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Predicting the Impact of College Subsidy Programs on College Enrollment

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ABSTRACT

There is currently a great deal of interest in the potential of reductions in or elimination of the cost of college attendance for students (here referred to as college subsidies) to increase equitable access to higher education. A number of Democratic presidential candidates have advanced proposals for such programs. However, because colleges and students differ in ways that are likely related to how subsidies might affect enrollment and because there is a large amount of interdependence between colleges and students over time (i.e. "spillover"), we cannot directly extrapolate from the relatively small number of moderately large-scale subsidy programs that have been rigorously evaluated to predict the effects of programs with alternative specifications (e.g. eligibility requirements or scale) on enrollment patterns. Therefore, we turn to a computational modeling approach ("Agent-based modeling") that allows us to explicitly simulate individual college and student decisions over time. Our model is grounded in a strong body of evidence about how students and colleges make application, admissions, and enrollment decisions given different salient attributes (e.g. family resources) and imperfect information. We use the model to explore the potential impact of different prospective college subsidy programs. We find that when subsidies have substantial effects, these tend to have direct effects (i.e. an increase in eligible students' enrollment in subsidized colleges) as well as indirect effects (i.e. a decrease in eligible students' enrollment in unsubsidized colleges). Program impacts are strongest when the programs themselves are limited in scope: smaller than full-scale (i.e. national-level programs), with eligibility restricted to higher-achieving students, and not all colleges subsidized.

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Motivation

There is currently a great deal of interest in the potential of college subsidy programs to increase equitable access to higher education and to reduce the financial burden on college attendees. While colleges may be subsidized in a variety of ways, such as through grants to institutions, we focus on college subsidy programs that directly reduce tuition, fees, or other educational expenses incurred by students. A number of Democratic presidential candidates have advanced proposals for programs that would eliminate tuition and fees at colleges and would forgive all or most outstanding student loan debt. Senator Sanders' College for All Act of 2019, for instance, would provide federal funding to states that agree to make public postsecondary education tuition- and fee-free, in addition to canceling all undergraduate and graduate student debt. The Debt-Free College Act of 2019, cosponsored by Senators Warren, Harris, Booker, and others, is more means-tested, proposing a federal-state match to subsidize college costs (including room, board, and textbooks) above a student's expected family contribution. Other plans, such as those supported by Vice President Biden and Senator Klobuchar, would cover tuition and fees only at community colleges.

Proponents of college subsidy programs argue that these programs will raise educational attainment and provide long-run private and public benefits, citing the high and rising college wage premium (see long-run trends in Acemoglu and Autor 2011). Completing a postsecondary credential confers significant benefits in employment and earnings (Barrow and Malamud 2015, Belfield and Bailey 2017), though some research has questioned the extent to which these benefits extend to students on the margin of college attendance, who tend to enroll in less selective institutions (Athreya and Eberly 2015). Students who attend moderately or highly selective colleges experience high labor market returns relative to those who attend less selective schools (Long, 2008; Hoekstra, 2009; Zimmerman, 2014; Goodman, Hurwitz, and Smith, 2017).[1] Some evidence suggests that the returns to attending a highly selective college are primarily experienced by students of lower socioeconomic status (Dale and Krueger, 2002; 2014), who are underrepresented at the most selective institutions (Chetty et al., 2017). Even low-income students who are academically qualified to attend highly selective institutions are less likely to attend these institutions than similarly qualified high-income students, a phenomenon known as "undermatching" (Hoxby and Avery, 2013; Dillon and Smith, 2017). Undermatching appears to be driven in large part by perceived rather than actual college cost barriers (Hoxby and Turner, 2015); high-profile college subsidy programs may work in part by addressing these misperceptions (Dynarski et al., 2018). We are thus interested in assessing how college subsidy

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[1] Lower returns at less selective colleges result in part from lower completion rates (Baum and Holzer, 2017). Six-year completion rates are under 40% for students who start at two-year public institutions and nearly 75% for those who start at four-year private nonprofit institutions (Shapiro et al., 2018). Non-completion negatively affects individuals by imposing costs of attendance without many of the attendant benefits, contributing to poor labor market and loan outcomes (Looney and Yannelis, 2015; Baum and Johnson, 2015). While lower completion rates at less selective colleges are partly the product of student characteristics, institutional characteristics also play a role in determining student outcomes. For instance, Cohodes and Goodman (2014) study a subsidy program that lowered college completion rates among eligible students by incentivizing enrollment in less selective public institutions.

programs might affect college enrollment patterns in terms of both whether and where students from different socioeconomic backgrounds enroll in college.

The relationship between college costs and enrollment has been investigated in a variety of experimental and quasi-experimental contexts (see reviews in Avery et al., 2019 and Deming and Dynarski, 2009). However, because existing college subsidy programs vary widely in scope, structure, and context, it is difficult to extrapolate from their effects. Subsidy programs are often targeted toward specific student populations, as defined by academic merit or financial need; may only be used at particular subsets of colleges, such as in-state public institutions; provide different levels or types of subsidies; and are enacted in specific settings (e.g. a single U.S. state). Additionally, a program that initially serves only a small number of students may produce different outcomes when implemented at scale. We would ideally like to isolate the effects of variations in program structure and scale to make statements about the potential impact of prospective programs, including large-scale programs like the ones that are currently being proposed.

There are two challenges to addressing open questions about potential program effects on enrollment patterns. The first is that what we have learned thus far has been through experimentation with and implementation of specific programs. This has provided a strong foundation of rigorous evidence about how these programs might impact enrollment in colleges. However, experimentation and program implementation are costly and, in some cases, infeasible. A program that subsidizes college tuition at substantial levels for even moderately large numbers of students can necessitate ongoing, annual direct costs in the tens or hundreds of millions of dollars. In addition, large-scale programs offering subsidies can face serious political obstacles. The second challenge is that extrapolation from the effects of programs that have already been implemented is not straightforward. This is because college enrollment is the result of a *complex adaptive systems* process. It is shaped by a substantial amount of interdependence, adaptivity, and heterogeneity. Enrollment is the result of interaction between colleges and prospective students through application, admissions, and enrollment decision-making. Students and colleges are not independent: admissions and enrollment decisions are inherently zero-sum (i.e. one student's admission implies another's rejection, and a student's decision to attend one college precludes enrollment elsewhere). Students and colleges can affect one another's outcomes and adapt their behavior over time (as, say, colleges adjust the number of students they admit based on enrollment in prior years). And students and colleges are not uniform in their attributes and strategies, with differences in these having important implications for how a given change might affect overall enrollment patterns as well as specific effects for different colleges and students. Analyses that do not explicitly incorporate the interdependence, adaptivity, and heterogeneity inherent in college enrollment are likely to be misleading in two key respects. They may only capture the immediate impact of prospective college subsidy programs; these effects might change substantially over time, however, as colleges and students adjust their behaviors to an altered landscape. And they may inaccurately predict the effects of programs that directly affect sets of students and colleges that differ from those affected by existing programs, both because of differences in how different sets of students and colleges respond to subsidy eligibility and because outcomes for those targeted by programs are also influenced by the behaviors and outcomes of those who are not.

Therefore, we turn to an analytic approach that explicitly embraces the complex adaptive systems nature of questions about college subsidy program effects on enrollment patterns. Specifically, we develop an *agent-based model* of the enrollment process that can be used to provide insight into the potential impact of a large number of possible college subsidy programs. An agent-based model is a computational simulation in which each actor ("agent") within a system is fully represented *in silico*, allowing its interactions with other agents and its artificial environment to be observed over time. Thus, we can capture the interdependence, adaptivity, and heterogeneity described above. The model we developed provides us with a "virtual policy laboratory" in which we can explore what effects policies might have overall as well as for different subsets of actors, and gives us the ability to better understand why these outcomes occur.

Approach

Model Overview

We employ an agent-based model (ABM) that simulates the college enrollment process. This model is a variation on one that has been developed and used over the past several years to explore how family resources affect whether and where their children attend college and to compare race-based affirmative action policies with race-neutral alternatives. We ground our model in a large body of extant literature on how students and colleges make their decisions and enroll in colleges. Although it is a stylized model of the world that does not explicitly represent the intricacies of tuition and financial aid, we believe that it can provide important insights into how large-scale college enrollment patterns might be affected by college subsidy programs that alter students' application and enrollment behaviors. The agents in this version of the model are intended to represent American high school seniors and selective colleges. We model enrollment as the result of a three-phase process (Figure 1). Each year, a new cohort of students considers their options and makes decisions about where to apply, colleges then decide which applicants to admit, and students then decide which admissions to accept. In addition to the description below, we provide complete model details in our Supplementary Materials.

Simulated Students and Colleges

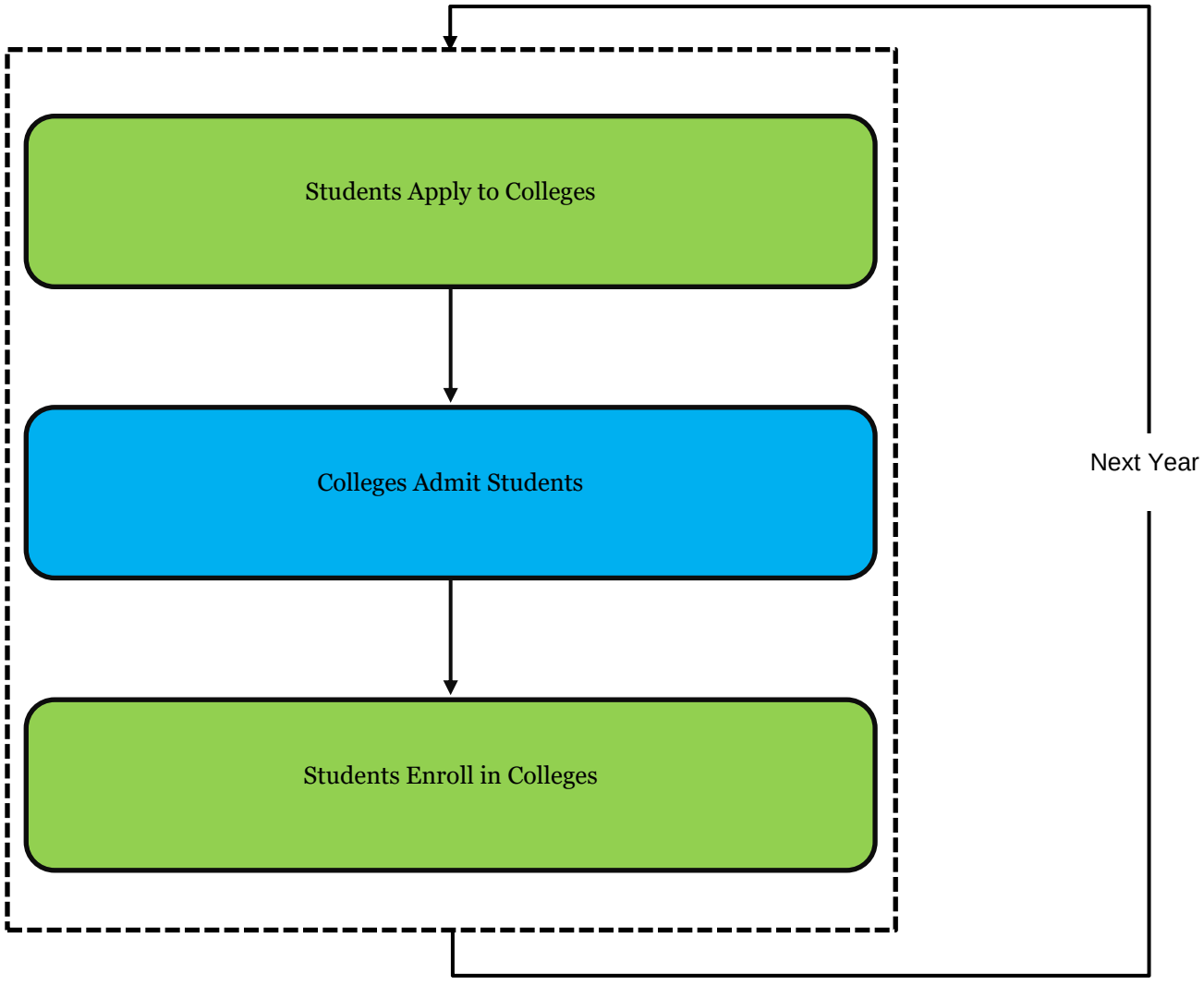
Students in our model have three attributes: observable academic achievement, resources, and race. Achievement represents educational achievement through high school (e.g. GPA and test scores). Resources represent a student's socioeconomic background. We include four race categories: Black, Hispanic, White, and Asian. Race-specific distributions of and correlations between achievement and resources are drawn from nationally representative data (Education Longitudinal Study of 2002). Colleges all have the same number of available spaces for incoming students, and thus can best be thought of not as analogues of specific real-world institutions but rather sectors of selective four-year institutions, ranging from elite private nonprofit to moderately selective public. These simulated colleges differ in quality, a dynamic attribute that represents the value that they impart to attendees at a given point in time (e.g. through training,

credentialing, or socialization), reflecting both the consumption value of attendance as well as effects on later life outcomes (e.g. labor market, health, and social prestige) relative to not attending any college. Although disaggregating this construct into constituent components might have interesting implications, it is beyond the scope of this current project.

Model Dynamics

During the **application phase**, students form perceptions of the utility of attending each college. Their perceptions of colleges' quality values are "noisy." This not only reflects imperfect information, but also idiosyncratic preferences; we do not differentiate between these both because available data and evidence are insufficient to do so and because it is not necessary for our analyses. Students with greater family resources have more accurate (but still not perfect) estimates, as their real-world counterparts are more likely to engage in effective (but time-

Figure 1: Model Design



consuming) search activities, have access to academic advising, and glean high-quality information from their social networks. Perceived utility is simply value (i.e. quality) minus cost. We allow cost to differ as a function of family resources, reflecting differences in things such as need for, access to, and terms of student loans; difficulty of handling ancillary costs (e.g. lodging, books); opportunity costs; and temporal discounting. We discuss the calibration of this cost function in greater detail below.

We allow students to "enhance" their apparent achievement (i.e. desirability to colleges) values during the application process (e.g. through test preparation, help with college essays, or strategic participation in extracurricular activities), with students with greater resource values receiving greater enhancement. As with their perception of colleges, students have imperfect information about their own apparent achievement, and students with greater resource values have more accurate estimates.

Based on their estimates of colleges' quality values and their own apparent achievement as well as admissions from prior years, students estimate their probability of admission into each college.[2] Using their perceptions of utility and admission probability, students determine a set of colleges to which they will apply that maximizes expected utility. This set of colleges is greater for students with higher resource values (i.e. we specify a relationship between student resources and number of applications submitted).

In general, our characterization of this phase results in students attempting to submit a mix of applications to "safety," "match," and "reach" colleges, with students from higher resource backgrounds doing so more effectively.

During the **admission phase**, colleges observe the students who applied to them in a simulated year. Colleges have "noisy" perceptions of applicants' apparent achievement; as with students, this reflects both imperfect information and idiosyncratic preferences. Based on prior work with this model, we allow "elite" colleges (described below) to engage in race- and socioeconomic-based affirmative action during admissions. This increases these colleges' perceptions of affected students' apparent achievement. Colleges each have the same number of students whom they wish to enroll each year (i.e. the number of available spots in their incoming class). However, we allow them to admit different numbers of students based on their enrollment yields in previous years. In our model, they simply admit the top applicants ranked on their perceptions of apparent achievement.

During the **enrollment phase**, students enroll in the college with the highest perceived utility to which they have been admitted.

After the three phases (application, admission, and enrollment), colleges update their quality values based on enrollment. That is, we allow quality to change as a result of which students actually enroll. For example, a moderate quality college that consistently enrolls high-quality students can slowly increase in quality to reflect changes in things such as reputation, academic culture, and alumni networks. We run the model for 30 simulated years and implement . . .

[2] For the sake of model parsimony and feasibility (i.e. so that we only need to generate a single probability function for each simulated year), we assume uniform observation of previous admissions.

affirmative action and college subsidy policies (described below) after year 15. This allows enough time for college quality, enrollment yields, and student estimates of admission probability to stabilize both before and after these changes. Thus, our findings should not be merely an artifact of early-run model dynamics or short-term policy effects.

Model Parameterization and Calibration

In previous versions of this model, simulated colleges represented all U.S. colleges, including community and for-profit colleges. However, different college sectors face different supply constraints. In general, selective four-year institutions are unable to rapidly expand enrollment because they require students to be physically present (and thus require physical facilities for students to live and work) and because they rely to a large extent upon full-time, tenure-track faculty, who in many fields are in short supply and whose employment is less flexible than that of part-time or adjunct faculty. While selective colleges may be able to increase capacity over the medium term, it is not clear that they will do so unless reductions in costs to students are accompanied by increases in institutional funding that are sufficient to maintain current per-student funding under enrollment increases (Bound and Turner, 2007).[3] Community colleges and for-profit institutions generally face fewer supply constraints and may more rapidly expand their supply of available seats. Increases in college enrollment during the Great Recession were largely absorbed by community colleges and for-profit colleges (Barr and Turner, 2013). Because we are uncertain how they might increase capacity in response to different subsidy programs, we cannot confidently incorporate these schools into our simulations. Therefore, our model exclusively represents colleges that are at least moderately selective and are unlikely to substantially expand available enrollment in the short to medium term. Fortunately, as noted above, these are the set of institutions that we are especially interested in, both because of the benefits that accrue from attendance and because of existing socioeconomic disparities in enrollment.

In order to alter the model so that simulated colleges represent only selective colleges (and thus non-enrollees in our model represent those who either do not attend college or attend non-selective schools), we made three changes. The first was to use a ratio of students to available college spots that matches overall enrollment in selective colleges, estimated using the High School Longitudinal Study of 2009 (HSLS09). We then adjusted the definition of "elite" colleges that engage in race- and socioeconomic-based affirmative action to match the set of selective colleges instead of all colleges (Reardon et al., 2018). The third change required us to engage in model calibration. We expected our model to generate enrollment patterns in selective schools similar to those observed in the real world (Table 1).

In order to achieve this, we added resource-based "cost" terms to the utility function used by students during the application phase. This was an attractive approach for three reasons. The

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[3] Evidence from England and Chile suggests that inadequate funding for institutions to respond to increased enrollment demand resulting from free tuition programs can threaten the longevity of such programs and may lead either policymakers or institutions to try to limit further enrollment increases (Murphy, Scott-Clayton, and Wyness, 2018; Delisle and Bernasconi, 2018).

first is that it allows lower-resourced students in the model to engage in the application process differently from their higher-resourced counterparts in ways that result in lower enrollment (i.e. the set of colleges they consider and how they evaluate them). The second is that it makes intuitive sense: for those with fewer resources, there are greater obstacles to attending college (e.g. direct and indirect costs relative to available assets, access to and terms of student loans, perceived opportunity costs) that can affect decision-making. And finally, it matches nicely with college subsidies, which we characterize as operating opposite to these "cost" terms in the utility function. Because there are no data that can directly inform this function, we explored a moderately large set of specifications and selected one that produced enrollment patterns consistent with those in the real world.

Table 1: Expected College Enrollment Patterns by Resource Quintile

	Selective private or out-of-state 4-year (top 40% of selective colleges in model)	Selective in-state public 4-year (bottom 60% of selective colleges in model)	Less selective 4-year, 2-year, or less-than-2-year (outside of model)	Did not attend college (outside of model)
Quintile 1	5%	7%	44%	44%
Quintile 2	6%	14%	43%	38%
Quintile 3	9%	17%	44%	29%
Quintile 4	16%	25%	40%	18%
Quintile 5	29%	37%	27%	7%

High School Longitudinal Study of 2009 (HSLS09) and Beginning Postsecondary Students Longitudinal Study of 2011-12 (BPS)

Next, we needed to determine the magnitude of the effect of subsidies on students' perceptions of colleges (i.e. how much more attractive subsidized tuition makes a college when students calculate utility of attendance). To do this, we again engaged in model calibration: we compared subsidy effects on recipients' enrollment produced by the model to those observed from actual subsidy programs in the real world. Here we turn to a randomized controlled trial evaluation of the Susan Thompson Buffett Foundation (STBF) scholarship, which covers up to five years of tuition and fees for high-achieving, low- to middle-income graduates of Nebraska high schools who attend in-state public institutions (Angrist et al. 2019). Not only does this evaluation provide rigorous experimental evidence, but its findings are broadly consistent with other college subsidy effect literature (Dynarski, 2000; Dynarski, 2003; Abraham and Clark, 2006; Cohodes and Goodman, 2014; Bruce and Carruthers, 2014; Castleman and Long, 2016). Compared to many state-level awards that cover only the cost of tuition, the STBF scholarship is particularly generous in that it covers the full cost of tuition and fees for up to five years and can be used for textbooks, room and board, and other educational expenses (much like the proposed Debt-Free College Act of 2019). Additionally, while large-scale scholarship programs sometimes "crowd out" other sources of aid or lead schools to increase mandatory fees (see, for

example, Dynarski, 2000), resulting in smaller net awards for students, Angrist et al. find that relatively little of the average STBF award was lost to crowding out of other aid. This suggests that the STBF scholarship provides a good upper bound for subsidy effects, representing a subsidy that covers close to the full cost of attendance.

Between 2012 and 2015, STBF randomly offered awards to a sample of applicants who met the eligibility requirements, which take into account both merit and need. Angrist et al. found that award recipients were 3.3 percentage points more likely to enroll in a college with an admissions rate of at most 75%, and 7.4 percentage points more likely to enroll in a college with an admissions rate of at most 90%. If we assume that the 3.6-percentage-point reduction in the proportion attending out-of-state or private colleges observed resulted almost exclusively in a corresponding increase in attendance in subsidized selective colleges, then we obtain an estimated 11-percentage-point increase in enrollment at selective in-state public schools.

We first parameterized our model to best approximate the subsidy program. Eligible schools include in-state public institutions, which we define in our model as the bottom 60% of schools. Students eligible for the STBF subsidies had minimum high school GPAs of approximately 2.7 and maximum expected family contributions (EFCs) of under $15,000. Using the High School Longitudinal Study of 2009, which has observations of non-honors-weighted GPAs drawn from students' transcripts, we selected a threshold for eligibility in our model: those above the 62nd percentile achievement are eligible for the subsidy. The Urban Institute estimates that the median expected family contribution for students whose parents earn $90,000-$95,000 is slightly under $15,000; this corresponds to approximately the 70th to 75th percentiles of pre-tax income among parents whose children were born in 1991, measured when the children were 15 to 19 years old, according to data from Chetty et al. (2017). Therefore, we conservatively set our model threshold such that the bottom 80% of students on the resource distribution are eligible for the subsidy. Given that the program was both state-level and randomized, we randomly select a small set (10%) of recipients from those eligible in our simulations.[4]

We explore a range of subsidy effect magnitudes, selecting one that produces effects similar to those obtained from the real-world program evaluation: across the last five years of repeated runs, we see a 2.3-percentage-point increase in enrollment, with a 9.8-percentage-point increase in those attending the bottom 60% of colleges.[5]

Because characterizing the effect of college subsidies on student perceptions of the utility of attending colleges (and, through this, their application and enrollment behavior) is central to our analyses, we engage in "out of sample" testing here. We use the subsidy effect magnitude

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[4] Although our model represents all U.S. high school seniors and this program affected much less than one tenth of those students in the real world, we select this value because in practice it is small enough that spillover effects from recipients to non-recipients in our model are minimal, and doing so allows us to obtain a large enough treated sample for our analyses without the computational cost of selecting a small value and conducting more runs.

[5] We deem this to be sufficiently similar given differences between the program context and that represented in our model. In addition, we conducted sensitivity analyses around the effect magnitude parameter value and present the results in our Supplementary Materials.

that we arrived at in our calibration above to simulate three additional, large-scale college subsidy programs that have been quantitatively evaluated:

1. Tennessee HOPE (Bruce and Carruthers, 2014). We characterize this as providing subsidies for students above the 60th percentile in observable achievement at in-state public colleges (the bottom 60% of selective colleges in our model).

2. Florida Student Access Grant (Castleman and Long, 2016). We characterize this as providing subsidies for students below the 35th percentile in student resources at in-state public colleges (the bottom 60% of selective colleges in our model).

3. Massachusetts Adams Scholarship (Cohodes and Goodman, 2014). We characterize this as providing subsidies for students above the 75th percentile in observable achievement at in-state public colleges (the bottom 60% of selective colleges in our model).

We then compare the effects of subsidies produced by our model to those from evaluations of these programs. We find that simulated effects are similar, but slightly to moderately larger than real-world evaluation estimates. This is consistent with differences between these three programs and the one used to calibrate our model (primarily the fraction of the cost of attendance that is covered by the STBF award). Thus, we believe that our model represents a plausible upper bound on the effect of college subsidies on student behavior during the enrollment process.

We provide a more detailed description of our model parameterization and calibration in our Supplementary Materials.

Policy Experiments

Once we were reasonably confident that our model could produce behavior sufficiently similar to that observed in the real world, we engaged in experimentation. We used 15 runs of the model without any subsidy policies as a "baseline" (i.e. they plausibly represent the current college enrollment landscape), and then explored 15 runs each for 36 "virtual counterfactual" scenarios that represent the additional presence of different subsidy program configurations; repeated runs allow for analyses that are robust against stochasticity (i.e. the influence of "noise" in student and college decisions). We fully explored the following combinations of college eligibility, student eligibility, and program scale:

- **College eligibility:** Three college eligibility scenarios reflect which colleges would have subsidized tuition. When all colleges are eligible, students receive subsidies even at the most elite private institutions; when only the bottom 20% of colleges are eligible, subsidies are restricted to less selective public colleges, which may be thought of as public colleges that admit 75 to 90% of applicants (i.e. public colleges excluding most state flagships). The middle setting (bottom 60% of colleges are eligible) is most similar to existing "free college" proposals, which would apply to all public institutions in a student's state.

- **Student eligibility:** We explore four different eligibility criteria that determine whether students are restricted from receiving subsidies based on achievement (roughly equivalent to ones where the subsidy is available only to students with GPAs of at least 3.0), family resources (where the subsidy is available to low- and middle-income students), both achievement and resources, or neither. These choices are based on common differences in real-world subsidy criteria. For instance, West Virginia PROMISE selects entirely on merit; the federal Pell Grant program selects on need; California's Cal Grant considers both merit and need; and many local Promise programs have no merit or need requirements.

- **Scale:** We vary the proportion of eligible students who actually receive offers of subsidized tuition. This reflects the difference between, say, many of the smaller-scale subsidies that have been implemented in reality (e.g. state-level), and the universal elimination of tuition and fees that has been proposed.

Results

During each of 15 runs for the 37 different conditions that we explored, we output an abundance of student- and college-level data. We limit our findings to the final five years from each run; by aggregating data across both years and repeated runs, we can be confident that our results are not driven by stochastic differences between either years or runs. The outcomes that we focus on are enrollment effects of subsidy policies experienced by policy recipients. We calculate this as the difference in enrollment outcomes for students who can receive subsidies under a given policy condition and those experienced by the same population of students in our baseline model runs (i.e. for potential recipients in the absence of active subsidy policies). The enrollment outcomes that we explore are:

1. Whether students enroll in any selective college

2. Whether students enroll in a selective college where enrollment is or would be subsidized

3. Whether students enroll in an "elite" college (i.e. the top 20% of selective colleges)

In the dynamic visualization that accompanies this report, we present each of these outcomes for recipients overall as well as disaggregated by resource quintiles.

Although there are many specific program effects that interested readers can view at their leisure, we wish to draw attention to several patterns that emerge.[6]

- **Effect sizes and directions.** When subsidies have substantial effects, these are experienced most frequently and strongly as increases in enrollment in subsidized colleges, then increases in college overall, and finally as decreases in enrollment in elite

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[6] We subject these findings to sensitivity analyses that are described and presented in our Supplementary Materials.

colleges. Subsidized college options attract students to apply and enroll in them, creating observable direct effects for eligible students (i.e. take-up of subsidies through attendance in subsidized schools). Subsidies can also have indirect effects for these students: they change potential recipients' application strategies (which colleges they consider and apply to) and enrollment decisions, thus increasing attendance in the set of selective colleges overall in some cases (i.e. making application strategies more effective) and shifting attendance away from non-subsidized colleges (including elite colleges under many subsidy program formulations). Generally, direct subsidy effects are greatest for higher-resourced recipients, while indirect effects tend to be weakest for that same set of students. Students with greater resources are in a better position to take advantage of subsidies by gaining admission to subsidized schools, but are also less likely to shift their application and enrollment strategies in ways that affect whether they attend selective schools overall or elite colleges to which they are admitted.

- **Program scale.** The effects of subsidy programs on potential recipients' enrollment patterns are largest when the programs themselves are smallest in scale. When more students are offered subsidized college options, there is increased competition for spots in those schools, decreasing effects on enrollment. In the extreme, this has the potential to decrease enrollment in selective schools for eligible students as large numbers of students apply exclusively to the same set of subsidized schools.

- **Student eligibility**. Subsidy effects are greatest when restricted by student achievement. This is because higher achieving students are more likely to be admitted to selective colleges to which they apply, and so the effect of subsidies on their enrollment is more pronounced. Program effects when the top resource quintile are eligible to receive subsidies are similar in size to those when they are not; enrollment patterns for this set of students can be affected by receiving subsidies, but effects for other resource quintiles do not appear to change much as a result.

- **College eligibility.** Subsidy effects are greatest when restricted to the bottom 60% of colleges and weakest when all colleges are subsidized. The former condition induces potential recipients to substantially change their application and enrollment behaviors, but not in ways that effectively "crowd out" other students, as can occur when only a small set of colleges are eligible and a large number of students vie for spots in them. Conversely, when all colleges are subsidized, students' application behavior is only marginally affected (i.e. as subsidies only induce students to consider a somewhat wider set of schools) and enrollment not at all.

Implications

Our research reveals that the effects of college subsidy programs on enrollment in selective colleges are neither straightforward nor uniform. We discuss and explain some general patterns that emerge from our simulations above. However, before conducting these analyses, we would not have known under which conditions subsidy policies would have produced

substantial effects, let alone the magnitudes (or even directions) of those effects overall or for students with different levels of family resources. And there remain combinations of program specifications that produce outcomes that unexpectedly run counter to general trends. For example, a "full-scale" subsidy program restricted to high-achieving students who attend the bottom 60% of colleges produces an overall *decrease* in potential recipients' enrollment in selective colleges that appears to be driven by effects on higher-resourced students.

Therefore, we believe that this research supports three important takeaways for policymakers:

1. A strong recommendation to be cautious when crafting college subsidy policies and to not overestimate their impact prior to implementation. Our results indicate that a number of large-scale programs would have little effect on who enrolls in selective colleges or even in which colleges students will enroll. In addition, policy specifications may result in unintended effects, such as a decrease in recipients' attendance at elite schools (in turn affecting the composition of student bodies at prestigious institutions) or localization of subsidy effects among potential recipients who are already relatively advantaged.

2. The results of our simulation can be used to provide guidance on how subsidy policy specifications might affect enrollment in selective colleges. Not only can the general patterns that we highlight above be useful, but policymakers can also make use of simulated effects under specific combinations of program conditions to make decisions about whether and how to engage in program design for desired outcomes. We wish to stress, however, that our findings are not intended to provide exact predictions of program effects.

3. Although we conducted a large number of simulated policy experiments, our exploration of policy options was far from exhaustive. We believe that the tool that we have developed and deployed here (or something similar) has the potential to provide additional insight for alternative subsidy policy specifications, or for effects in different contexts.

Our research leaves room for future study in this policy space. We focus exclusively on enrollment as a policy outcome. There are likely to be important secondary effects of subsidy programs on outcomes such as college completion, employment, and home ownership. Also, we only model selective college enrollment here. As we discuss above, this is because we do not have sufficient evidence to accurately represent responses of non-selective colleges to changes in demand. Although the impact of attending selective colleges in greatest on life outcomes (e.g. employment), there are meaningful distinctions between attending a non-selective college and not attending college. It would thus be useful to consider the effect of college subsidies on enrollment in this set of schools.

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