Can Financial Aid Help to Address the Growing Need for STEM Education? The Effects of Need-Based Grants on the Completion of Science, Technology, Engineering and Math Courses and Degrees

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ABSTRACT

Although workers in science, technology, engineering and math (STEM) fields earn above-average wages, the number of college graduates prepared for STEM jobs lags behind employer demand. A key question is how to recruit and retain college students in STEM majors. We offer new evidence on the role of financial aid in supporting STEM attainment. Exploiting a regression discontinuity that allows for causal inference, we find that eligibility for need-based financial aid increased STEM credit completion by 20-35 percent among academically-ready students in a large, public higher education system. These results appear to be driven by shifting students into STEM-heavy courseloads, suggesting aid availability impacts the academic choices students make after deciding to enroll. We also find suggestive evidence that aid offers increase degree attainment in STEM fields, although we cannot rule out null impacts on STEM degree production.

Keywords: Postsecondary degree completion; Financial aid; Major choice; STEM education
JEL Classification Codes: I2, J24

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I. INTRODUCTION

Employers in the United States are seeking to hire more workers in the Science, Technology, Engineering, and Mathematics (STEM) sector. Since 2008, the number of STEM jobs has increased by 14 percent compared to 2 percent in non-STEM fields, and above-average growth in STEM employment is projected to continue over the next decade (Fayer, Lacey, & Watson, 2017; Noonan, 2017). Workers in STEM fields also earn a wage premium, even after controlling for ability sorting in school and the workplace (Arcidiacono, 2004; Hastings, Neilson, & Zimmerman, 2013; Kirkeboen, Leuven, & Mogstad, 2016). The average starting salary for entry-level STEM jobs requiring an associate and bachelor's degree is $50,000 and $69,000 (in 2017 dollars), respectively, which represent 30 percent premiums over other entry-level jobs with the same degree requirements (Burning Glass Technologies, 2014).

Given the private returns to STEM attainment and the labor market demand for more college-educated workers in those fields, a key policy question is how to increase educational investments and degree completion in STEM. STEM attainment is especially low for low-income and minority students. Only 40 percent of college students overall and one-quarter of Black and Latino students initially interested in pursuing STEM majors persist to earn a degree in the field(Higher Education Research Institute, 2010; ACT, 2014). These rates concern policymakers because the country is projected to require one million *additional* STEM professionals over the next decade to retain global competiveness in science and technology (Lacey and Wright, 2009; Langdon, McKittrick, Beede, Khan, and Doms, 2011). With foreign-born workers currently accounting for less than 20 percent of STEM workers with a bachelor's degree (Hanson and Slaughter, 2016), meeting current and future STEM employment needs will require substantially increasing the number of domestic college graduates qualified for STEM jobs unless employment-based immigration or international student recruitment is expanded, neither of which appears to be the focus of current policy.

In this paper, we examine a potentially overlooked barrier to STEM attainment in college: the financial cost to pursuing study in STEM courses and majors. While other work has investigated the role of information, identity, preferences, and peer influence on STEM attainment (Espinosa, 2011;

Griffith, 2010; Price, 2010; Steele & Aaronson, 1995; Wang, 2013), there are several reasons why policies targeting affordability could impact STEM attainment, including by altering the decision of whether to enroll in college for students on the margin of attendance, as well as where to enroll and what field to study among inframarginal enrollees. Our paper offers new insight into the role that affordability plays in determining whether students pursue and persist in STEM fields.

We examine the effects of need-based grant eligibility on STEM attainment using a quasi-experimental research design. Specifically, we focus on the impact of eligibility for the need-based Florida Student Assistance Grant (FSAG) on whether students complete courses and degrees in STEM fields. In the early 2000s, colleges and universities in Florida determined eligibility for the FSAG using the federal need analysis calculation.[1] During the 2000-01 school year, students whose Expected Family Contribution (EFC) was less than or equal to $1,590 were eligible for a $1,300 FSAG award (in 2000 dollars); this translates to families with incomes below approximately $30,000 being eligible for a FSAG. The state grant was sufficient to cover 57 percent of the average cost of tuition and fees at an average public, four-year university in Florida (IPEDS, 2011). These students also qualified for at least a $1,750 Federal Pell Grant; as a result, FSAG awards increased the amount of need-based financial aid eligible students could receive by nearly 75 percent. In contrast, students whose EFCs were just above $1,590 were not eligible for the FSAG and only received the Federal Pell Grant.

Capitalizing on this EFC threshold for aid eligibility, we utilize a regression-discontinuity (RD) approach to estimate the causal effect of FSAG eligibility on STEM credit and degree attainment. To focus on students who could plausibly enroll in STEM courses, we limit the sample to Florida high school graduates who demonstrate academic readiness for postsecondary study in STEM fields. We proxy for STEM readiness in two ways. First, we condition on students who surpass college-ready math standards on the Florida College Placement Test in Math (CPT-M) or the

[1] Applying for federal financial aid, and often for state and institutional aid, requires a student to complete the Free Application for Federal Student Aid (FAFSA). The FAFSA collects information on family income and assets to determine the Expected Family Contribution (EFC), the amount that a family is estimated to be able to pay for college. To calculate need, the government subtracts the EFC from the total cost of attendance. A student's financial need, in combination with his or her EFC, determines whether the student is eligible for certain grants and loans.

SAT Math exams. Second, we condition on students who completed trigonometry or a more advanced mathematics class in high school, given that high school math achievement is predictive of entrance into STEM majors (Wang, 2013).

We find meaningful effects of need-based grant aid eligibility on STEM attainment among students ready for college-level STEM coursework. FSAG award offers increased cumulative STEM course completion seven years following high school graduation by 3.7 credits for students who placed into college-level math and 7.3 credits for students who completed trigonometry or higher in high school, which represent respective gains of 20 percent and 34.5 percent relative to students just above the aid eligibility cut-off. Award offers also had a concentrated effect on STEM-related outcomes, rather than just improving academic outcomes across all subjects. FSAG eligibility shifted students' course loads towards more STEM-heavy choices and this effect does not appear to be driven by the impact of aid offers on institutional choice. The pattern of results therefore suggests that students make cost-conscious decisions when choosing not only where, but what to study in college. We find weaker evidence that award offers increased bachelor's degree attainment in STEM fields. The magnitude of the estimates suggest that FSAG eligibility increased STEM degree completion by 3 percentage points (representing gains of 50-60 percent relative to students just above the EFC threshold), but the effect estimate is only significant at the 10 percent level in one of sample and non-significant in the other. We therefore cannot rule out that FSAG award offers had no impact on STEM degree production.

We structure the remainder of the paper into four sections. In Section II, we review the existing literature on college access and success pertinent to our examination of need-based grants and STEM achievement. In Section III, we describe our data and research design. We present our results in Section IV. Section V concludes and discusses the implications of the results for policy and research.

II. BACKGROUND

Possible Impacts of Financial Aid on STEM Attainment

Offering students more generous need-based aid could theoretically increase STEM attainment in college on either the extensive (e.g., enrollment) or intensive (e.g., major choice) margins. On the extensive margin, need-based aid has been shown to increase investments in schooling by reducing credit constraints for some students (i.e., by producing an income effect) and by lowering the cost of attendance relative to non-schooling options (i.e., by producing a substitution effect) [see Dynarski & Scott-Clayton (2013) for an extensive review of this literature]. Offering more generous need-based aid may therefore induce some students with STEM aptitude into college who would otherwise not enroll.

Financial aid may also impact STEM attainment on the intensive margin, although it is not immediately obvious if the effect would be positive or negative. On the one hand, if need-based grants increase the likelihood of attending flagship universities that offer more robust STEM programs and make those majors more attractive than institutions with fewer resources, aid might increase STEM attainment.[2] However, there are at least two reasons why the effects, conditional on enrollment, are ambiguous. First, most grant aid, including the FSAG we study, is not targeted. As a result, on the intensive margin financial aid may continue to relax credit constraints via an income effect but will generally not produce a substitution effect by altering the relative tuition cost of pursuing different majors.

Second, it is unclear whether the income effect on the intensive margin will encourage or discourage students from studying STEM. For example, financial aid could have a negative effect by relieving pressure students feel to pursue a major with high expected earnings (Rothstein & Rouse, 2011; Andrews & Stange, 2016). Additional grant aid may therefore encourage some students who would experience greater non-pecuniary benefits from alternative majors to switch away from STEM fields. Alternatively, aid could have a positive effect by lowering investment costs, which may be

[2] Between the 2000-01 and 2006-07 school years, the three public flagship universities in Florida – the University of Florida, Florida State University, and University of South Florida – offered 17 or more STEM programs of study. This exceeded the number of STEM programs available at each of the other 7 public universities in the State.

real costs students incur, such as lab or materials fees that make STEM fields more expensive than alternative options (Stange, 2015), effort costs required to succeed in rigorous coursework, or perceived costs of foregone work and leisure time. Additional financial aid may therefore free up time and lower costs to pursuing more demanding coursework by reducing the hours needed to work and allow credit-constrained students to pay extra costs associated with STEM programs that would otherwise be unaffordable.[3]

The combined effect of lowering net cost on the intensive margin is therefore ambiguous and depends on whether the effect on earnings expectations or investment costs dominates. Furthermore, it is reasonable to assume that those effects will vary in size across students and produce heterogeneous impacts of financial aid on STEM attainment. Indeed, because experimental evidence indicates that student preferences are a more important factor than expected earnings in choosing a major (Wiswall & Zafar, 2015), it is plausible that additional need-based aid would have null effects among students with weak academic backgrounds and preferences for STEM, as well as students with very strong backgrounds and preferences who do not face financial barriers to pursuing STEM coursework. Yet for students prepared for and interested who cannot afford to pursue STEM coursework in college, the net impact of additional grant aid on STEM attainment may be positive and increasing in both interest and financial need.

Prior Literature

Previous work investigating the impact of financial aid on STEM college outcomes is very limited, has found mixed results, and may not generalize to non-targeted, need-based aid programs like the FSAG. Two studies of which we are aware have examined the impacts of the federal SMART grant, a targeted aid program that awarded grants to low and moderate income college juniors and seniors who majored in STEM during the 2007-2011 academic years. Whereas Denning and Turley (2017) find that income-eligible students in Texas were approximately 3 percentage points more likely to major in STEM fields in their junior or senior year, Evans (2017) finds no

[3] We refer the reader to Appendix A for a model of major choice that would generate these ambiguous predictions.

evidence of SMART grant impacts on whether students in Ohio persisted in STEM majors or earned STEM degrees.

Other studies have examined the effects of non-targeted aid programs on STEM attainment, but this literature is limited to investigations of merit-based scholarship programs and the evidence to date is also inconclusive. Zhang (2011) finds little evidence that merit aid programs in Florida and Georgia influenced the share of degrees conferred in STEM fields, although the possibility of merit-induced selection effects are not accounted for in this study. By comparison, Sjoquist and Winters (2015a; 2015b) account for the effects of merit aid programs on student quality and find evidence that state merit aid programs decrease the number of STEM graduates, perhaps because academic renewal requirements have the unintended consequence of inducing students to avoid rigorous coursework to maintain their awards (Cornwell, Lee & Mustard, 2005; 2006). Yet because need-based aid programs typically have less stringent renewal requirements than merit aid programs and target more credit-constrained students, whether need-based aid creates positive or negative incentives for students to pursue STEM coursework remains an open question.

Ours is the first paper of which we are aware that examines the impact of eligibility for a non-targeted, need-based grant at the end of high school on whether students accumulate STEM credits and earn STEM degrees. Because the FSAG grant program was not targeted specifically to students pursuing STEM fields and neither is most need-based aid, its impact is likely more generalizable to financial aid policy making than previous research. For instance, compared to federal government expenditures of $195 million annually through the SMART grant program in the 2006-07 and 2007-08 school years, federal and state governments spend over $40 billion annually on need-based grant programs that are similar in structure and design to the FSAG award (Baum, Elliot and Ma, 2014; Newman, 2014). Programs like FSAG therefore represent the principle sources of need-based aid allocated to support college access and attainment.

Background on Florida and the FSAG Program

This paper examines the following research question: does eligibility for additional need-based grant funding (above the federal Pell Grant) increase the number of STEM credits that students

accumulate in college and increase their probability of earning a bachelor's degree in a STEM field? To investigate our research question, we focus on Florida high school seniors who graduated in the 1999-00 school year. The impact of need-based financial aid in Florida is potentially informative about the efficacy of financial aid programs in a broad range of settings across the country. Similar shares of students attend Florida public institutions and enroll at in-state institutions as in the country overall (88 percent vs. 91 percent and 86 percent vs. 92 percent, respectively). The average in-state tuition, room, and board levels at Florida public four-year institutions is also fairly similar in Florida compared to public four-years across the country ($14,677 vs. $18,632) (National Center for Education Statistics, 2016). Florida also represents the increasing racial and ethnic diversity of the country as a whole: 16 percent of its residents are Black and 23 percent of its residents are of Hispanic or Latino origin (U.S Census Bureau, 2011).

Specific to the context of financial aid, Florida students could qualify for both need- and merit-based state grants. Each year, families must complete the FAFSA, which asks for information on income, assets and family size. Using this information, the U.S. Department of Education (USDOE) estimates the families' EFC which it uses, along with the cost of attendance at students' intended institutions, to determine each student's eligibility for financial aid. States also use the EFC to award need-based grants, which totaled $8 billion in the 2012-13 academic year (Baum, Elliot and Ma, 2014).

To apply for the need-based FSAG, students needed to complete the FAFSA by March 1st of their senior year in high school. The Florida Department of Education sets an EFC cut-off each year to determine FSAG eligibility, which during the 2000-01 academic year was $1,590 (Florida Postsecondary Education Planning Commission, 2001). Institutions were prohibited from awarding grants to students whose families exceeded this amount, thus making this a sharp eligibility cut-off. Students could use the FSAG at any public two- or four-year college or university in Florida. During the 2000-01 academic year, the FSAG award for which students were eligible ($1,300) was sufficient to pay 57 percent of the average cost of tuition and fees at a public university in the state or about 28 percent of the average cost of tuition/fees, room, and board (IPEDS, 2011). Added on top of the

federal Pell Grant, which all students around the FSAG cutoff were eligible to receive, students could receive up to $3,050 in need-based grants. The FSAG was also renewable from one year to the next, conditional on students remaining financially eligible and maintaining a cumulative college GPA of 2.0 or higher.[4]

In addition to FSAG, Florida students were also eligible for the merit-based Florida Bright Futures Scholarship (BFS). There are two tiers of BFS awards. The lower tier amounted to approximately $1,700 for students who completed 15 core academic credits, had a cumulative high school GPA of 3.0 or higher, and had a composite SAT score of 970 or higher. Seventy percent of students who received a BFS award in the 2000-01 academic year received the lower-tier award. The higher tier offered a $2,500 award plus a small living stipend and was offered to students who completed 15 core academic credits, had a cumulative high school GPA of 3.5 or higher, and had a composite SAT score of 1270 or higher. Approximately 54 percent of students were eligible for a BFS award in our analytic samples. We control for BFS eligibility in our analysis to account for this potential confounding source of state grant aid; however, because students immediately on either side of the cut-off were equally likely to qualify for the BFS, in practice our results are robust to excluding this control. We also find no evidence that effects on STEM attainment are concentrated among BFS-eligible students. It therefore does not appear that this source of aid is responsible for any differences in academic outcomes at the FSAG eligibility cut-off.

In Figure 1, we summarize the variation in total grant aid eligibility in Florida according to small differences in family resources. Focusing on the area around the FSAG eligibility cutoff, students ineligible for the BFS could receive $3,050 in total FSAG and Pell Grant funding if their EFC did not exceed $1,590, or only $1,750 in Pell Grants if their EFC was above $1,590. For students who met the criteria for BFS eligibility, being above or below the FSAG cutoff resulted in the same difference in aid, but the levels of grant aid were higher ($4,750 versus $3,450 for lower-tier BFS-eligible students on either side of the cut-off, and $5,650 versus $4,350 for the higher-tier BFS-eligible students).

[4] There was no limit on the number of years for which students in our data could renew their FSAG award.

III. EMPIRICAL ANALYSIS

Data

The data in this article are from the Florida Department of Education K-20 Data Warehouse (KDW), which maintains longitudinal student-level records at Florida public colleges and universities. We also have data from KDW secondary-school records, including demographics, high school transcripts, and college entrance examination scores. These data are linked to KDW postsecondary data which provides the financial information that families supplied when completing the FAFSA and all financial-aid disbursements students received while enrolled in college. The postsecondary data also tracks students' enrollment and course-taking histories and their degrees received. We therefore observe students' semester-by-semester STEM credits attempted and completed and can examine credit accumulation over short-, medium-, and long-term intervals.

The data also includes students' field of study each semester, although we are unable to distinguish between intended and declared majors. We instead focus on the number of STEM credits students attempted each semester as a better measure of the extent to which they advanced towards a STEM degree over time. We also observe whether students earned degrees and their field of study at the time of degree receipt, which enable us to report on bachelor's degree attainment in STEM fields. These three measures – STEM credits attempted, STEM credits completed, and bachelor's degree receipt in STEM disciplines – are our primary outcomes of interest.

Defining STEM Courses and Degrees

We employed two methods to define STEM courses and degrees in the data, both of which avoided counting math and science courses as STEM which non-STEM majors are often required to complete to graduate. At the course level, we identified STEM using course prefix codes included in the KDW postsecondary data file. This was our best method of identifying STEM courses by department at both 2- and 4-year institutions, and it eliminated reliance on indiscriminate course names across subjects and institutions to flag courses as STEM. To identify STEM degrees, we matched NCES Classification of Instructional Program (CIP) codes in the KDW data to the list of STEM-designated CIP codes maintained by the National Center for Education Statistics and U.S.

Department of Homeland Security (NCES, 2011; U.S. DHS, 2012). Unfortunately, we could not identify programs of study for most students attending 2-year colleges in the data; we therefore identified STEM degrees exclusively for bachelor's degree recipients.[5] We also separately identified the types of STEM courses and degrees (e.g. Computer Science, Physical Sciences, Health Sciences, etc.) to examine the sensitivity of our results to more and less restrictive definitions of STEM. The results we present throughout the paper are based on our most restrictive definition of STEM, comprised of Computer Science, Engineering, Mathematics & Statistics, Physical Sciences, and Biological Sciences, although our results are robust to alternative definitions that include Agricultural, Health, and Environmental Sciences.

Samples

The KDW dataset captures college enrollment and completion records for the majority of college-bound, low-income Florida high school seniors. During the 2000-01 academic year, 90 percent of Florida residents who enrolled in college for the first time did so at in-state institutions and 74 percent of first-time freshmen enrolled in public institutions (NCES, 2002). The coverage of the data is likely even higher for low-income Florida residents because the average cost of attendance at private and out-of-state colleges was considerably higher than the price of Florida public colleges and universities for in-state students. To investigate this, we examined the college enrollment patterns of high-achieving, low-income high school seniors in the Educational Longitudinal Study of 2002 (ELS:2002). Because this is a nationally-representative sample of students there are only 43 – 63 high-achieving, low-income Florida students in the sample, depending on the definition of high-achievement that is used. However, among those students, only 6 to 9 percent enrolled at out-of-state institutions. Furthermore, we also observe a proxy for enrollment at private, four-year colleges and universities in Florida in the KDS data based on receipt of the Florida Resident Assistance Grant (FRAG). The FRAG was a tuition-assistance grant of $2,800 automatically awarded to students to offset the cost of tuition at private institutions. In fall 2000, only 7 percent of all public high school

[5] Approximately three-quarters of students attending 2-year colleges had an uninformative major code of "General Degree Transfer".

graduates in the 1999-00 school year who filed a FAFSA received a FRAG award. Taken together, the evidence above lends support for the case that the KDW data capture college outcomes for the vast majority of STEM-ready, low-income students in Florida.

In our empirical work, we focus on a subset of Florida high school graduates in the 1999-00 academic year who demonstrate academic readiness for STEM coursework in college. We present results for two analytic samples.[6] Of the 101,094 graduates in Florida that year, we first restricted our samples to include only students who submitted a FAFSA application since this is a necessary step for receiving government and most institutional aid. This restriction resulted in the exclusion of 55,309 students from our sample.

We proxied for STEM readiness by further restricting the data in two ways: first, we conditioned on students who surpassed college-ready math standards on the Florida College Placement Test in Math (CPT-M) or the SAT Math exams. Florida's CPT is designed to provide placement, advisement, and guidance information for students entering 2- or 4-year colleges and universities. For the incoming class of first-year college students in the 2000-01 academic year, Florida established a mandatory cut score of 72 out of 120 points on the CPT-M exam for placement into college-level math (FDOE, 2006). Because students with SAT Math scores of 440 points or higher were exempted from taking the CPT placement exam, we also include in this sample students with missing CPT-M scores who had SAT Math scores above the exemption threshold (FDOE, 2006).[7] This yields a sample of 20,738 students with college entrance exam scores above the state-mandated cut-off for placement into college-level math courses, 2,834 of whom had EFCs near the FSAG eligibility cut-off (i.e., +/- $1,000 around the cut-off).[8]

[6] As a falsification test, we also estimated FSAG eligibility impacts for a third sample comprised of Florida high school graduates near the FSAG eligibility cut-off who were not academically prepared for STEM coursework in college. Results for this sample are presented in Appendix Table A4. We find negligible impacts on STEM outcomes for this group of students.

[7] In practice, nearly all students with missing placement exam scores scored considerably higher than 440 on the SAT Math. The mean score for this subset of students is 556 points with a standard deviation of 79.8 points.

[8] Although this sample is conditioned on a potentially endogenous regressor–completion of a college placement test–students only learn if they have been offered an FSAG award after they have received admissions offers. Furthermore, because our second sample is free of this endogeneity, we believe this sample offers a useful robustness check for whether our results hold across different definitions of STEM-ready in college. Our results are substantively similar across both samples and the point estimates tend to be larger in the second sample.

We constructed a second sample because the mandatory CPT-M and SAT Math scores that determined placement into college-level coursework established relatively low thresholds for STEM readiness. Our second analytic sample is conditioned on students who completed trigonometry or a more advanced math class (e.g. calculus, differential equations, linear algebra, etc.) in high school. We established trigonometry as the cut-point by examining the math course enrollment patterns of Florida high school seniors; after the typical three-course sequence comprised of algebra 1, geometry, and algebra 2, trigonometry was the next most popular course students took in 12th grade. This restriction generated a sample of 8,907 students, 1,283 of whom had EFCs within $1,000 of the FSAG eligibility cut-off, and likely captures students more prepared to pursue STEM at the start of college.

In Table 1, we present empirical evidence that the restrictions we employ do in fact identify students who are more likely to study STEM in college. Students who met the test score conditions and enrolled in college in fall 2000 completed 21 credits in STEM on average throughout their time in school, and 6 percent earned a bachelor's degree in a STEM field. By comparison, students with lower achievement scores completed 10 fewer credits in STEM and only 1 percent earned a STEM degree. We observe similar differences in STEM attainment between students who completed trigonometry or a more advanced math course in high school and those who did not. The results in Table 1 also indicate that our restriction conditions establish relatively conservative proxies for STEM readiness. For example, whereas 16 percent of students who completed calculus or another advanced math course in high school earned a BA in STEM, only 4 percent of students who took math up to trigonometry graduated with a degree in STEM. In spite of this evidence, we adhere to conservative proxies because we do not observe enough students with higher preparation around the FSAG eligibility cut-off to detect effects using more stringent thresholds. Our results likely provide lower-bound effect estimates as a result, given that some students in our samples may have had insufficient backgrounds for studying STEM at selective four-year universities in Florida.[9]

[9] In Appendix Table A1, we present additional evidence of math achievement differences across the two samples. Students who completed pre-calculus scored, on average, 89 and 526 points on the CPT-M and SAT Math exams, respectively, which lie well above the college math placement cut-offs on both exams. Our second sample therefore

Taken together, these two samples allow us to explore the impact of FSAG eligibility for different groups of students. In Table 2, we present descriptive statistics for the full sample of students (column 1) and compare them to all STEM-prepared graduates (columns 2 and 4) and the subset of STEM-prepared graduates included in our analytic samples (columns 3 and 5).[10] There are clear differences between the full census of public high school students and the subset in our estimation samples. For instance, our analytic samples are more heavily female than the full sample (59 and 61 percent versus 53 percent) and have greater minority representation (46 and 49 percent in the analytic samples versus 39 percent in the full sample). Students in our conditioned samples also have considerably higher senior year GPAs (3.04 among students ready for college-level math and 3.18 for advanced high school math takers versus 2.84 in the full sample). By construction, we also observe higher achievement on college entrance exams among the conditioned samples. To the extent that these observed differences correlate with interest in and proclivity for STEM, our effect estimates likely demonstrate the impact of aid eligibility on STEM attainment for low-income students who are most likely to consider pursuing STEM majors in college.[11]

Empirical Strategy

We use a regression-discontinuity (RD) approach to estimate the causal effect of FSAG eligibility on whether students pursued and completed courses and degrees in STEM fields. In earlier work, [Author] and [Author] use a similar research design and demonstrate that FSAG award offers led to substantial increases in overall credit completion and degree attainment at Florida public institutions. In their analysis, the authors focus on all high school seniors who filed a FAFSA and were eligible to receive FSAG awards. In this paper, we focus on a subset of Florida high school graduates who demonstrate academic readiness for postsecondary study in STEM fields and we compare the STEM outcomes for students just below the EFC cut-off to students who are just above

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includes higher math achievers, while our first sample captures all students near the FSAG eligibility cut-off who, according to FDOE guidelines, were prepared to undertake college-level math at the start of college.

[10] As discussed below, we restricted the samples in our analysis to students within $1,000 of the EFC cut-off.

[11] Because they have the highest math scores, and are therefore best positioned to pursue STEM fields in college, a priori we might expect that the students in our second analytic sample would be most responsive to the offer of need-based grant assistance.

the cut-off. The RD design therefore allows us to infer the effects of FSAG award offers for students on the margin of grant eligibility (Shadish, Cook, & Campbell, 2002; Murnane & Willett, 2011). We focus on intent-to-treat (ITT) estimates and employ a "sharp" RD design (Imbens & Lemieux, 2008). This means that we can directly interpret a jump in STEM outcomes at the FSAG cut-off as the causal effect of FSAG eligibility for marginal students around the cut-off.

To estimate the causal effects of FSAG eligibility on STEM college outcomes we fit the following OLS/LPM regression model:[12]

(1) $$STEM\_OUTCOME_{ij} = \beta_0 + \beta_1 EFC_{ij} + \beta_2 FSAG_{ij} + \beta_3 FSAGijxEFC_{ij} + \gamma ACAD_{ij} + \rho DEMOG_{ij} + SCHOOL_{ij} + \epsilon_{ij},$$

where *STEM_OUTCOME* is one of several outcomes of interest corresponding to STEM attainment in college for student *i* attending high school *j* in 12th grade. *EFC* measures students' Estimated Family Contribution to college and is centered at the FSAG cut-off. *FSAG* is an indicator variable that takes on the value of "1" if students are below the FSAG cut-off, and zero otherwise. The $FSAGxEFC$ interaction term allows the slope of the relationship between EFC and each outcome to vary on either side of the eligibility cut-off. To increase the precision of our estimates, we also include several controls in the model.[13] *ACAD* is a vector of academic covariates, and *DEMOG* is a vector of demographic covariates. *SCHOOL* is a vector of high school fixed-effects that control for time-invariant school-specific (and by proxy, neighborhood-specific) effects on educational attainment. ϵ_{ij} is a residual error term, which we cluster at the high-school-level to adjust for the potential correlation of residuals within school. In this model, parameter β_2 is our coefficient of interest and describes the causal effect of being just below the FSAG cut-off on STEM attainment in college.

As indicated in equation (1), we incorporate a broad range of academic and demographic covariates into our analyses. We include measures of students' senior year high school GPA, their

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[12] We present results from OLS/LPM models throughout the paper as a conservative estimate of the impact of FSAG eligibility on STEM attainment. Tobit models return estimates that are approximately one credit larger across all credit outcomes. We also modeled STEM degree receipt using a logistic regression specification, which also returned slightly larger but substantively similar estimates to those that we report.

[13] Results from specifications without covariates are presented in Appendix Table A4 and are similar in magnitude to our main results.

SAT math and verbal scores, whether students participated in a gifted and talented program during high school, parents' adjusted gross income as reported on the FAFSA, and students' gender, race/ethnicity, and age at expected high school graduation.[14] We also include a dummy variable that indicates whether students were eligible for a Bright Futures scholarship award to account for the potential effect of other financial aid eligibility on STEM attainment.[15]

The selection of bandwidth is a critical decision in RD analyses: the wider the bandwidth, the greater the statistical power to detect an effect. However, a wider bandwidth also makes it more difficult to model the functional form of the relationship between the forcing variable (EFC) and the outcome of interest (Imbens & Lemieux, 2008). In our analysis, we employed the Calonico, Cattaneo, & Titiunik (2014) method for bandwidth selection on the full analytic samples, which returned optimal widths ranging from 0.8-1.2 across outcomes and samples. For sample consistency, we estimate our main results on a subset of students with EFCs between $590 and $2,590, equivalent to the modal CCT bandwidth selection of +/- $1,000 around the FSAG eligibility cut-off. To examine the sensitivity of our results to the choice of bandwidth, we re-fit our models using varying window widths and separately test polynomial specifications of the relationship between EFC and each outcome. We describe these sensitivity analyses in more detail in section IV.

There are two limitations to the external validity of our analyses. First, our inferences are limited to the effect of FSAG eligibility on whether students pursue STEM courses and degrees at Florida public or private universities. As we mention above, students who enrolled in out-of-state institutions do not appear in our data. This missing data issue is unlikely to alter our substantive findings since, in their previous work, [Author] and [Author] (2016) find no evidence that FSAG award offers impacted enrollment at in-state private institutions or induced students attending out-of-

[14] The students in our samples have complete information for all academic and demographic covariates with the exception of SAT scores; approximately 30 percent of students did not take the college entrance exam. We include those students in our samples to increase the precision of our estimates and we predict missing scores using the full set of other baseline characteristics. In all our results, we present estimates from multiple imputation regressions that account for uncertainty in the imputed test scores of students who did not take the exam.

[15] BFS students were required to meet annual academic benchmarks to renew their scholarships. To explore whether these requirements created a perverse incentive among BFS awardees to enroll in fewer STEM courses, we examined the number of STEM credits BFS students attempted in their second semester among those on either side of the GPA renewal threshold after first semester. The results, presented in Table A2, suggest that BFS scholars on the margin of renewing their awards did not avoid enrolling in STEM courses to maintain merit aid.

state schools to enroll at public, in-state colleges and universities. Because we focus on low-income students and the main effects of the grant program were concentrated at the public institutions we observe in the dataset, we are likely capturing the impacts on STEM attainment for the vast majority of target students.

Second, given our sample restrictions, the students in our analytic samples represent only a fraction of college-bound low-income students. However, they likely comprise those most interested in and prepared to pursue STEM majors in college, and for whom affordability may determine whether they are able to enroll and persist in STEM programs of study. Furthermore, because Florida is demographically and socioeconomically representative of other large states in the US, our results should also inform how need-based financial aid impacts STEM credit and degree attainment among academically qualified low-income students at other public institutions nationwide.

Testing for Statistical Equivalence around the Cut-off

The key assumption underlying our research design is that students immediately on either side of the FSAG eligibility cut-off are equivalent, on average, on all observed and unobserved dimensions. That is, we expect that students on either side of the cut-off differ only in terms of whether they are eligible for the FSAG grant. This assumption implies that we should observe a smooth density of students across the EFC cut-off. Spikes in the fraction of students just below the cut-off could indicate sorting bias and violate the equality assumption upon which our identification strategy relies (Urquiola & Verhoogen, 2009). In the case of the FSAG award, sorting does not appear to be a major concern. The EFC cut-off values used to determine FSAG eligibility were not publicly reported by the Florida Department of Education Office, and institutional financial aid websites also did not make this information available to students and their families. While Florida statutes from the time period reference an EFC threshold beyond which students would not be eligible for the FSAG, an exhaustive search found only one document from the Florida Postsecondary Planning Commission (2001) that reports the actual cut-off value. Given the difficulty low-income students often experience in completing financial aid applications and the effort required

to calculate the EFC, it is unlikely that the students in our study strategically positioned themselves below the eligibility cut-off to receive award offers.

To empirically test whether sorting is a concern in our study, we employ McCrary's (2008) density test around the EFC cut-off. In Figure 2, we present graphical results of these tests. A statistically significant spike in the density of students on either side of the cut-off would suggest that students were strategically manipulating their EFC values to be just above or below the cut-off. While there are small visual discontinuities at the cut-off for the two samples, neither is statistically significant, as evidenced by the overlapping 95 percent confidence intervals on either side of the vertical line positioned at the threshold. We therefore fail to reject that students in our analytic samples did not strategically position themselves around the EFC threshold, reinforcing that endogenous sorting does not appear to be a major concern in our analysis.

To further test the assumption of baseline equivalence around the EFC cut-off, we fit a version of equation (1) in which the dependent variable is one of several baseline student characteristics and all other student-level academic and demographic covariates are excluded. If students are equal in expectation on either side of the cut-off, then we should not observe statistically significant differences on student background measures at the cut-off. We performed this analysis within two windows around the FSAG cut-off – a narrow ±$250 around the cut-off, as well as ±$1,000, which corresponds to the bandwidth we use to estimate our main results – since we expect students to differ on observed and unobserved dimensions the further we move away from the cut-off. We present the results of these baseline equivalence tests in Table 3. It appears that the students just below the cut-off in our sample come from families with slightly higher family income than students just above the cut-off ($30,000-$31,500 vs. $28,500), but we otherwise find no systematic evidence that students differ on other observable dimensions.[16]

[16] Column 4 of Table 3 also shows a significant difference on high school GPA in the Trig+ sample within the ±$1,000 window, although this difference disappears within the ±$250 window and is not distinguishable from zero in the college math sample. We also find no evidence of differences at the cut-off with respect to: (1) college entrance exam scores, (2) enrollment in gifted programs during high school, and (3) eligibility for state merit aid. We therefore find little evidence of differences in academic performance at entry on either side of the cut-off.

We also examined whether the full set of student covariates jointly predict whether students are eligible for the FSAG. The p-value associated with the F-test for joint significance is presented in the last row of Table 3. Across both samples, we fail to reject the null hypothesis that students on either side of the FSAG eligibility threshold are statistically equivalent within the narrow window of ±$250. These findings substantiate our use of an RD design to estimate causal effects for students immediately on either side of the eligibility cut-off. Still, the p-value in column 4 is significant at the 10 percent level ($p = 0.061$). Observed differences at the cut-off in the high school math sample might bias our results upwards if the full set of covariates we include fails to account for unobserved differences. In all of our results, we therefore view the high school math sample as providing upper bound estimates of the impact of FSAG eligibility on students' decisions to pursue and complete postsecondary study in STEM disciplines.

IV. RESULTS

First-Stage Effects on Financial Aid Receipt

We begin our presentation of results by examining the effect on financial aid receipt at the FSAG eligibility cut-off. Importantly, the FSAG award does not appear to have crowded out other forms of federal, state, or institutional grant aid. In Table 4, we present estimates of the aid packages that students received at the FSAG eligibility cut-off in the 2000-01 academic year. The results in columns 1-3 show that students just below the FSAG cut- off received approximately $700 more in FSAG and total grant aid than students just above the cut-off.[17,18] There is suggestive evidence in column 4 that the FSAG offer modestly displaced student borrowing. In the college math sample, students just below the cut-off borrowed $145 less to pay for college in 2000-01, and this difference

[17] There are two reasons why the estimates in column 1 are less than the statutory amount of $1,300. First, some students included in our samples did not enroll in college and therefore did not receive FSAG awards. Second, students who enrolled in college were only eligible to receive awards if they filed the FAFSA by March 1st. Although we do not observe students' FAFSA filing date in our data, analyses of the NCES ELS:2002 survey data suggest that fewer than 40 percent of low-income students nationally file by March 1st.

[18] Analogous estimates of effects on cumulative aid received through six years are reported in Appendix Table A3. Students just below the FSAG cut-off in year one received $786-$921 more in FSAG through six years. Most, if not all, of the effect on cumulative FSAG receipt is operating through the effect in year one, which is consistent with the assumption of the RD strategy that students just below the eligibility cut-off in year one would be equally likely to fall just above the threshold in later years.

is significant at the 10 percent level. As a result, the net increase in total financial aid that FSAG-eligible students received was slightly below the FSAG award amounts. However, the relevant counterfactual is that FSAG eligibility increased grant aid to students without affecting Pell Grant awards or other sources of need- or merit-based funding.

Graphical Results

In Figure 3, we present graphical descriptions of the bivariate relationship between the forcing variable (EFC) and our STEM credits completed and degree receipt outcomes. To capture differences over the full time span of our data set, we focus on the bivariate relationship between EFC and the outcome of interest after seven years. Each point on the graph reports the mean value of the dependent variable within a $100 EFC bin, where EFC has been centered at the FSAG cut-off. We have also superimposed linear regression lines onto the scatter plots which capture secular trends in the bivariate relationship between EFC and the STEM outcome on either side of the eligibility cut-off.

By visual inspection, it appears that FSAG eligibility has a positive impact on STEM credit completion. As shown in Panel A of Figure 3, students who are prepared for college-level math based on their CPT or SAT scores and who fall just below the cut-off appear to have accumulated 21 STEM credits through seven years of college, which is 3 more credits than their peers above the FSAG threshold. The credit attainment gap is more pronounced in Panel B, where FSAG-eligible students who completed trigonometry or higher during high school earned approximately 7 additional STEM credits compared to their peers just above the cut-off. Given that FSAG-ineligible students completed 20 STEM credits through seven years of college, this jump at the cut-off represents a 35 percent increase over the control group mean and 9 percent of the average number of STEM credits completed by students who earned bachelor's degrees in STEM fields.

It is less obvious whether FSAG eligibility had an impact on STEM degree attainment from the graphical results in Figure 3. Although the fitted lines indicate a small gap at the cut-off that is suggestive of FSAG award offers increasing STEM degree attainment by 2 to 3 percentage points, many of the data points lie far from the line on both sides of the cut-off. In summary, these visual

illustrations suggest that FSAG eligibility had a positive effect on STEM credit attainment and an ambiguous effect on bachelor's degree attainment in STEM fields for academically prepared students at the FSAG eligibility cut-off.

RD Analysis: The Effects on STEM Credit and Degree Attainment

We now turn to the results of fitting our statistical models to the data, which largely confirm the conclusions from the graphical analyses above. In Table 5, we present estimates of the effect of FSAG eligibility on cumulative STEM credits attempted and completed. The first two columns present short-term impacts through one year following high school graduation. Columns 3 and 4 present outcomes through three years of postsecondary study for students who seamlessly transitioned from high school to college. Columns 5 and 6 present long-term outcomes through seven years of college and are analogous to the outcomes presented graphically above. Across all time horizons, our estimates of the impact of FSAG award offers on the cumulative number of STEM credits attempted are positive, but lack precision and are mostly indistinguishable from zero. The results therefore provide weak evidence that additional need-based aid encouraged FSAG-eligible students to enroll in more STEM courses, although we cannot rule out that award offers had no impact on students' course enrollment decisions.

We find larger and more conclusive impacts on STEM credit completion. For students who were ready for college-level math, we estimate that FSAG award offers increased STEM course completion by 0.7, 2.3, and 3.7 credits through year one, three, and seven, respectively. These effects, though small in absolute terms, represent large relative gains of 16 – 20 percent because the average number of STEM credits completed among FSAG-ineligible students is small. We estimate the largest credit completion effects, which increase to 1.9, 4.7 and 7.3 credits in the short-, medium- and long-term, respectively, among students who completed trigonometry or higher in high school. For this subgroup, FSAG-eligible students earned 34.5 percent more STEM credits through seven years compared to their peers just above the aid eligibility cut-off. In other words, students just below the cut-off were approximately one to two courses ahead of students just above the cut-off after three years, and they maintained this margin seven years following high school graduation.

In the final column of Table 5, we present impact estimates of an FSAG award offer on whether students earned bachelor's degrees in STEM fields within seven years of high school graduation. For students with math scores above the college placement threshold, the coefficient on FSAG implies a 2.7 percentage point (63 percent) increase in STEM degree attainment among FSAG-eligible students. The estimate of 2.8 percentage points (47 percent) is similar for students in the high school trigonometry sample. The estimate in Panel A is significant at the 10 percent level and the estimate in Panel B is not significant. The results therefore provide weak evidence that award offers increased STEM degree attainment, although once again we cannot rule out that the effects are due to sampling error.

It is possible that the results in Table 5 merely reflect that FSAG offers drew new college-ready students in our samples into college. In Table 6, we examine whether this explains the effects on STEM attainment. The results provide no evidence that FSAG award offers increased overall enrollment at public colleges in Florida (column 1), nor do they suggest that award offers induced students to attend public instead of private institutions in Florida (column 2). Although estimated imprecisely, the point estimates on both outcomes are negative or near zero in both samples. In column 3, we examine whether FSAG award offers influenced the quality of institution where students chose to attend. The results indicate that FSAG award offers increased attendance at Florida State University, the University of Florida, or the University of South Florida, the three public flagship universities in Florida in 2000-01, by 9-10 percentage points (30-35 percent).

If the effects on STEM attainment are not driven by overall attendance gains, we should observe a shift towards more intensive STEM course-taking at the FSAG cut-off. We examine evidence for this in column 4 of Table 6, which shows the proportion of total credits students completed in STEM fields through seven years following high school completion. The overall STEM credit gains of 3.7 and 7.3 credits reported in column 6 of Table 5 represent increases in the share of credits completed in STEM fields of 4.6 (24 percent) and 7.8 (33 percent) percentage points among students in the college math and high school trigonometry samples, respectively. To further examine whether these effects are mechanically produced by selection into college, in column 5 we condition

the samples on students who entered college in fall 2000. The coefficients are similar in magnitude and significance in the conditioned samples, reinforcing that FSAG award offers had a large influence on course selection among inframarginal college-goers.[19]

As suggested by the literature on academic mismatch and our results on flagship attendance, one avenue through which FSAG eligibility might lead to improved STEM outcomes is by inducing students to attend higher-quality institutions where there are more STEM course offerings and more academic supports for students pursuing STEM programs of study (Arcidiacono, 2004; Roderick et al, 2008; Bowen, Chingos & McPherson, 2009).[20] However, another possibility is that additional grant aid lowers non-institutional obstacles to STEM attainment, perhaps by reducing the financial barriers to pursuing more costly courses or by enabling students to substitute working for pay with more demanding coursework. To investigate which of these mechanisms appears to be driving our results, we add college fixed effects to the regression model in column 6 of Table 6.[21] If FSAG eligibility raised STEM attainment by inducing students to attend higher-quality institutions, then the magnitude of the effect should attenuate when we limit our comparisons to students who attended the same institutions. The estimates in column 6 (4.8 and 8.1 percentage points in the college math and Trig+ samples, respectively, which represent cumulative STEM credit increases of 4.7 and 11.5 credits in the enrollment-conditioned samples), do not diminish with the addition of college fixed effects. The results therefore suggest that the FSAG effects on STEM attainment are primarily explained by within-institution factors rather than which schools students chose to attend, despite the

[19] In Appendix Table A6, we present estimates of the effect of FSAG eligibility on non-STEM outcomes. The estimates on credit attainment are negative or near zero in both samples. The estimates on degree completion are suggestive of a positive effect in the College Math sample and no effect in the Trig+ sample. Although the STEM and non-STEM estimates are not statistically distinguishable, the results in Table A6, alongside those in Table 6 and Table A4, provide additional evidence that STEM attainment gains are not due to broad enrollment effects.

[20] Our analysis of STEM degree rates by institution also confirms this reasoning. Among high school graduates in 1997-98 who attended a Florida public university, the University of Florida, a flagship campus and the only public university with a “highly competitive” Barron’s ranking, reported the top STEM degree rate of 12.2 percent, more than 3 percentage points above the second highest-performing institution (Florida Agricultural & Mechanical University).

[21] We also examined whether FSAG eligibility increased the probability of summer enrollment and the number of STEM courses attempted and completed in summer terms, on the hypothesis that award offers may have allowed students to distribute more rigorous coursework throughout the academic year or re-take courses they had previously failed. We find no evidence that the STEM attainment gains are driven by changes in summer course-taking behavior.

fact that FSAG eligibility increased attendance at flagship institutions and exposed students to more STEM options. This result is consistent with recent work by Arcidiacono, Aucejo, and Hotz (2016), who find that students at the margin of attending more selective public universities in California would have been more likely to graduate in the sciences had they attended less selective campuses. It is therefore possible that attending higher-quality institutions is not a channel through which FSAG eligibility increased STEM attainment because the exposure effect was offset by the rigor of coursework at flagship institutions, which presented an additional barrier to STEM attainment for marginal enrollees.

Robustness Checks

We perform a number of robustness tests to validate our results. We first address the possibility that our results are sensitive to the EFC window around which we conducted our analysis by re-fitting our regression models using a variety of window widths. To the extent that our results capture the true causal effect of FSAG eligibility, the parameter estimates associated with FSAG eligibility should be robust to the choice of bandwidth selected. For illustrative purposes, in Table 7 we present the effect of FSAG eligibility on STEM credit accumulation through seven years using various window widths. Moving from left to right, each of the first five columns presents the results of fitting equation (1) using progressively wider window widths. We observe very little fluctuation in the coefficients on FSAG for both estimation samples which suggests that our main results are robust to the choice of window width.

In addition to bandwidth selection, another possible concern is that our results may be sensitive to the functional form of the relationship between EFC and our STEM outcomes of interest. Misspecifying the functional form of the forcing variable in RD models can yield particularly problematic findings, as the relatively small number of observations within the analytic windows can cause outlying observations just above or below the cut-off to have disproportionate influence on the estimated slope coefficients. This, in turn, could lead to biased effect estimates in our models (Murnane & Willett, 2011). In all of our analyses we modeled a locally linear relationship between the forcing variable and the outcome of interest within $1,000 of the FSAG eligibility cut-off. To test

whether we correctly specified the model, in columns 6 through 8 of Table 7 we add polynomial EFC terms to equation (1) and include two-way interactions between each of these terms and the FSAG eligibility indicator variable. None of the polynomial specifications are statistically significant. In column 9, we follow the suggestion of Cattaneo, Titiunik and Vazquez-Bare (2017) and estimate the effect on STEM credit attainment using a kernel-weighted nonparametric local-linear specification. The point estimates remain significant at the 10 and 5 percent levels in Panel A and B, respectively, and are of similar magnitude to our main estimates, reproduced in column 3 for ease of comparison. Taken together, the results in Table 7 suggest that within our chosen bandwidth of +/- $1,000 we have correctly specified a locally linear relationship between EFC and cumulative STEM credit completion.[22]

As a final robustness test, we consider the possibility that our results are not capturing true causal effects, but rather idiosyncratic fluctuations in the data at the EFC cut-off of $1,590. If this were the case, then we might also expect to detect increases in STEM attainment at arbitrarily chosen points along the EFC distribution. We conduct this falsification test by re-fitting equation (1) using a $1,000 window around four arbitrarily selected EFC "cut-offs": a) at the actual eligibility cut-off of $1,590 in column 1; b) at $500 below the actual cut-off in column 2; c) at $500 above the actual cut-off in column 3; and d) at $1,000 above the actual cut-off in column 4. We present the results of this test in Table 8. In columns 2 through 4, the estimated "effect" of FSAG eligibility on STEM credit accumulation through seven years is smaller in absolute magnitude than the actual estimate and not distinguishable from zero. This suggests that our estimates in column 1, and throughout our main results, are detecting causal effects rather than random fluctuations in the data around the EFC cut-off.

[22] We conducted similar analyses for all outcomes with statistically significant effects and reach the same conclusions: (1) the polynomial EFC terms and the interactions between FSAG and the polynomial terms are not necessary within the ± $1,000 analytic window, and (2) the estimates are robust to estimating effects using nonparametric local-linear specifications.

V. CONCLUSIONS & IMPLICATIONS

Increasing college STEM attainment among students with the interest and preparedness to succeed in STEM courses promises to maximize private returns to college and help to address the anticipated shortage of STEM workers in the labor force. A barrier to STEM attainment largely overlooked to date is the financial cost to pursuing study in those fields. Despite a wide array of policy initiatives at the institutional, state, and federal level, including financial aid for students pursuing STEM fields, there has been little research investigating the causal impact of grant aid on students' credit accumulation and degree attainment in STEM fields. We add to both the STEM and financial aid literatures by examining the effect of need-based grant eligibility on credit and degree attainment in STEM fields.

Our results indicate that financial aid policy has a role to play in increasing STEM attainment in college because students make cost-conscious decisions when choosing what to study. Using a RD design, we find a positive effect of FSAG eligibility on whether students with sufficient high school academic preparation accumulate STEM credit. When we adjust our estimates into magnitudes per $1,000 of grant aid, our results indicate that eligibility for a modest amount of additional grant aid in the first year of college alone led to students accumulating between 2.9 – 5.6 additional credits after seven years, depending on the sample. While these impacts are modest in absolute magnitude, they are quite large given that students just below the cut-off at the start of college were equally likely to be above the cut-off in subsequent years. In relative terms, the effects are also economically significant, representing increases of 20 – 35 percent over the STEM credit accumulation of students who were ineligible for the FSAG award in 2000-01. We also find suggestive evidence that award offers increased bachelor's degree attainment in STEM fields by 3 percentage points, although the degree effects are not precisely estimated and we cannot rule out that award offers had no effect on STEM degree production.

However, if the effects on degree attainment are real, then the FSAG program would appear to be a cost-effective investment towards increasing the production of STEM degrees. On the assumption that 300 students (i.e. roughly 10 percent of the college math sample) were sufficiently

close to the cut-off and academically prepared to study STEM, our results suggest that FSAG award offers induced approximately 8 more students (off a baseline of 13 students) to earn STEM degrees. Since FSAG-eligible and FSAG-ineligible students in our samples received average cumulative awards of $816 and $1,602 through six years, the total expenditure on students close to the cut-off (including the 300 STEM-ready students and 400 additional students close to the cut-off who were not academically prepared to study STEM) was $846,300 and the cost per student to produce 8 more STEM graduates was $105,788.[23] Given the STEM wage premium among entry-level college-educated workers, which was estimated at $10,000 in 2013, the social and private benefits of FSAG would have exceeded the costs within eleven years (Carnevale, Cheah, and Hanson, 2015).[24] In addition, because average earnings of STEM majors grow more quickly than other majors over the course of a career, this simple "back of the envelope" calculation indicates that FSAG likely has a positive rate of return even if the true effects on degree attainment are smaller than those we estimate.

A natural question that emerges is the mechanism(s) by which FSAG eligibility increased STEM attainment. We find that despite increasing attendance at institutions with more STEM offerings, the effects of FSAG eligibility on STEM attainment are primarily explained by within-institution factors rather than which schools students chose to attend. Unfortunately, we were unable to pin down the precise mechanisms by which additional grant aid lowered non-institutional obstacles to STEM attainment. We examined, but find no evidence that award offers increased summer enrollment, thereby enabling students to distribute STEM coursework throughout the academic year or more easily re-take STEM courses they had previously failed.

We also investigated whether FSAG eligibility lowered the financial barriers to pursuing more costly courses by examining variation in effects by STEM field of study. While certain fields

[23] The marginal number of graduates produced is derived from the estimates in column 7 of Table 5 (Panel A). Cumulative FSAG receipt is reported in Table A3. As explained in footnote 20, students ineligible for FSAG awards in year one averaged $816 in FSAG aid over six years because some students just below the eligibility cut-off initially became eligible for awards in later years. The total expenditure on students close to the cut-off is therefore $846,300 $[\text{i.e.}, 700 * .5 * (\$816 + \$1602)]$.

[24] Our estimates also imply that if the FSAG program had been targeted exclusively to STEM-ready students, the cost per student would have been approximately $45,000 and the total cost would have been recouped within five years.

like engineering may require students to incur additional lab and materials costs, other disciplines like mathematics or statistics are less likely to have additional costs (beyond the costs associated with taking any course, such as purchasing textbooks). As a result, we might expect to see pronounced effects of need-based aid for students in more cost-intensive courses if additional need-based aid makes those courses affordable. We find no evidence of differential effects by STEM field to suggest that effects operated through this channel. However, because Florida did not charge differential tuition in the years we observe in this study, it is possible that the students in our samples encountered similar costs across STEM fields. In other contexts where students pay higher tuition for more expensive programs of study, grant aid may enable cost-constrained students to afford taking STEM courses. A further mechanism by which FSAG may have positively impacted STEM outcomes is by reducing the hours students had to work in college, thereby allowing them to devote more time to their coursework. We were unable to empirically examine this hypothesis with our data, and it remains another plausible mechanism that merits further inquiry.

In summary, our results suggest that expanding need-based aid programs may be a sound investment, in tandem with efforts to address academic readiness and psychosocial barriers to STEM attainment, towards addressing the mismatch between the STEM training college students in the United States receive and the demands of employers in the labor market. Our findings also reveal that the potential impact of interventions designed to raise STEM attainment levels and lower socioeconomic gaps may not be fully realized if financial barriers to pursuing STEM are overlooked. More broadly, the results presented here indicate that financial barriers can affect the academic choices students make after deciding to enroll. Unpacking precisely how college affordability influences those decisions warrants further research to help fulfill our labor market needs and to help students reap the fullest returns to their postsecondary education.

REFERENCES

ACT (2014). *The condition of STEM 2014*. Iowa City, IA: ACT.

Andrews, R., & Stange, K. (2016). *Price regulation, price discrimination, and equality of opportunity in higher education: Evidence from Texas* (NBER Working Paper No. 22901). Cambridge: National Bureau of Economic Research.

Arcidiacono, P. (2004). Ability sorting and the returns to college major. *Journal of Econometrics*, *121*(1-2), 343-375.

Arcidiacono, B. P., Aucejo, E. M., & Hotz, V. J. (2016). University differences in the graduation of minorities in STEM fields: Evidence from California. *American Economic Review*, *106*(3), 525–562.

[Author] & [Author]. (2016). Looking beyond enrollment: The causal effect of need-based grants on college access, persistence, and graduation. *Journal of Labor Economics*, *34*(4), 1023-1073.

Baum, S., Elliot, D.C., & Ma, J. (2014). *Trends in student aid 2014*. Trends in Higher Education Series. Washington, DC: The College Board.

Bowen, W. G., Chingos, M. M. & McPherson, M. S. (2009). *Crossing the finish line: Completing college at America's public universities*. Princeton, NJ: Princeton University Press.

Burning Glass Technologies. (2014). *Real-time insight into the market for entry-level STEM jobs*. Boston: Burning Glass Technologies.

Calonico, S., Cattaneo, M., & Titiunik, R. (2014). Robust nonparametric confidence intervals for regression-discontinuity designs. *Econometrica*, *82*(6), 2295-2326.

Cattaneo, M. D., Titiunik, R., & Vazquez-Bare, G. (2017). Comparing inference approaches in RD designs: A reexamination of the effect of Head Start on child mortality. *Journal of Policy Analysis and Management*.

Carnevale, A.P., Cheah, B., & Hanson, A.R. (2015). *The economic value of college majors*. Washington, D.C.: Georgetown University, Center on Education and the Workforce.

Cornwell, C.M., Lee, K.H., & Mustard, D.B. (2005). Student responses to merit scholarship retention rules. *Journal of Human Resources*, *40(4)*, 895-917.

Cornwell, C.M., Lee, K.H., & Mustard, D.B. (2006). *The effects of state-sponsored merit scholarships on course selection and major choice in college*. IZA Discussion Paper No. 1953. Bonn, Germany: Institute for the Study of Labor.

Denning, J. T., & Turley, P. (2017). Was that smart? Institutional financial incentives and field of study. *Journal of Human Resources*, *52*(1), 152-186.

Dynarski, S., & Scott-Clayton, J. (2013). Financial Aid Policy: Lessons from Research. *Future of Children*, *23*(1), 67–91.

Espinosa, L. L. (2011). Pipelines and pathways: Women of color in undergraduate STEM majors and the college experiences that contribute to persistence. *Harvard Educational Review*, *81*(2), 209-241.

Evans, B. J. (2017). SMART Money: Do Financial Incentives Encourage College Students to Study Science? *Education Finance and Policy*, *12*(3), 342-368.

Fayer, S., Lacey, A., & Watson, A. (2017). *STEM occupations: Past, present, and future* (Spotlight on Statistics). Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics.

Florida Department of Education. (2006, October 25). Articulation Coordinating Committee Meeting Agenda. Retrieved May 21, 2014 from http://www.fldoe.org/articulation/pdf/acc_102506ada.pdf.

Florida Postsecondary Education Planning Commission. (2001). *State student financial aid policy*. Council for Education Policy Research and Improvement. Retrieved May 21, 2014 from http://www.cepri.state.fl.us/pdf/flfinaid.pdf.

Griffith, A. L. (2010). Persistence of women and minorities in STEM field majors: Is it the school that matters? *Economics of Education Review. 29*(6), 911-922.

Hanson, G. H., & Slaughter, M. J. (2016). *High-skilled immigration and the rise of STEM occupations in the U.S. employment* (NBER Working Paper No. 22623). Cambridge: National Bureau of Economic Research.

Hastings, J. S., Neilson, C. A., & Zimmerman, S. D. (2013). *Are some degrees worth more than others? Evidence from college admission cutoffs in Chile* (NBER Working Paper No. 19241). Cambridge: National Bureau of Economic Research.

Higher Education Research Institute. (2010). *Degrees of Success: Bachelor's Degree Completion Rates among Initial STEM Majors.* Los Angeles, C.A.: University of California-Los Angeles.

Imbens, G. W., & Lemieux, T. (2008). Regression discontinuity design: A guide to practice. *Journal of Econometrics, 142*(2), 615.

Kirkeboen, L. J., Leuven, E., & Mogstad, M. (2016). Field of study, earnings, and self-selection. *The Quarterly Journal of Economics*, *131*(3), 1057–1111.

Lacey, A.T., & Wright, B. (2009). *Occupational Employment Projections to 2018.* Monthly Labor Review. Washington, D.C.: U.S. Department of Labor, Bureau of Labor Statistics. Retreived from http://www.bls.gov/opub/mlr/2009/11/art5full.pdf.

Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). *STEM: Good Jobs Now and for the Future*. Economics and Statistics Administration Issue Brief #03-11. Washington, D.C.: U.S. Department of Commerce.

Lee, D. S., & Lemieux, T. (2010). Regression discontinuity designs in economis. *Journal of Economic Literature*, *48*(2), 281-355.

McCrary, J. (2008). Manipulation of the running variable in the regression discontinuity design. A density test. *Journal of Econometrics*, *142*(2), 698-714.

Murnane, R. J., & Willett, J. B. (2010). *Methods matter: Improving causal inference in educational and social science research*. Oxford: Oxford University Press.

National Center for Education Statistics. (2002). *Digest of education statistics 2002. Tables 182 and 203*. Washington D.C.: United States Department of Education.

National Center for Education Statistics. (2010). *Characteristics of the 100 public elementary and secondary school districts in the United States: 2008-2009,* Table D-3. Washington, D.C.: United States Department of Education.

National Center for Education Statistics. (2011). *Postsecondary awards in science, technology, engineering, and mathematics (STEM), by state: 2001 and 2009*. NCES Publication No. 2011-226. Retrieved from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2011226.

Newman, J. (2014, January 29). State Funding for Need-Based Aid Averages Less Than $500 per Student. *The Chronicle of Higher Education*. Retrieved from http://chronicle.com/blogs/data/2014/01/29/state-funding-for-need-based-aid-averages-less-than-500-per-student/.

Noonan, R. (2017). *STEM Jobs: 2017 Update* (ESA Issue Brief #02-17). Washington, DC: U.S. Department of Commerce, Economics and Statistics Administration, Office of the Chief Economist.

Price, J. (2010). The effect of instructor race and gender on student persistence in STEM fields. *Economics of Education Review, 29*(6), 901-910.

Roderick, M., Nagaoka, J., Coca, V., Moeller, E., Roddie, K., Gilliam, J., & Patton, D. (2008). *From high school to the future: Potholes on the road to college*. Chicago, IL: Consortium on Chicago School Research.

Rothstein, J., & Rouse, C. E. (2011). Constrained after college: Student loans and early-career occupational choices. *Journal of Public Economics, 95*(1–2), 149–163.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Boston, MA: Houghton Mifflin

Sjoquist, D.L., & Winters, J.V. (2015). State merit aid programs and college major: A focus on STEM. *Journal of Labor Economics*, *33(4)*, 973-1006.

Sjoquist, D.L., & Winters, J.V. (2015). The effect of Georgia's HOPE scholarship on college major: A focus on STEM. *IZA Journal of Labor Economics*, *4*(1), 1-29.

Stange, K.M. (2015). Differential pricing in undergraduate education: Effects on degree production by field. *Journal of Policy Analysis and Management, 34(1)*, 107-135.

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69*(5), 797-811.

United States Census Bureau. (2011). *State and county quick facts.* Retrieved October 25th, 2011 from http://quickfacts.census.gov/qfd/index.html.

United States Department of Homeland Security (2012). *STEM Designated Degree Programs List*. Retrieved May 21, 2014 from http://www.ice.gov/sevis/stemlist.htm.

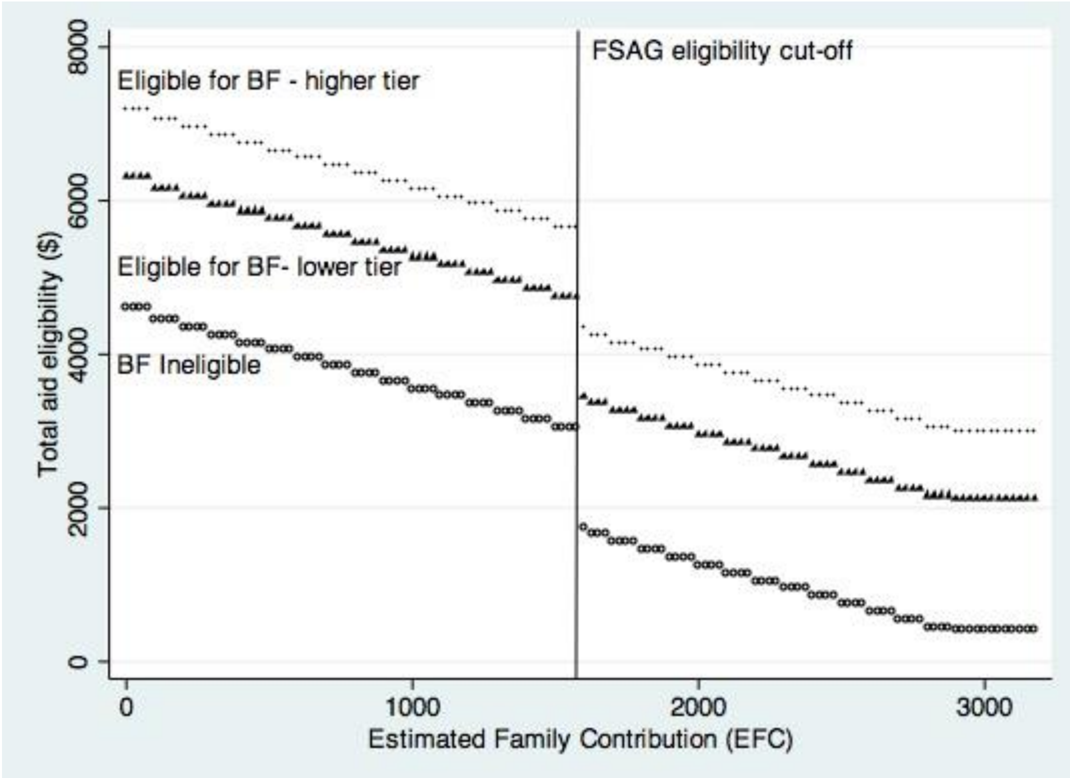
Urquiola, M., & Verhoogen, E. (2009). Class-size caps, sorting, and the regression discontinuity design. *American Economic Review, 99*(1), 179-215.

Wang, X. (2013). *Why Students Choose STEM Majors: Motivation, High School Learning, and Postsecondary Context of Support*. *American Educational Research Journal, 50*(5), 1081-1121.

Wiswall, M., & Zafar, B. (2015). Determinants of College Major Choice: Identification using an Information Experiment. *Review of Economic Studies, 82*(2), 791–824.

Zhang, L. (2011). Does merit aid affect degree production in STEM fields? Evidence from Georgia and Florida. *Journal of Higher Education, 82*(4), 389–415.

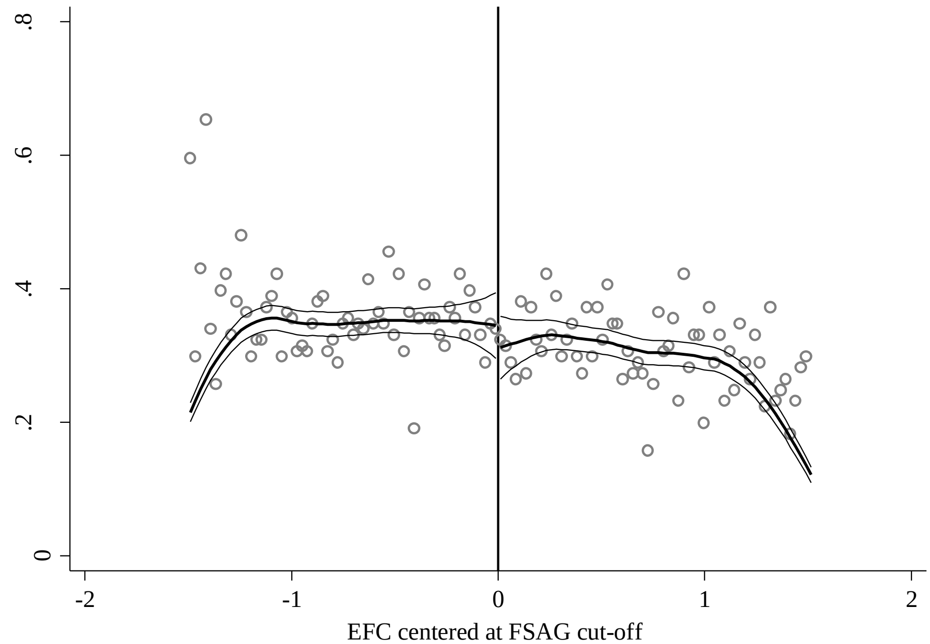
Figure 1: Federal and Florida Grant Aid Eligibility by EFC



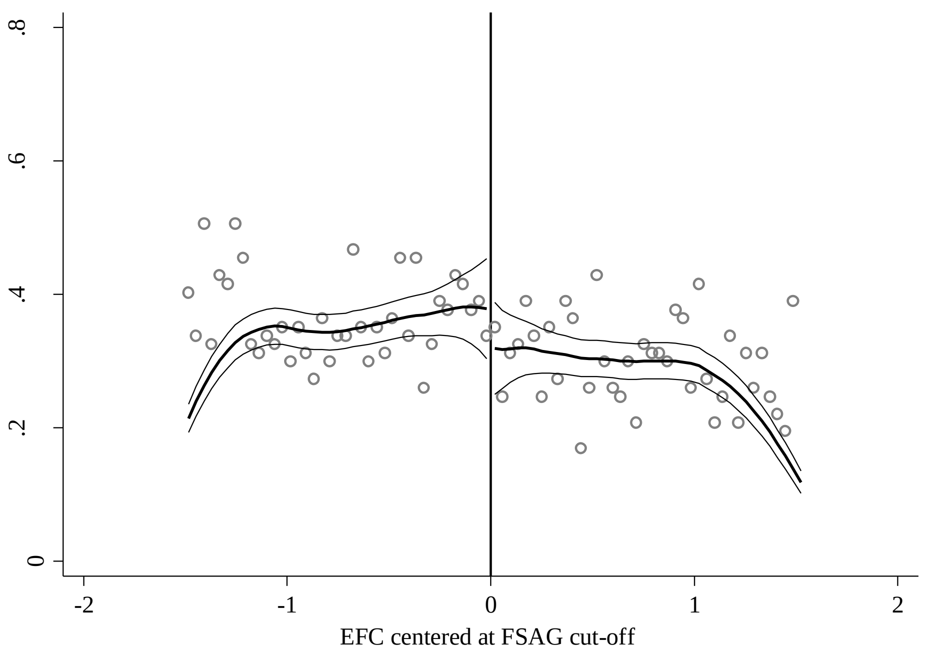
Notes: Total aid eligibility is the sum of the federal Pell Grant, Florida Student Access Grant (FSAG), and Bright Futures Scholarship (BF) awards for which students qualify. During the study period, students with EFCs below $1,590 were eligible for FSAG awards which offered $1,300 in additional need-based aid per year. The two tiers of merit-based BF scholarships vary in generosity based on students' incoming high school GPA and SAT scores. See text for eligibility details.

Figure 2: Density of observations within ±$1,000 of the FSAG eligibility cut-off

A. College Math Sample



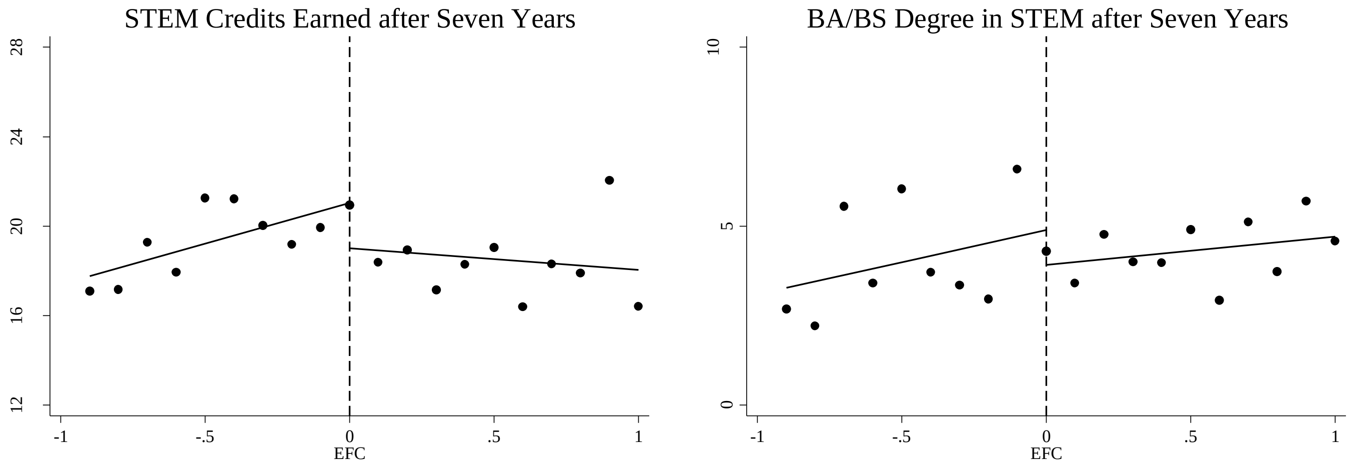
B. HS Trig+ Sample



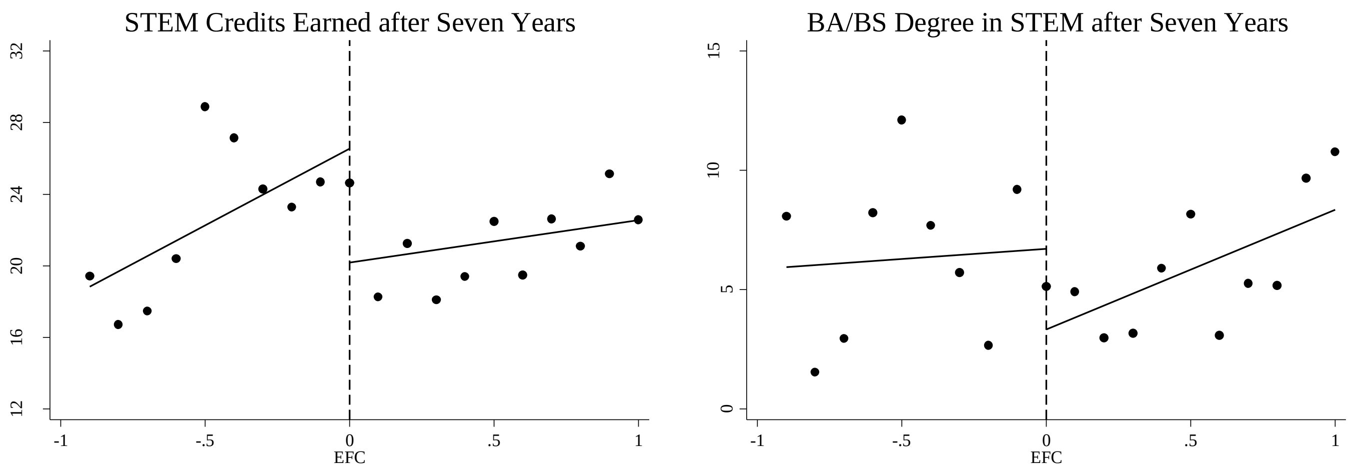
Notes: EFC is divided by $1,000 and centered at the FSAG cut-off. The density function of EFC was estimated using McCrary's (2008) test for manipulation of the forcing variable in regression discontinuity analyses.

Figure 3: Relationship between EFC and selected outcomes, with locally linear regressions fit on either side of the FSAG cut-off

A. College Math Sample



B. HS Trig+ Sample



Notes: EFC is divided by $1,000 and centered at the FSAG cut-off. Each point represents the mean of the dependent variable within a $100 bin of EFC. The trend lines present uncontrolled, locally-linear regressions within $1,000 of the aid eligibility cut-off.

Table 1: STEM Attainment by College Math Test Scores and Highest Math Course Completed in High School, among College Enrollees in Fall 2000

	(1)	(2)	(3)
	STEM Credits Completed Through Year 7	BA/BS Degree in STEM	N
A. College Math Test Scores			
CPT < 40	6.45	0.00	4,398
40 <= CPT < 60	10.05	0.01	4,652
60 <= CPT < 80	13.30	0.01	4,068
80 <= CPT < 100	17.96	0.03	4,026
100 <= CPT	25.85	0.08	2,488
Missing CPT	19.39	0.06	27,743
SAT < 400	14.12	0.01	1,708
400 <= SAT < 500	15.66	0.02	8,177
500 <= SAT < 600	19.88	0.05	10,626
600 <= SAT < 700	27.92	0.13	5,216
700 <= SAT	42.44	0.28	1,062
Missing SAT	19.39	0.06	27,743
Excluded from College Math Sample	11.01	0.01	18,072
In College Math Sample (CPT >= 72 | SAT >= 440)	20.64	0.06	29,303
B. Highest Math Course in High School			
Algebra 1	7.08	0.01	1,796
Geometry	8.42	0.01	5,255
Algebra 2	13.87	0.02	19,162
Trigonometry	19.04	0.04	5,413
Pre-Calculus	22.57	0.06	5,028
Calculus or Higher	32.20	0.16	5,922
Missing HS Math Course	15.35	0.03	4,799
Excluded from HS Trig+ Sample	13.96	0.02	36,019
In HS Trig+ Sample	26.51	0.10	11,356

Notes: Means are reported in columns 1 and 2. Sample sizes are reported in column 3. The sample is restricted to Florida high school graduates in 1999-2000 who attended in-state public colleges and universities in fall 2000.

Table 2: Summary Statistics of the Data

	(1)	(2)	(3)	(4)	(5)
	All public Florida high school seniors	College Math Sample		HS Trig+ Sample	
		All Students	EFC ±$1,000	All Students	EFC ±$1,000
Female	0.53	0.58	0.59	0.57	0.61
White	0.62	0.63	0.54	0.64	0.52
Black	0.20	0.15	0.20	0.15	0.22
Hispanic	0.15	0.15	0.20	0.13	0.18
Other Race	0.04	0.06	0.06	0.08	0.09
Age	17.92	17.82	17.83	17.81	17.81
	(0.57)	(0.49)	(0.50)	(0.48)	(0.49)
	[99,067]	[20,400]		[8,775]	
EFC	$6,889	$7,750	$1,570	$9,060	$1,560
	($12,128)	($13,950)	($570)	($15,290)	($570)
	[45,785]				
AGI	$43,662	$51,780	$28,380	$55,110	$28,630
	($41,607)	($44,310)	($10,280)	($46,740)	($10,040)
	[43,784]	[20,028]		[8,668]	
12th Grade GPA	2.84	3.10	3.04	3.23	3.18
	(0.75)	(0.63)	(0.64)	(0.56)	(0.55)
	[57,021]	[18,599]		[8,879]	
CPT Math Score	59.43	92.81	91.62	89.27	87.18
	(27.02)	(13.55)	(13.28)	(22.49)	(23.31)
	[36,328]	[6,005]	[886]	[2,121]	[345]
SAT Math Score	528.73	554.04	536.98	579.55	557.1
	(97.27)	(81.76)	(75.63)	(88.80)	(85.94)
	[35,080]	[16,188]	[2,102]	[6,487]	[877]
FSAG in 2000-01	$195	$221	$412	$242	$482
	($432)	($462)	($462)	($462)	($462)
	[45,727]				
Total Grants & Loans in 2000-01	$1,795	$2,834	$3,355	$3,602	$4,389
	($2,787)	($3,087)	($3,397)	($3,297)	($3,680)
	[45,727]				
Observations	101,094	20,738	2,834	8,907	1,283

Notes: Means are shown with standard deviations in parentheses and the number of observations in brackets if less than the full sample. Columns 2-5 are restricted to students with non-missing FAFSA information. EFC = Expected Family Contribution towards college, AGI = parents' adjusted gross income, CPT = College Placement Test, and Grade 12 GPA is weighted on a 4.5 scale.

Table 3: Test for Baseline Equivalence around the FSAG Eligibility Cut-Off

	(1)	(2)	(3)	(4)
	College Math Sample		HS Trig+ Sample	
EFCs window around FSAG eligibility cut-off	±$250	±$1,000	±$250	±$1,000
Female	-0.172	-0.007	-0.150	-0.015
	[0.104]	[0.042]	[0.225]	[0.072]
Black	0.017	-0.031	0.198	-0.054
	[0.090]	[0.033]	[0.160]	[0.057]
Hispanic	-0.024	-0.001	-0.061	-0.003
	[0.077]	[0.029]	[0.157]	[0.051]
Other Race	0.004	0.021	0.018	0.008
	[0.054]	[0.020]	[0.118]	[0.044]
Age	0.099	0.005	0.009	-0.025
	[0.141]	[0.043]	[0.322]	[0.076]
Parents' Adjusted Gross Income (AGI)	1.845	1.572*	2.247	2.923**
	[2.107]	[0.848]	[4.794]	[1.361]
Eligible for Bright Futures Scholarship	-0.090	-0.006	-0.237	-0.103
	[0.115]	[0.042]	[0.212]	[0.068]
Enrolled in Gifted/Talented Program	-0.007	0.019	0.025	-0.002
	[0.045]	[0.018]	[0.088]	[0.030]
High School Senior Year GPA	0.126	0.078	0.004	0.149**
	[0.141]	[0.056]	[0.269]	[0.069]
SAT Math	-6.654	-4.639	-32.622	0.816
	[18.361]	[7.105]	[39.872]	[12.980]
SAT Verbal	-12.505	-6.893	-36.264	-5.982
	[20.528]	[7.725]	[43.228]	[13.360]
Observations	739	2,834	346	1,283
P-value on F-test for Joint Significance	0.710	0.353	0.986	0.061

*** p<0.01 ** p<0.05 * p<0.10

Notes: Each cell reports the coefficient estimate from an OLS/LPM regression of the student characteristic on the FSAG eligibility indicator. All models control for EFC (centered at the cut-off), the interaction of the FSAG eligibility indicator and EFC, and high school fixed effects. Standard errors, clustered by high school, are reported in brackets. SAT math and verbal scores have been imputed where missing using multiple imputations. The F-test for joint significance tests whether the full set of baseline characteristics jointly explain variation in whether students were just above or below the FSAG eligibility cut-off.

Table 4. The Effect of FSAG Eligibility on Financial Aid Receipt in 2000-01

	(1)	(2)	(3)	(4)	(5)
	FSAG	Total Grant Aid	Grant Aid minus FSAG	Loan Aid	Total Aid from All Sources
Panel A: College Math Sample					
Eligible for FSAG	673.97***	694.92***	20.95	-145.04*	549.88**
	[38.45]	[198.15]	[186.31]	[84.60]	[234.09]
EFC (centered at FSAG cut-off)	-12.14	-457.94*	-445.80*	-144.99	-602.93**
	[31.38]	[236.41]	[230.25]	[126.36]	[292.84]
FSAG x EFC	33.37	398.88	365.50	147.67	546.54
	[71.12]	[404.25]	[375.44]	[163.41]	[467.36]
R-squared	0.449	0.403	0.401	0.161	0.371
Outcome mean above FSAG cut-off	0	2580	2580	358	2938
N			2,834		
Panel B: HS Trig+ Sample					
Eligible for FSAG	673.05***	735.40*	62.35	-105.65	629.75
	[67.84]	[423.58]	[408.00]	[207.08]	[501.40]
EFC (centered at FSAG cut-off)	-92.67	-520.41	-427.74	-176.61	-697.02
	[63.54]	[569.89]	[559.77]	[255.58]	[673.47]
FSAG x EFC	-15.25	422.23	437.49	311.07	733.30
	[125.69]	[814.13]	[780.06]	[297.04]	[918.23]
R-squared	0.568	0.452	0.453	0.252	0.416
Outcome mean above FSAG cut-off	0	3430	3430	496	3925
N			1,283		

*** p<0.01 ** p<0.05 * p<0.10

Notes: Robust standard errors, clustered at the high school level, are shown in brackets. All results are from multiple imputation OLS specifications estimated with an EFC window +/- $1,000 around the FSAG cut-off and include the following covariates: race dummy variables (Black, Hispanic, and Other race/ethnicity); female dummy variable; high school senior year GPA (weighted 4.5 scale); SAT math and verbal scores (imputed where missing); whether the student was in a gifted and talented program; parental adjusted gross income; student age, and whether the student was eligible for the Florida Bright Futures Scholarship. All models also include school fixed effects and a constant.

Table 5: The Effect of FSAG Eligibility on Cumulative STEM Credits and BA/BS Degrees Earned in STEM Fields

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Through Year 1		Through Year 3		Through Year 7		
	STEM Credits Attempted	STEM Credits Completed	STEM Credits Attempted	STEM Credits Completed	STEM Credits Attempted	STEM Credits Completed	BA/BS Degree in STEM
Panel A: College Math Sample (N = 2,834)							
Eligible for FSAG	0.514	0.722*	1.600	2.254**	2.701	3.705**	0.027*
	[0.471]	[0.413]	[1.311]	[1.113]	[2.076]	[1.800]	[0.015]
EFC (centered at FSAG cut-off)	0.553	0.439	1.756	1.577	1.165	1.219	0.022
	[0.558]	[0.491]	[1.553]	[1.312]	[2.462]	[2.054]	[0.021]
FSAG x EFC	-0.574	-0.106	-1.360	-0.137	1.061	2.642	0.008
	[0.719]	[0.677]	[1.996]	[1.847]	[3.185]	[2.793]	[0.026]
R-squared	0.191	0.208	0.202	0.216	0.195	0.204	0.191
Outcome mean above FSAG cut-off	5.63	4.31	15.99	12.41	23.55	18.27	0.043
Panel B: HS Trig+ Sample (N =1,283)							
Eligible for FSAG	1.805*	1.947**	3.615	4.721**	5.456	7.259**	0.028
	[0.940]	[0.837]	[2.514]	[2.164]	[4.115]	[3.533]	[0.032]
EFC (centered at FSAG cut-off)	2.105*	1.723	4.555	4.785	3.016	4.389	0.040
	[1.219]	[1.080]	[3.371]	[2.953]	[5.043]	[4.379]	[0.044]
FSAG x EFC	-1.019	-0.300	-4.015	-3.430	0.340	0.153	-0.055
	[1.531]	[1.431]	[4.163]	[3.801]	[6.588]	[5.708]	[0.051]
R-squared	0.319	0.326	0.322	0.330	0.300	0.310	0.290
Outcome mean above FSAG cut-off	6.51	5.28	18.06	14.44	26.47	20.98	0.059

*** p<0.01 ** p<0.05 * p<0.10

Notes: Robust standard errors, clustered at the high school level, are shown in brackets. All results are from multiple imputation OLS/LPM specifications estimated with an EFC window +/- $1,000 around the FSAG cut-off and include the following covariates: race dummy variables (Black, Hispanic, and Other race/ethnicity); female dummy variable; high school senior year GPA (weighted 4.5 scale); SAT math and verbal scores (imputed where missing); whether the student was in a gifted and talented program; parental adjusted gross income; student age, and whether the student was eligible for the Florida Bright Futures Scholarship. All models also include high school fixed effects and a constant.

Table 6: The Effect of FSAG Eligibility on Enrollment and the Share of Credits Completed in STEM Fields through Seven Years Following High School Graduation

	(1)	(2)	(3)	(4)	(5)	(6)
	All Students				Students Enrolled in Fall 2000	
	Enrolled at Any College	Enrolled at in-State Private College (FRAG proxy)	Enrolled at UF, FSU, or USF	Share of Credits Completed in STEM	Share of Credits Completed in STEM	Share of Credits Completed in STEM
Panel A: College Math Sample						
Eligible for FSAG	-0.006	0.003	0.086***	0.046**	0.047**	0.048***
	[0.025]	[0.025]	[0.032]	[0.018]	[0.019]	[0.018]
EFC (centered at FSAG cut-off)	0.003	-0.015	0.064	0.034	0.021	0.018
	[0.028]	[0.030]	[0.041]	[0.022]	[0.021]	[0.021]
FSAG x EFC	-0.011	-0.001	0.009	0.003	0.016	0.021
	[0.036]	[0.042]	[0.061]	[0.029]	[0.028]	[0.028]
R-squared	0.182	0.149	0.258	0.188	0.243	0.265
Outcome mean above FSAG cut-off	0.926	0.0848	0.242	0.223	0.217	0.217
Observations	2,834	2,834	2,834	2,834	2,151	2,151
Panel B: HS Trig+ Sample						
Eligible for FSAG	-0.020	0.007	0.098	0.078**	0.071**	0.081**
	[0.045]	[0.038]	[0.061]	[0.033]	[0.035]	[0.036]
EFC (centered at FSAG cut-off)	-0.004	-0.019	0.100	0.055	0.059	0.072
	[0.054]	[0.044]	[0.076]	[0.041]	[0.044]	[0.046]
FSAG x EFC	0.036	-0.006	-0.051	-0.020	-0.058	-0.065
	[0.077]	[0.073]	[0.103]	[0.057]	[0.059]	[0.062]
R-squared	0.315	0.300	0.362	0.321	0.384	0.426
Outcome mean above FSAG cut-off	0.893	0.0911	0.324	0.235	0.232	0.232
Observations	1,283	1,283	1,283	1,283	971	971

*** p<0.01 ** p<0.05 * p<0.10
See Table 4 for model details. Results in column (6) also include college fixed effects.

Table 7: Robustness of the estimated effect on cumulative STEM credit completion within seven years to differing window widths around the FSAG cut-off and specification of the functional form

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	EFC Window around the Cut-Off					Checks of Functional Form			
	±$800	±$900	±$1,000	±$1,100	±$1,200	EFC Window = ±$1,000			
Panel A: College Math Sample									
Eligible for FSAG	3.354	3.561*	3.705**	3.897**	2.857*	2.327	3.575	6.050	3.011*
	[2.118]	[1.906]	[1.800]	[1.679]	[1.637]	[2.617]	[3.451]	[3.721]	[1.711]
EFC (centered at FSAG cut-off)	2.637	2.463	1.219	0.346	0.621	7.995	19.050	50.338	
	[3.352]	[2.562]	[2.054]	[1.673]	[1.530]	[8.133]	[20.761]	[39.445]	
FSAG x EFC	-0.705	0.071	2.642	4.976**	1.294	-18.856	-25.993	-39.032	
	[4.519]	[3.350]	[2.793]	[2.317]	[2.265]	[12.005]	[30.997]	[59.233]	
EFC^2 and $(FSAG \times EFC)^2$						✓	✓	✓	
EFC^3 and $(FSAG \times EFC)^3$							✓	✓	
EFC^4 and $(FSAG \times EFC)^4$								✓	
Observations	2,272	2,573	2,834	3,102	3,368	2,834	2,834	2,834	2,834
R-squared	0.221	0.219	0.204	0.194	0.192	0.170	0.170	0.170	0.204
P-value on F-test of EFC polynomials						0.384	0.549	0.496	
P-value on F-test of FSAG x EFC interactions						0.440	0.885	0.729	
Panel B: HS Trig+ Sample									
Eligible for FSAG	7.580*	8.201**	7.259**	8.208**	7.267**	5.235	6.438	12.948*	6.782**
	[4.385]	[3.943]	[3.533]	[3.299]	[3.172]	[5.061]	[6.127]	[6.830]	[2.722]
EFC (centered at FSAG cut-off)	7.441	8.176	4.389	4.010	5.286*	20.997	49.877	116.161	
	[6.913]	[5.530]	[4.379]	[3.383]	[2.860]	[16.346]	[46.401]	[75.980]	
FSAG x EFC	-5.240	-5.371	0.153	2.942	-3.279	-46.708**	-89.887	-91.368	
	[9.329]	[7.273]	[5.708]	[4.530]	[4.332]	[23.154]	[71.136]	[115.590]	
EFC^2 and $(FSAG \times EFC)^2$						✓	✓	✓	
EFC^3 and $(FSAG \times EFC)^3$							✓	✓	
EFC^4 and $(FSAG \times EFC)^4$								✓	
Observations	1,035	1,157	1,283	1,408	1,525	1,283	1,283	1,283	1,283
R-squared	0.339	0.336	0.309	0.298	0.283	0.289	0.289	0.289	0.309
P-value on F-test of EFC polynomials						0.317	0.433	0.340	
P-value on F-test of FSAG x EFC interactions						0.521	0.821	0.639	

*** p<0.01 ** p<0.05 * p<0.10

Notes: Robust standard errors, clustered at the high school level, are shown in brackets. Results in columns (1)-(8) are from multiple imputation OLS specifications that include the same set of covariates as in Table 4. See Table 4 for details. Results in column (9) are from a triangular kernel-weighted nonparametric local-linear specification.

Table 8: Falsification test for whether estimated effects of FSAG eligibility on STEM credit completion within seven years are unique to the actual FSAG cut-off

	(1)	(2)	(3)	(4)
Eligibility Cut-Off at EFC =	$1,590 (actual)	$1,090	$2,090	$2,590
Panel A: College Math Sample				
Eligible for FSAG	3.705**	-0.729	0.376	1.127
	[1.800]	[1.704]	[1.756]	[1.933]
EFC (centered at FSAG cut-off)	1.219	-2.391	1.440	1.938
	[2.054]	[2.024]	[2.472]	[2.396]
FSAG x EFC	2.642	4.233	-3.329	-1.294
	[2.793]	[2.909]	[3.145]	[2.906]
Observations	2,834	2,988	2,673	2,519
R-squared	0.204	0.200	0.195	0.180
Outcome mean above FSAG cut-off	18.27	19.32	17.83	17.95
Panel B: HS Trig+ Sample				
Eligible for FSAG	7.259**	-1.536	-2.546	3.093
	[3.533]	[3.523]	[3.971]	[3.884]
EFC (centered at FSAG cut-off)	4.389	-6.784	4.168	4.266
	[4.379]	[4.536]	[5.096]	[4.935]
FSAG x EFC	0.153	6.456	-10.176	0.895
	[5.708]	[6.829]	[6.508]	[6.794]
Observations	1,283	1,355	1,232	1,121
R-squared	0.310	0.288	0.321	0.363
Outcome mean above FSAG cut-off	20.98	22.56	22.03	22.40

*** p<0.01 ** p<0.05 * p<0.10

Notes: Robust standard errors, clustered at the high school level, are shown in brackets. All results are from multiple imputation OLS specifications estimated with an EFC window +/- $1,000 around the FSAG cut-off and include the following covariates: race dummy variables (Black, Hispanic, and Other race/ethnicity); female dummy variable; high school senior year GPA (weighted 4.5 scale); SAT math and verbal scores (imputed where missing); whether the student was in a gifted and talented program; parental adjusted gross income; student age, and whether the student was eligible for the Florida Bright Futures Scholarship. All models also include school fixed effects and a constant.

Appendix A: Predictions of Financial Aid Effects on Major Choice

Below, we specify a model of major choice that illustrates the theoretical uncertainty of the impact of financial aid on STEM attainment. First, assume that students choose a major that maximizes net expected value, with the value to student i from pursuing major k at institution j captured by:

(1) $$V_{ijk} = \gamma E_{ijk} + \rho\left(E_{ijk} * NCT_{ij}\right) + \tau I_{ijk} + \pi\left(I_{ijk} * NCT_{ij}\right) + \delta_{ijk}.$$

In this model, net value (V_{ijk}) is a function of four factors: 1) net cost of tuition to the student (NCT_{ij}), which for simplicity is assumed to vary across schools but is constant over majors within schools; 2) expected post-schooling earnings (E_{ijk}), 3) investment costs required to pursue a given major (I_{ijk}), and 4) non-financial benefits associated with the major (δ_{ijk}), such as the utility derived from studying intrinsically enjoyable subject matter.

Assuming that a conditional logit model correctly specifies the probability of choosing major k over an alternative, the marginal effect of lowering net tuition cost on the share of students choosing major k at school j is:

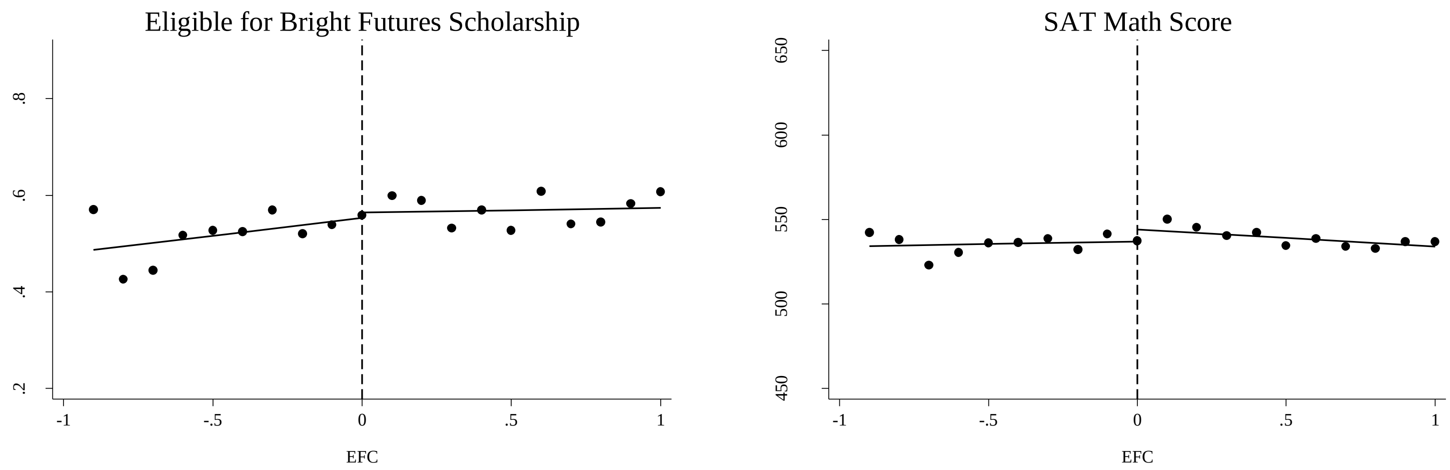
(2) $$\frac{dShare_{jk}}{dNCT_j} = (\rho + \pi)(Share_{jk})(1 - Share_{jk}),$$

where ρ denotes how the effect of expected earnings on major choice changes when net costs increase and π captures the analogous interaction effect with respect to investment costs. On the one hand, it is assumed that $\rho \geq 0$ since, all else equal, higher cost will increase pressure to pursue lucrative majors. On the other hand, we expect that $\pi \leq 0$. Higher costs will exacerbate financial constraints to pursuing majors that demand relatively more investments of time and money. The combined effect of lowering net cost on the intensive margin is therefore ambiguous and depends on whether $\pi > \rho, \pi < \rho$, or $\pi = \rho$.

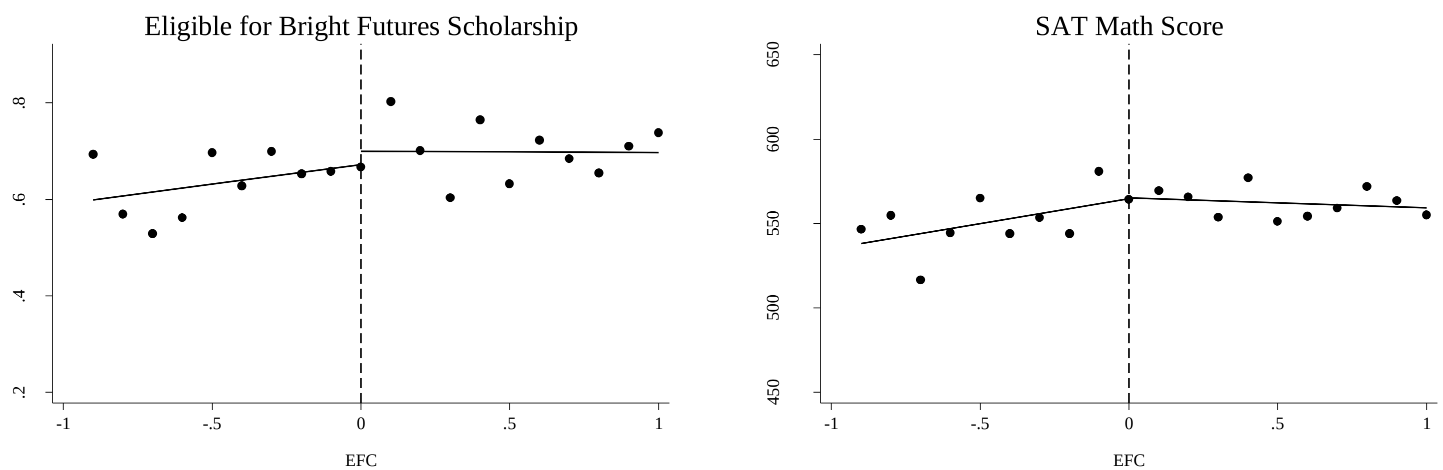
Appendix B: Additional Figures and Tables

Figure A1: Bivariate relationship between the forcing variable and selected covariates, with locally linear regressions fit on either side of the cut-off

A. College Math Sample



B. HS Trig+ Sample



Notes: EFC is divided by $1,000 and centered at the FSAG cut-off. Each point represents the mean of the covariate within a $100 bin of EFC. The trend lines present uncontrolled, locally-linear regressions within $1,000 of the aid eligibility cut-off.

Table A1: CPT and SAT Math Scores by Highest Math Course Completed in High School

	(1)	(2)	(3)	(4)
	All public Florida high school seniors		EFCs ±$1,000 of FSAG eligibility cut-off	
	CPT	SAT	CPT	SAT
Algebra 1	41.87	452.20	42.40	442.00
	(19.08)	(95.66)	(18.92)	(100.46)
	[1,387]	[199]	[140]	[25]
Geometry	47.13	457.44	47.62	445.83
	(20.51)	(71.94)	(20.24)	(70.60)
	[4,582]	[3,592]	[436]	[391]
Algebra 2	59.15	459.32	58.86	432.39
	(22.04)	(93.99)	(21.62)	(86.64)
	[4,788]	[1,464]	[426]	[155]
Trigonometry	80.87	546.17	78.85	524.90
	(22.71)	(72.81)	(24.50)	(75.85)
	[1,411]	[2,574]	[143]	[255]
Pre-Calculus	85.01	530.85	88.92	525.56
	(22.67)	(71.43)	(21.23)	(77.52)
	[1,170]	[2,792]	[111]	[239]

Notes: Means are shown with standard deviations in parentheses and the number of observations in brackets.

Table A2: STEM Credits Attempted Second Semester by First Semester GPA, among BFS Scholarship Recipients

	(1)	(2)	(3)	(4)	(5)	(6)
Below BF GPA Renewal Threshold	-0.290***	0.318**	0.371**	0.334*	0.410*	1.053***
	[0.076]	[0.145]	[0.157]	[0.178]	[0.229]	[0.336]
First Semester GPA (centered at BF renewal cut-off)		0.652***	0.303**	-0.053	-0.008	0.358
		[0.152]	[0.153]	[0.254]	[0.432]	[1.021]
Below BF GPA Renewal Threshold x GPA		-0.100	0.343	1.024**	1.312*	5.671***
		[0.243]	[0.263]	[0.407]	[0.724]	[1.873]
Additional Covariates			✓	✓	✓	✓
School Fixed Effects			✓	✓	✓	✓
GPA Window (1.00 = optimal)	1.00	1.00	1.00	0.75	0.50	0.25
Observations	9,000	9,000	8,225	6,307	4,288	2,421
R-squared	0.002	0.005	0.135	0.139	0.162	0.230
Outcome mean above GPA renewal cut-off	3.74	3.74	3.74	3.68	3.78	3.78

*** p<0.01 ** p<0.05 * p<0.10

Notes: Robust standard errors, clustered at the high school level, are shown in brackets. All results are estimates from multiple imputation OLS specifications that include a constant. Columns 3 through 6 also include school fixed effects and the following covariates: race dummy variables (Black, Hispanic, and Other race/ethnicity); female dummy variable; high school senior year GPA (weighted 4.5 scale); SAT math and verbal scores (imputed where missing); whether the student was in a gifted and talented program; parental adjusted gross income; and student age.

Table A3. The Effect of FSAG Eligibility on Cumulative Financial Aid Receipt through 2005-06

	(1)	(2)	(3)	(4)	(5)
	FSAG	Total Grant Aid	Grant Aid minus FSAG	Loan Aid	Total Aid from All Sources
Panel A: College Math Sample					
Eligible for FSAG	785.92***	1,183.83	397.90	-364.47	819.35
	[119.42]	[785.03]	[722.33]	[664.17]	[1,218.98]
EFC (centered at FSAG cut-off)	-306.43**	-2,134.21**	-1,827.78**	-277.92	-2,412.13*
	[124.31]	[904.85]	[851.80]	[851.74]	[1,418.60]
FSAG x EFC	262.91	2,211.48*	1,948.57	524.33	2,735.81
	[206.73]	[1,322.02]	[1,225.31]	[1,086.43]	[2,015.23]
R-squared	0.290	0.397	0.405	0.203	0.341
Outcome mean above FSAG cut-off	815.5	9487	8672	4806	14293
N			2,834		
Panel B: HS Trig+ Sample					
Eligible for FSAG	920.88***	1,457.70	536.82	621.62	2,079.33
	[207.43]	[1,565.69]	[1,456.39]	[1,459.50]	[2,469.09]
EFC (centered at FSAG cut-off)	-178.81	-2,103.23	-1,924.42	157.59	-1,945.63
	[236.47]	[1,830.71]	[1,732.98]	[1,599.47]	[2,715.25]
FSAG x EFC	-96.95	2,418.02	2,514.98	2,273.82	4,691.84
	[385.39]	[2,681.86]	[2,483.57]	[2,212.48]	[4,196.05]
R-squared	0.402	0.442	0.451	0.291	0.384
Outcome mean above FSAG cut-off	957.6	12339	11381	5888	18226
N			1,283		

*** p<0.01 ** p<0.05 * p<0.10

Notes: Robust standard errors, clustered at the high school level, are shown in brackets. All results are from multiple imputation OLS specifications estimated with an EFC window +/- $1,000 around the FSAG cut-off and include the following covariates: race dummy variables (Black, Hispanic, and Other race/ethnicity); female dummy variable; high school senior year GPA (weighted 4.5 scale); SAT math and verbal scores (imputed where missing); whether the student was in a gifted and talented program; parental adjusted gross income; student age, and whether the student was eligible for the Florida Bright Futures Scholarship. All models also include school fixed effects and a constant.

Table A4: The Effect of FSAG Eligibility on Cumulative STEM Credits and BA/BS Degrees Earned in STEM Fields, among Florida High School Graduates Not Academically Prepared for Postsecondary Study in STEM fields (N = 3,769)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Through Year 1		Through Year 3		Through Year 7		
	STEM Credits Attempted	STEM Credits Completed	STEM Credits Attempted	STEM Credits Completed	STEM Credits Attempted	STEM Credits Completed	BA/BS Degree in STEM
Eligible for FSAG	0.377*	0.318*	0.93	0.684	1.01	0.558	-0.001
	[0.221]	[0.184]	[0.645]	[0.501]	[1.095]	[0.814]	[0.004]
EFC (centered at FSAG cut-off)	-0.063	0.13	-0.047	0.155	0.379	0.472	0.004
	[0.268]	[0.222]	[0.844]	[0.648]	[1.393]	[1.011]	[0.005]
FSAG x EFC	0.867**	0.394	1.471	1.015	0.471	0.208	-0.01
	[0.342]	[0.289]	[1.092]	[0.874]	[1.737]	[1.315]	[0.007]
R-squared	0.181	0.183	0.158	0.164	0.138	0.147	0.151
Outcome mean above FSAG cut-off	1.47	0.95	5.41	3.64	8.85	6.05	0.003

Notes: Robust standard errors, clustered at the high school level, are shown in brackets. All results are from OLS/LPM specifications estimated with an EFC window +/- $1,000 around the FSAG cut-off and include the following covariates: race dummy variables (Black, Hispanic, and Other race/ethnicity); female dummy variable; high school senior year GPA (weighted 4.5 scale); whether the student was in a gifted and talented program; parental adjusted gross income; student age, and whether the student was eligible for the Florida Bright Futures Scholarship. All models also include high school fixed effects and a constant.

Table A5: The Effect of FSAG Eligibility on Cumulative STEM Credits and BA/BS Degrees Earned in STEM Fields, excluding student-level academic and demographic covariates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Through Year 1		Through Year 3		Through Year 7		
	STEM Credits Attempted	STEM Credits Completed	STEM Credits Attempted	STEM Credits Completed	STEM Credits Attempted	STEM Credits Completed	BA/BS Degree in STEM
Panel A: College Math Sample (N = 2,834)							
Eligible for FSAG	0.633	0.756**	2.300*	2.653***	3.142	3.982**	0.027*
	[0.429]	[0.384]	[1.200]	[1.025]	[1.936]	[1.663]	[0.014]
EFC (centered at FSAG cut-off)	0.528	0.371	1.616	1.336	0.954	1.04	0.019
	[0.510]	[0.450]	[1.430]	[1.200]	[2.279]	[1.883]	[0.018]
FSAG x EFC	-0.169	0.251	-0.342	0.838	1.947	3.356	0.013
	[0.633]	[0.600]	[1.806]	[1.644]	[2.994]	[2.588]	[0.024]
R-squared	0.001	0.002	0.001	0.002	0.001	0.003	0.002
Outcome mean above FSAG cut-off	5.63	4.31	15.99	12.41	23.55	18.27	0.043
Panel B: HS Trig+ Sample (N =1,283)							
Eligible for FSAG	1.649**	1.856***	4.542**	5.388***	7.250**	8.853***	0.047*
	[0.715]	[0.638]	[2.006]	[1.749]	[3.166]	[2.748]	[0.025]
EFC (centered at FSAG cut-off)	1.665*	1.614**	5.281**	5.520***	5.711	6.609**	0.070**
	[0.869]	[0.763]	[2.405]	[2.119]	[3.652]	[3.195]	[0.033]
FSAG x EFC	-0.185	0.136	-2.522	-1.912	0.601	0.928	-0.059
	[1.096]	[1.035]	[3.118]	[2.876]	[5.071]	[4.414]	[0.042]
R-squared	0.006	0.008	0.005	0.008	0.004	0.008	0.004
Outcome mean above FSAG cut-off	6.51	5.28	18.06	14.44	26.47	20.98	0.059

Notes: Robust standard errors, clustered at the high school level, are shown in brackets. All results are estimates from OLS specifications that include a constant.

Table A6: The Effect of FSAG Eligibility on non-STEM College Outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Through Year 1		Through Year 3		Through Year 7		
	Non-STEM Credits Attempted	Non-STEM Credits Completed	Non-STEM Credits Attempted	Non-STEM Credits Completed	Non-STEM Credits Attempted	Non-STEM Credits Completed	BA/BS Degree in Non-STEM Field
Panel A: College Math Sample (N = 2,834)							
Eligible for FSAG	0.216	0.445	0.295	0.692	-2.021	-0.602	0.051
	[0.796]	[0.764]	[2.333]	[2.299]	[3.885]	[3.656]	[0.042]
EFC (centered at FSAG cut-off)	0.472	0.354	-1.271	-1.749	-5.038	-4.075	0.02
	[0.976]	[0.895]	[2.801]	[2.747]	[4.683]	[4.418]	[0.051]
FSAG x EFC	0.419	0.802	3.45	4.11	7.421	7.133	0.033
	[1.288]	[1.171]	[3.789]	[3.640]	[6.109]	[5.810]	[0.066]
R-squared	0.169	0.207	0.182	0.213	0.176	0.206	0.214
Outcome mean above FSAG cut-off	13.29	11.19	42.32	36.06	72.09	61.95	0.367
Panel B: HS Trig+ Sample (N =1,283)							
Eligible for FSAG	-0.852	0.088	-1.961	-0.083	-5.988	-2.459	0.007
	[1.188]	[1.186]	[3.972]	[3.659]	[7.077]	[6.178]	[0.068]
EFC (centered at FSAG cut-off)	-0.259	0.492	-0.362	0.829	-5.144	-1.71	0.014
	[1.551]	[1.485]	[4.954]	[4.603]	[8.108]	[7.272]	[0.084]
FSAG x EFC	0.97	0.454	4.673	3.607	12.177	9.392	0.032
	[2.180]	[2.026]	[7.214]	[6.720]	[11.977]	[11.131]	[0.121]
R-squared	0.290	0.290	0.305	0.318	0.296	0.307	0.278
Outcome mean above FSAG cut-off	12.95	11.22	43.24	37.64	74.57	65.05	0.433

Notes: Robust standard errors, clustered at the high school level, are shown in brackets. All results are from multiple imputation OLS/LPM specifications estimated with an EFC window +/- $1,000 around the FSAG cut-off and include the following covariates: race dummy variables (Black, Hispanic, and Other race/ethnicity); female dummy variable; high school senior year GPA (weighted 4.5 scale); SAT math and verbal scores (imputed where missing); whether the student was in a gifted and talented program; parental adjusted gross income; student age, and whether the student was eligible for the Florida Bright Futures Scholarship. All models also include high school fixed effects and a constant.