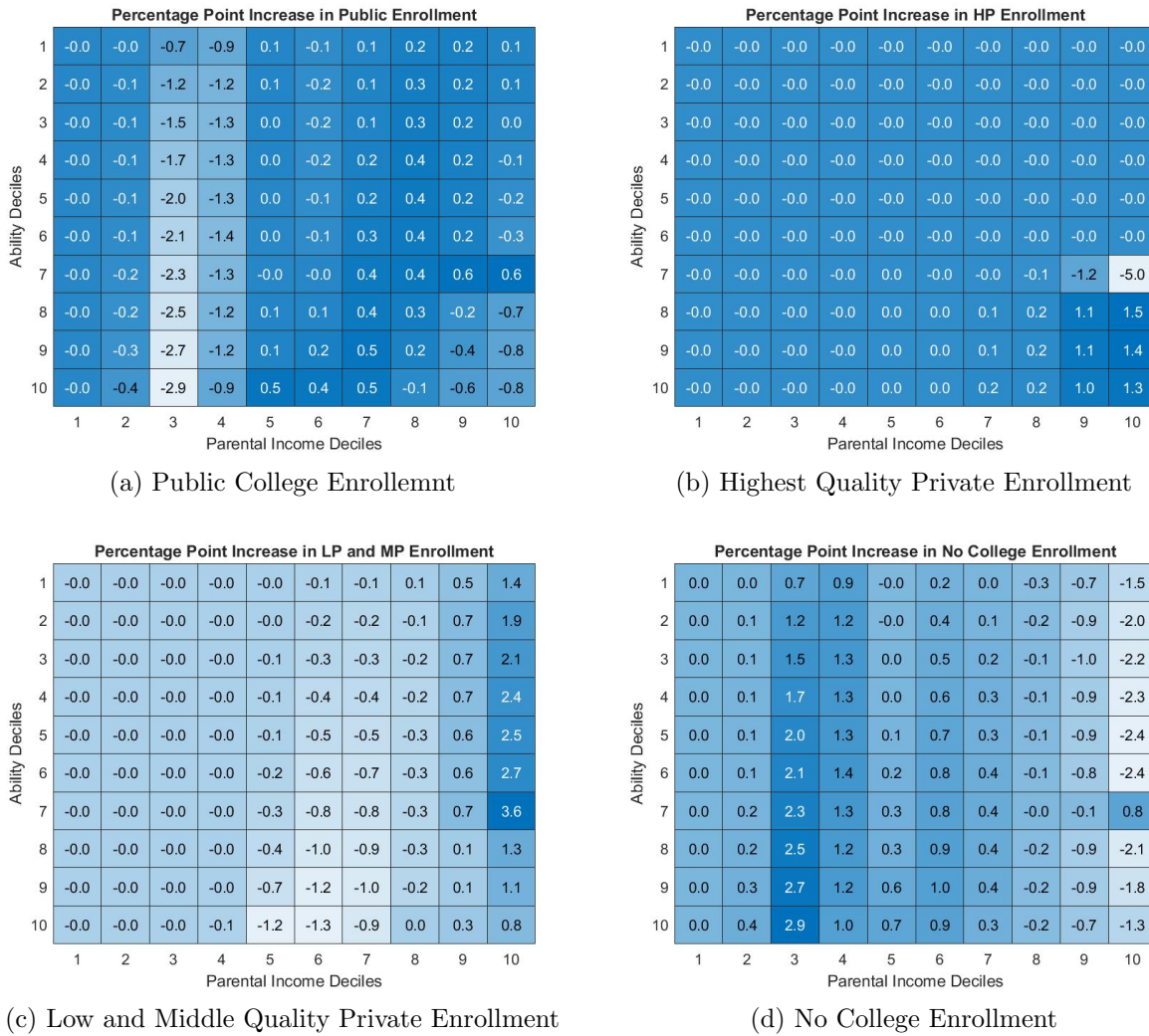


Figure 8: Public Investment and Enrollment with Fixed Sticker Prices

Note: Each panel of the figure is a heat map showing the percentage point increase in student enrollment after a 10 percent decrease in state appropriations per student, when allowing private college sticker prices are fixed to their baseline levels. A darker shade denotes that enrollment increases by more after appropriations decrease.

### C. Additional Empirical Tests of the Model

Following the empirical strategy of Sections 5.1 and 5.4, we estimate the following specifications on four year public colleges to test the model’s prediction about the change in student ability after a decrease in the college’s own state’s spending per student,  $z_{st}$ :

$$\log(SAT_{jt}) = \sum_{d=1}^{10} \kappa_d \mathbb{1}_{dj} \log(z_{st}) + \pi_j + \psi_t^1 + \psi_s^2 t \mathbb{1}_s + u_{jt} \quad (20)$$

where  $SAT_{jt}$  is the average of the 25th and 75th math and verbal SAT score percentiles for students enrolled in public college  $j$  in year  $t$ ,  $\mathbb{1}_{dj}$  is an indicator that is 1 if college  $j$  is in decile  $d$  of public college Fall 2001 SAT scores,  $\pi_j$  are institution fixed effects,  $\psi_t^1$  are year fixed effects, and  $\psi_s^2 t \mathbb{1}_s$  are state linear time trends. Since the treatment here is at the state level, we cannot include state-by-year fixed effects like in the other specifications on the private colleges. The unconditional specification estimates the general equilibrium effect. We additionally estimate a specification where we control for the log of the average private college sticker price in college  $j$ ’s state in a given year to approximate our fixed sticker price simulations. The coefficients are plotted in Figure 9.

The results provide some mixed evidence for the model predictions. From the model, we would expect that the higher quality public colleges (deciles six through ten) that compete with the privates would see an increase in student SAT scores after a decrease in state funding per student. Only the point estimates for three of the five deciles have the predicted sign, but the estimated effect is negative and significant for the ninth decile. The model also predicts that the general equilibrium elasticity should be more negative when holding private college sticker prices fixed. We find this to be the case in the data for all ten deciles, which supports the main mechanism we highlight in the model about the importance of private college market power and sticker prices.

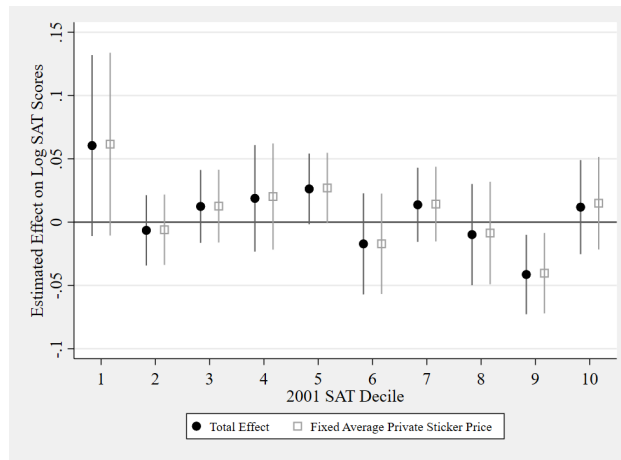


Figure 9: State Appropriations and Public College SAT Scores

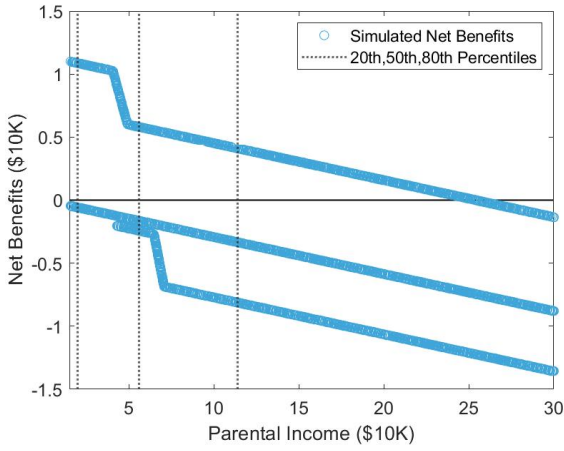
Note: The figure presents elasticity estimates and 95 percent confidence intervals of the effect of changes in public college  $j$ 's own state's appropriations per student on SAT scores by 2001 SAT decile using data from IPEDS 2002 to 2017. The sample size is 3480 and standard errors are clustered by institution. The solid circles show the total effect, while the open squares control for the log of the average private college sticker price in  $j$ 's state in a given year.

#### D. Incidence by Attendance Decision

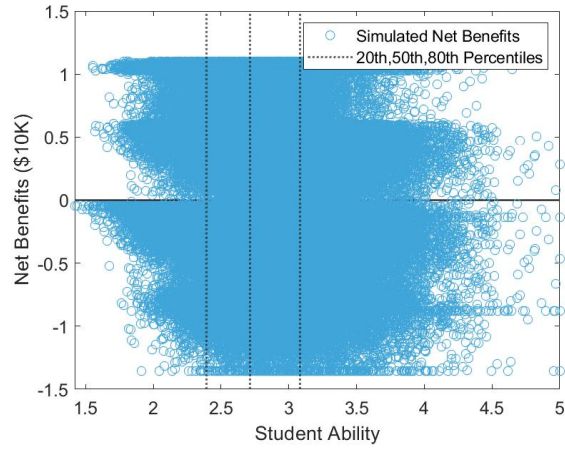
We present our model implied net benefits and compensating variation for each household of type  $(b, y, \epsilon)$ . Figure 10 presents the net benefits from the model implied accounting approach conditional on students' enrollment decisions. In panel (a) shows that there are three possible values for net benefits based on a household's income. For the very low income who cannot afford the out-of-state public, there are only two possible values. This is because public tuition, net of federal aid, and taxes are determined by income alone. The top line represents those who attend the publics and pay low tuition but receive instructional and capital expenditure, the middle line represents those who attend the privates or do not attend college and therefore only pay taxes, and the bottom line represents those who pay high out-of-state tuition plus taxes in exchange for the public college's services. Panels (c) and (d) show how the accounting measure changes after a 10 percent decrease in appropriations. Although these illustrations are helpful for seeing the magnitude of net benefits based on enrollment, it does not show the likelihood of taking up the services by income or ability,

which are important for incidence.

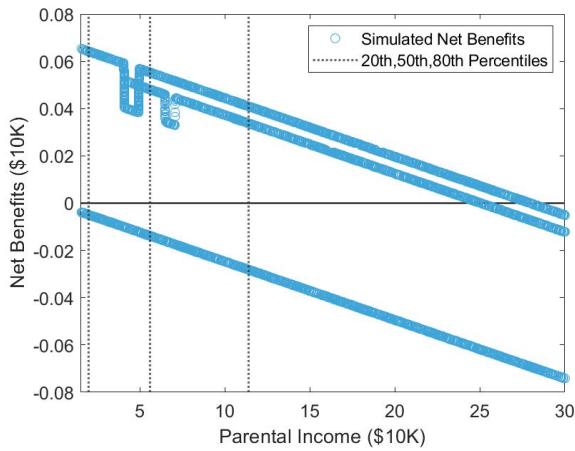
Figure 11 conducts a similar exercise conditional on students' enrollment decisions in both the baseline and counterfactuals using the general equilibrium model and our CV framework. Conditional on college enrollment decisions, CV is mostly linear in income and ability which generates the horizontal lines in the figure. For example, the bottommost line in all panels corresponds to students who attend the out-of-state public in the baseline, but then enroll in the privates when state spending is lower. They are better off because the returns to college quality increased while taxes decreased, and were nearly indifferent between those two options in the baseline. CV for these students is especially low because they no longer help finance public expenditure with high out-of-state tuition. Students who lose access to the highest quality college have much larger CVs and are located above the horizontal lines.



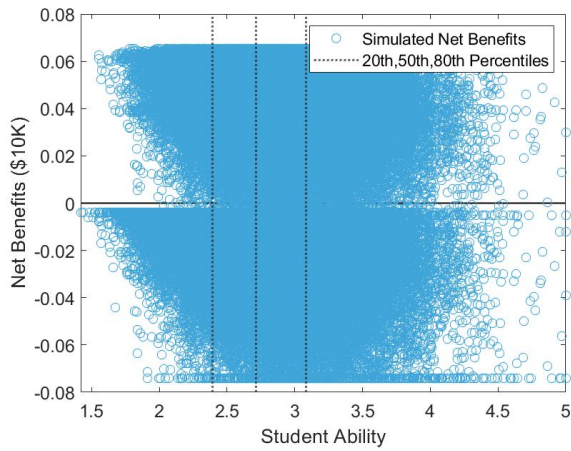
(a) Total net benefits by income



(b) Total net benefits by ability



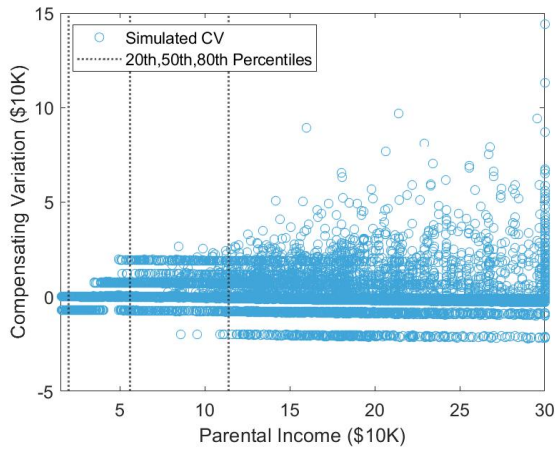
(c) 10% decrease net benefits by income



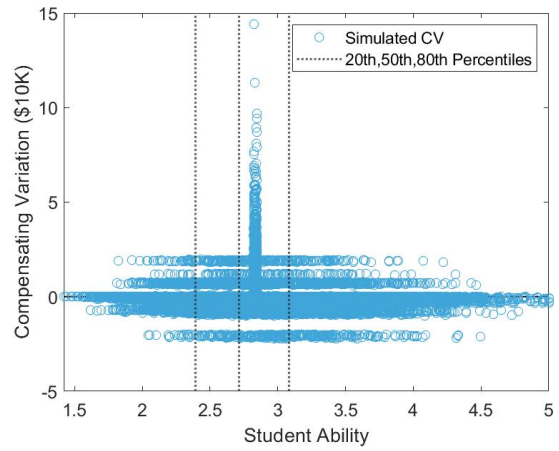
(d) 10% Decrease net benefits by ability

Figure 10: Net Benefits by Attendance Decisions

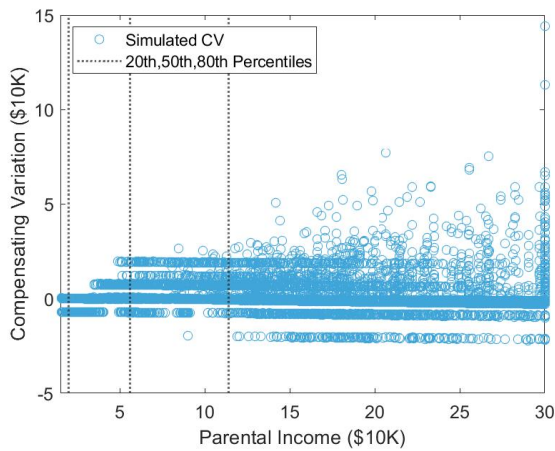
Note: Each open circle represents average net benefits for one draw from the joint distribution of income and ability using the accounting approach based on the household's preference shocks and corresponding enrollment decision. For each of 100,000 households, we take 20 draws from the preference distribution. Panels (a) and (b) present the distribution for public colleges, while (c) and (d) for a 10 percent decrease in appropriations. The dotted vertical lines represent the 20th, 50th and 80th percentiles of the income and ability distribution. A positive value implies that the household of type  $(b, y, \epsilon)$  receives more in college expenditure than it pays in tuition and taxes.



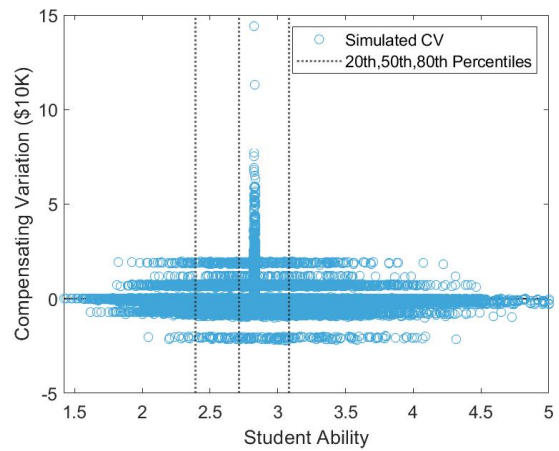
(a) CV by income with fixed sticker prices



(b) CV by ability with fixed sticker prices



(c) CV by income with endogenous sticker prices



(d) CV by ability with endogenous sticker prices

Figure 11: Incidence by Attendance Decisions

Note: Each open circle represents average compensating variation (CV) for one draw from the joint distribution of income and ability. For each household, we take 20 sets of draws from the preference distribution, compute the corresponding CV, and then average over the draws. The dotted vertical lines represent the 20th, 50th and 80th percentiles of the income and ability distribution. A positive value in panels (a) and (b) denotes that the household is better off under the baseline than when appropriations decrease by 10 percent, holding private college sticker prices fixed. Panels (c) and (d) compute average CV when private college's sticker prices endogenous adjust.

## E. Incidence Comparative Statics

To further highlight how changes in the private college market affect the incidence of public investment in higher education, we simulate the effect of a 1 percent increase in  $\gamma$  and  $\omega$  with endogenous sticker prices. Changes in these parameters affect student sorting through the returns to attending a higher quality institution as well as private college admissions decisions and pricing (Equations 7 and 8). In aggregate, these decisions affect the labor market returns to college as well but the effect is very small for only a 1 percent increase.

For each change in the structural parameters, we simulate the corresponding changes in compensating variation (CV) for a 10 percent decrease in appropriations per student:

$$\Delta CV(\gamma) = CV(1.01\gamma) - CV(\gamma) \tag{21}$$

$$\Delta CV(\omega) = CV(1.01\omega) - CV(\omega)$$

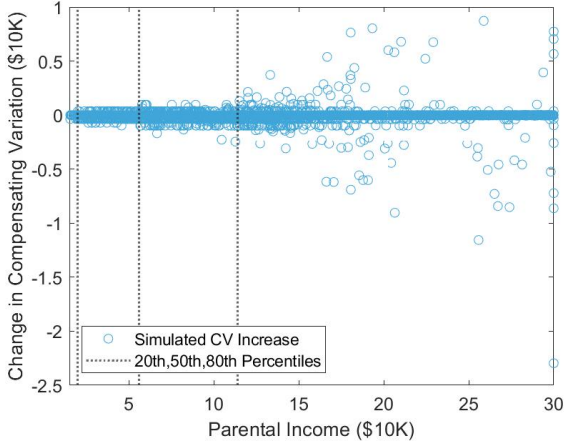
and plot the results in Figure 12. A positive value implies that a household has larger benefits from public investment in higher education when the structural parameter,  $\gamma$  or  $\omega$ , is high.

Panels (a) and (b) show how CV changes for a 1 percent increase in  $\gamma$ , or the returns to peer quality, by income and ability respectively. When  $\gamma$  is higher, there is an ambiguous effect on private college access. The implied increase in demand for the highest quality private, because the returns to quality are now higher, lead it to increase prices. Low-income students are less likely to attend and  $\theta_5$  falls slightly. At the same time, effective marginal costs are increasing in  $\gamma$  for all students with ability less than the college's average,  $\theta_5$ . We find that the baseline ( $z = \bar{z}$ ) minimum ability threshold is lower, and the counterfactual threshold rises more after the state spending decrease. Based on these two changes, Panel (b) shows both a large negative and positive spike in  $\Delta CV(\gamma)$ . When  $\gamma$  is higher, additional students near the 60th percentile of ability are crowded out from decreases in public

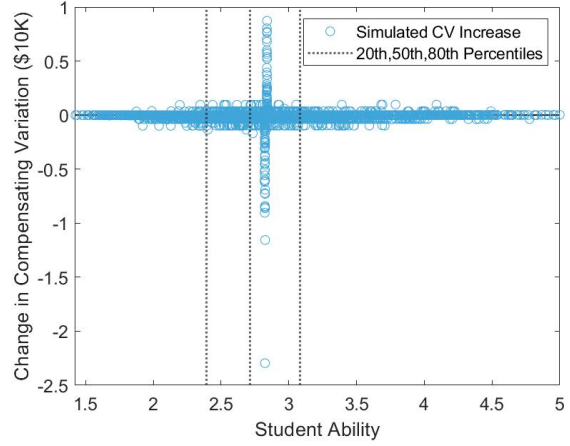
investment, while fewer are near the 62nd percentile.

Panels (c) and (d) present the effect of a 1 percent increase in  $\omega$ , or the returns to instructional expenditure, on CV. When the privates value collecting tuition revenue more, additional students with lower ability are admitted to the highest quality private in the baseline with state spending is high. The minimum ability threshold falls, allowing more high-income-modest-ability students to enroll. However, these students are crowded out of the market when state spending falls. More baseline private college students are affected by the decrease in public investment in higher education when the returns to instructional expenditure are high.

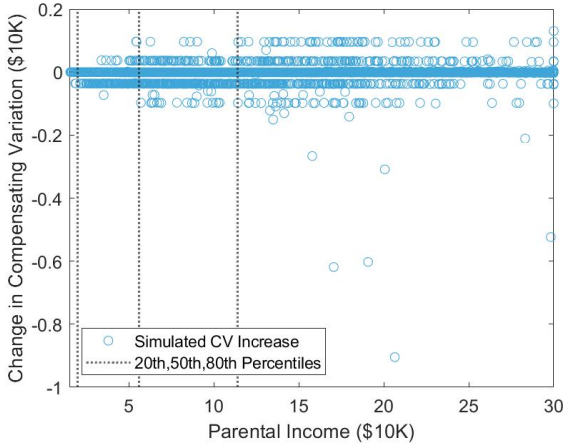
In both comparative statics, others students have a non-zero change in CV largely because the increase in the structural parameters affects the likelihood they enroll in the publics. This creates relatively large changes in public college tuition and relatively small changes in the individual household's value of public spending,  $\nu$ . Since increases in the structural parameters affect the returns to any college, the returns to college quality, and prices, some students are induced into the publics while others into the private market, generating the horizontal lines in all panels.



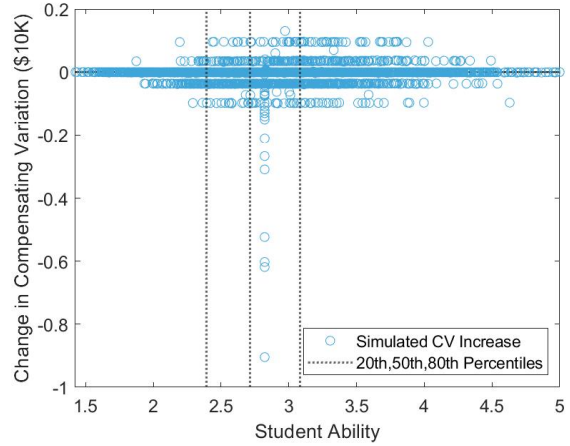
(a) 1 Percent Increase in  $\gamma$  by Income



(b) 1 Percent Increase in  $\gamma$  by Ability



(c) 1 Percent Increase in  $\omega$  by Income



(d) 1 Percent Increase in  $\omega$  by Ability

Figure 12: Compensating Variation Comparative Statics

Note: Each open circle represents the difference in average compensating variation for one draw from the joint income and ability distribution. For each household, we take 20 sets of draws from the preference distribution, compute the corresponding CV based on the equilibrium changes for the structural parameter and a 1 percent increase in the parameter, and average over the 20 estimates. The dotted vertical lines represent the 20th, 50th, and 80th percentiles of the distributions. A positive value implies that a household has larger benefits from public investments when the parameter ( $\gamma$  or  $\omega$ ) is high.