ProPelled: The Effects of Grants on Graduation, Earnings, and Welfare[*]

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Abstract

We estimate the effect of grant aid on poor college students' attainment and earnings using student-level administrative data from four-year public colleges in Texas. To identify these effects, we exploit a discontinuity in grant generosity as a function of family income. Eligibility for the maximum Pell Grant significantly increases degree receipt and earnings beginning four years after entry. Within ten years, imputed taxes on eligible students' earnings gains fully recoup total government expenditures generated by initial eligibility. To clarify how these estimates relate to social welfare, we develop a general theoretical model and derive sufficient statistics for the welfare implications of changes in the price of college. Whether additional grant aid increases welfare depends on (1) net externalities from recipients' behavioral responses and (2) a direct effect of mitigating credit constraints or other frictions that inflate students' in-school marginal utility. Calibrating our model using nationally representative consumption data suggests that increasing grant aid for the average college student by \$1 could generate negative externalities as high as \$0.50 and still improve welfare. Applying our welfare formula and estimated direct effects to our setting and others suggests considerable welfare gains from grants that target low-income students. *JEL codes: H21, H52, I22, D14, D15, D61.*

1 Introduction

Federal and state governments provide substantial funds to support college students in the United States. During the 2015-16 academic year alone, low- and middle-income college students received $28 billion in federal Pell Grants, while state governments spent $10.5 billion on student grant aid (Baum et al. 2016). Numerous studies have examined the effect of grant aid on student outcomes, but less is known about the social return to these expenditures. Many, but not all, grant programs have been shown to increase college enrollment and degree receipt, outcomes that are important but not sufficient for determining whether increasing grant generosity also raises social welfare.

Using a regression discontinuity design, we provide evidence that grant aid targeting disadvantaged college students generates significant attainment and earnings gains. Among low-income bachelor's degree-seeking students in Texas, qualifying for the maximum Pell Grant at college entry has small and statistically insignificant effects on enrollment and initial attainment. However, in later years, we find significant increases in credits attempted, graduation, and earnings. Attaining eligibility for the maximum Pell Grant at entry also increases the amount of grant aid received in later years, an added cost driven by behavioral responses. Nonetheless, effects on tax receipts are sufficiently large that the government should fully recover its financial investment within ten years.

To evaluate the welfare implications of changes in grant aid, we develop a theoretical model that allows for a general set of choice variables and potential constraints, including credit constraints. The model generates sufficient statistics for the welfare effect of changes in grant generosity, and more generally, changes in the cost of attending some set of colleges. Welfare effects depend on net externalities generated by behavioral responses to grant aid and direct effects on welfare when grants reduce consumption smoothing frictions. Estimated fiscal externalities, in the form of increased tax revenue, provide a lower bound for net externalities under the assumption that non-fiscal externalities are positive on net.[1] A simple ratio of marginal utilities fully captures direct welfare effects, regardless of the source of consumption-smoothing frictions. Using consumption data to estimate this ratio suggests that for common choices of utility parameters, a $1 transfer from unconstrained post-college years to college years would generate positive welfare gains of over $0.50 for the average college student. Direct benefits for low-income students are at least 30 percent larger.

Our empirical strategy exploits a fuzzy discontinuity in the Pell Grant formula. Pell Grant aid is a non-increasing function of the student's expected family contribution (EFC), and students with a $0 EFC qualify for the maximum Pell Grant. Students whose family income falls below a year-specific income threshold -

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[1]Lochner (2011) provides a review of research on the social returns to higher education, which suggest that increases in education levels generate net positive spillovers.

ranging from $15,000 to $32,000 in adjusted gross income (AGI) - meet one of the main criteria for receipt of an "automatic zero EFC." In our setting, students from families with AGIs below this threshold are 52 percentage points more likely to qualify for the maximum Pell Grant and receive an additional $711 in total grant aid (including federal and state) in their first year of college. Students learn the amount of their grant after acceptance to college. Consistent with past research on the Pell Grant, we find no significant effects on enrollment.[2]

We estimate the effect of automatic zero EFC eligibility on attainment over the short- and medium-run. We find no evidence of changes in first-year grade point average (GPA), credits attempted, or reenrollment; point estimates are small, positive, and statistically insignificant. In contrast, eligibility generates larger gains in later years. Eligible students attempt significantly more credits in each of the following two years and are 2 percentage points (13 percent) more likely to graduate within four years of entry. Estimated impacts on graduation up to seven years after college entry suggest permanent increases in degree receipt. Percentage increases are largest for science, technology, engineering, and math (STEM) majors.

Automatic zero eligibility also has significant effects on annual earnings starting four years after college entry, generating a five- to eight-percent increase. Earnings gains are comparable to estimated effects of increased grant aid and/or degree receipt found in other settings (e.g., Zimmerman 2014; Bettinger et al. 2016).[3] We find significant increases in estimated federal income and payroll tax liabilities.[4] We provide evidence that our reduced form effects of grant aid eligibility on attainment, earnings, and tax liabilities are not driven by potential confounds (such as selection into enrollment, the characteristics of enrollees, or the likelihood of moving out of state) and are robust to a variety of specifications and sample selection criteria.

Our theoretical model offers a general framework for assessing the welfare implications of changes in higher education prices. We follow the "sufficient statistics" approach described by Chetty (2009), focusing on a small change in grant aid in order to derive welfare implications under relatively weak assumptions. Potential students make discrete choices over whether to enroll, in which college, and at what intensity (e.g., part-time or full-time), and these choices may vary in both their current levels of subsidy and the extent to which they are affected by the reform under scrutiny. Thus, the model allows for grants to affect a variety of intermediate outcomes, e.g. reducing borrowing (Goldrick-Rab et al. 2016; Marx and Turner forthcoming) and in-school labor supply (DesJardins et al. 2010; Denning 2017), crowding out other sources of grant

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[2]Traditional-aged college students' enrollment decisions are not significantly affected by Pell Grant eligibility or generosity (Kane 1995; Rubin 2011; Turner 2014; Carruthers and Welch 2015; Marx and Turner forthcoming), while Seftor and Turner (2002) provide evidence of increases for older, nontraditional students. There is only limited evidence that Pell Grant aid causes attainment gains for enrolled students (Bettinger 2004; Marx and Turner forthcoming).

[3]Bettinger et al. (2016) study the effect of eligibility for a grant that is roughly three times larger than the change in grant aid in our setting and find statistically significant increases in earnings that are roughly twice as large. Zimmerman (2014) studies an admissions threshold for a four-year institution and finds receipt of a bachelor's degree is associated with an annual earnings increase of about $30,000 (in 2005 dollars). The corresponding association in our setting is about $32,000 (in 2013 dollars).

[4]Estimates are generated via NBER's TAXSIM.

aid (Turner 2014; Bettinger and Williams 2015), and inducing changes in choice of institution (Cohodes and Goodman 2014). Such effects have first-order welfare implications if they alter the amount of taxes students pay or educational subsidies they receive.

In our model, constraints are of a general form that would allow for lack of information, market-imposed credit limits related to creditworthiness, or self-imposed constraints. This generality is particularly useful when studying higher education, as past empirical research on traditional credit constraints is mixed (e.g., Lochner and Monge-Naranjo 2011 and Lochner and Monge-Naranjo 2012), and recent research provides evidence of less-commonly-modeled barriers, such as transaction costs and debt aversion (Calonico et al. 2014; Evans et al. 2016; Boatman et al. 2017; Marx and Turner 2017; Marx and Turner forthcoming). Thus, it is not necessary to know the underlying cause of any failures to smooth consumption because the ratio of marginal utilities within and after college is a sufficient statistic for the direct welfare effects of grant aid. We use the Consumer Expenditure Survey to estimate the relevant ratio of marginal utilities for several values of the real discount rate and the degree of relative risk aversion. On average, recent college attendees consume more than college students, implying that direct welfare gains should be considered in settings where grants generate smaller (or negative) net externalities. We present estimated upper and lower bounds of direct welfare effects for high-, average-, and low-income populations to facilitate application to other settings. As an illustration, we apply these direct effects and our welfare formula to effects of federal and state grant aid estimated by Marx and Turner (forthcoming) and Bettinger et al. (2016); welfare gains are largest when increased grant aid targets low-income students.

Our empirical findings contribute to a broad literature examining how college costs and financial assistance affect student outcomes. Prospective students' college enrollment decisions generally respond to changes in prices driven by variation in tuition and grant aid provided by simple, easily accessed programs (Deming and Dynarski 2010). A handful of studies find evidence that eligibility for state grant aid shifts students into college, across different types of institutions, and into degree receipt (e.g. Scott-Clayton 2011; Castleman and Long 2016; Bettinger et al. 2016; Scott-Clayton and Zafar 2016). As our model highlights, a policy that causes students to shift across sectors may have very different welfare implications than a policy that increases degree receipt.

Numerous papers that examine the effect of higher education subsidies on students also consider costs and benefits from the government's perspective.[5] We build upon this literature by considering effects on social welfare. Two recent papers examine the related issues of measuring productivity and optimal subsidies for higher education. Hoxby (forthcoming) quantifies the relative average productivity of institutions

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[5]As examples, Dynarski et al. (2013) discuss the cost-effectiveness of initiatives intended to increase college graduation while Hoxby and Turner (2013) compare cost-benefit ratios across interventions that aim to increase college-going and/or the quality of college attended.

across the distribution of selectivity, where productivity is measured by the average private (earnings) and social gains (public service and innovation) per dollar of social expenditures. Stantcheva (forthcoming) determines the full set of optimal taxes on income and human capital investment in a lifecycle model with asymmetric information. Our approach shows how a small number of statistics can be used to infer the welfare effect of a policy change in an area of major government expenditure, similar to applications in health insurance markets (Einav et al. 2010) and place-based subsidies (Busso et al. 2013).

The remainder of this paper proceeds as follows. In Sections 2 and 3 we describe the setting and data, respectively. We outline our empirical strategy in Section 4 and present the main results from this design in Section 5. Section 6 provides theoretical explanations for these results and derives sufficient conditions to infer welfare gains. In Section 7, we evaluate the welfare implications of increases in grant aid in our setting and others. Section 8 concludes.

2 Setting

We focus on students enrolled in Texas four-year public institutions. In Fall 2015, over 600,000 undergraduate students enrolled in one of 39 such institutions. Texas four-year public schools are largely representative of the average public four-year institution nationwide. For instance, in 2014-15, average annual in-state tuition and fees within Texas public four-year institutions was $7870 while the national average among four-year public institutions was $8543.[6] The six-year graduation rate among four-year public school students in Texas was 53 percent, while the national average was 60 percent (Texas Higher Education Coordinating Board 2016). Public four-year institutions in Texas range from selective, research universities (e.g., University of Texas at Austin and Texas A&M) to less selective, regional institutions.[7]

2.1 Federal student aid

In our setting, the major source of identifying variation comes from changes in federal need calculation that determines Pell Grant aid. A given student's Pell Grant depends on (1) the annual maximum and (2) the student's expected family contribution (EFC), which represents the federal government's estimate of the ability of the student and her family to pay for college. All students must complete a free application for federal student aid (FAFSA) to qualify for Pell Grant aid. FAFSA inputs determine EFC through a

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[6]Amounts in nominal terms; see National Center for Education Statistics (2016), Table 330.20.

[7]Texas also has a large community college sector with 80 public two-year institutions that enrolled over 700,000 students in Fall 2015 and 166 private institutions with Fall 2015 enrollment of 191,000 students. Data on students attending private institutions in Texas are not available for research. We exclude students entering community colleges from our analyses due to a lack of a significant effect of eligibility on grant aid (although we observe transfers between four-year public institutions and community colleges). As we discuss in Section 4.1, we can rule out all but very small changes in the probability of enrollment within the public four-year sector at the automatic zero EFC eligibility threshold, alleviating concerns over sorting responses to additional grant aid.

complicated nonlinear formula that takes into account family income, assets, family size, siblings in college, and a host of other factors.[8] A full-time, full-year student's Pell Grant is determined by the following formula:

$$Pell_{it} = \max\left\{\overline{Pell_t} - EFC_{it}, 0\right\} \tag{1}$$

Where $\overline{Pell_t}$ is the maximum Pell Grant in year t and EFC_{it} is student i's expected family contribution.[9] Only students who receive an EFC of zero qualify for the maximum Pell Grant.

Students whose families' adjusted gross income (AGI) falls below a year-specific threshold meet one of the requirements to qualify for an "automatic zero EFC." Only students who receive a zero EFC qualify for the maximum Pell Grant. Many state and institutional grant programs award grants based on EFC, and as a result, a zero EFC may also increase aid from other need-based grant programs. We exploit this threshold for identification using a regression discontinuity design.[10]

The automatic zero eligibility threshold has been shifted from year to year. Prior to the 2006-07 academic year (hereafter 2007), this threshold was $15,000. The cut-off increased to $20,000 in 2007 and remained at this level for the following two academic years. In 2010 and 2011, the cut-off was increased to $30,000 and again to $31,000 in 2012, before falling to $23,000 in 2013. Between 2014 and 2016, the threshold remained at $24,000 and increased to $25,000 in 2017. Figure 1 displays the annual automatic zero EFC threshold as well as the maximum Pell Grant award over this period, which ranged from approximately $4000 to approximately $6000 (all in nominal terms). The shaded region represents the period over which we observe students in our analysis sample entering college.

Students who complete a FAFSA are also eligible for federal loans. Loans provided by the federal government make up the bulk of undergraduate student loan aid, representing approximately 90 percent of disbursements in recent years (Baum et al. 2016). Federal subsidized loans, which do not accrue interest while a student is enrolled in at least 6 credits per semester, are available to students who have unmet need. Students may borrow subsidized loans up to the lesser of the subsidized loan maximum (e.g., $3500 for first year, dependent students) and unmet need.[11] Unsubsidized loans are available to all students regardless

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[8]The Department of Education's 2016-17 EFC guide is 36 pages and includes 6 worksheets and 17 corresponding calculation tables (https://studentaid.ed.gov/sa/sites/default/files/2016-17-efc-formula.pdf).

[9]Part-year students receive a prorated Pell Grant. Students with less than full-time enrollment are eligible for a lower maximum Pell with a flatter phase-out (e.g., $Pell_{it}|part-time = \max\left\{0.5\overline{Pell_t} - 0.5EFC_{it}, 0\right\}$). Awards are rounded to nearest $100. Full-time, full-year students with EFCs at the Pell Grant eligibility threshold receive a minimum Pell Grant that ranged from $500 to $1176 in recent years. In a small number of cases when students face a sufficiently low cost of attendance (which includes tuition, fees, room and board, and other expenses), Pell Grants may be reduced in size so as not to exceed total unmet need. See https://ifap.ed.gov/dpcletters/attachments/GEN1601Attach.pdf for the 2016-17 Pell Grant payment schedule.

[10]In addition to meeting the AGI requirement, a student's parents or legal guardian must also be eligible to file 1040A or 1040EZ tax return, which generally excludes high asset families. Students from families that received means-tested benefits in the prior year also qualify, regardless of family AGI. Only dependent students and independent students with dependents are eligible for an automatic zero EFC. All students under the age of 24 who are unmarried and have no dependents are classified as dependent students.

[11]Unmet need is equal to the student's total cost of attendance less their EFC and grant aid from all sources.

of financial need, have weakly-higher interest rates over the time period we examine and accrue interest beginning at loan disbursement.[12] Federal loans have yearly and lifetime borrowing limits. Private student loans may be available to students who have exhausted their federal loan eligibility. However, private loans entail a credit-worthiness requirement and/or require a cosigner and generally carry higher interest rates than federal loans. Nationwide, only 6 percent of undergraduate students with family AGIs near the automatic zero EFC eligibility threshold received private loans, while 28 percent stated that they would have borrowed more if funds were available, suggesting few undergraduates can access loans that are not publicly provided.[13]

2.2 Texas financial aid programs

Texas' largest financial aid program is the TEXAS (Towards EXcellence, Access and Success) Grant, which provided $200 million in disbursements in the 2008 school year. The maximum TEXAS Grant award available to bachelor's degree seeking students attending public institutions equals the statewide average of tuition and required fees within the four-year public sector. Initial eligibility for a TEXAS Grant depends on need and academic performance.[14] The program is oversubscribed, and only 50 percent of students who met the eligibility criteria received a TEXAS Grant in recent years (Cohen et al. 2010). Schools have some discretion over which students receive a TEXAS Grant and must use their own funds to cover any tuition and fees that remain after federal and TEXAS Grant aid is taken into account, which may provide an incentive for institutions to give TEXAS Grants to students who receive large amounts of other grant aid. Texas has several smaller grant and loan programs that make funds available to some students attending four-year public institutions. These programs are described in further detail in Online Appendix A.

3 Data and Sample

Our data primarily come from the Texas Higher Education Coordinating Board (THECB) and Texas Workforce Commission (TWC). The THECB collects administrative data on all public universities and colleges in Texas. The data include information on enrollment, graduation, college major, grade point average, credits attempted, and financial aid disbursed by the school. The TWC data contain quarterly earnings

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[12]Two smaller categories of federal loans may be available to undergraduate students. Perkins loans are campus-based loans that schools can provide to students with exceptional financial need, but not all students with unmet need receive loan offers. PLUS loans are available to credit-worthy parents of students. If a parent is denied PLUS loans due to "an adverse credit history," dependent students are eligible for additional unsubsidized loans. Online Appendix A provides additional information on federal loan options.

[13]Authors' calculations using the 2012 National Postsecondary Student Aid Study via PowerStats.

[14]To qualify, students must have financial need (e.g., a cost of attendance exceeding the sum of EFC and federal grants), an EFC less than $4000, graduate from a Recommended High School Program (RHSP) or higher, and enter public higher education within 16 months of high school graduation. To maintain eligibility after their first year, TEXAS Grant recipients must earn at least a 2.5 GPA, complete at least 24 credit hours in an academic year, and not receive grants that exceed their cost of attendance.

records for all persons employed in industries covered by unemployment insurance in Texas.[15] We base our measure of annual earnings on the academic year (AY) rather than calendar year. As an example, AY 2007-08 (hereafter, AY 2008) earnings equal the sum of quarterly earnings from 2007-Q4 through 2008-Q3. We impute federal tax liabilities for each student in each calendar year using NBER's TAXSIM, assuming that the sample member is single with no dependents, no deductions, and no income outside of earnings in covered sectors.[16] Texas does not have a state income tax. As we only observe two of the four quarters of the most recent tax year we impute tax liabilities for this year by doubling the earnings observed in the first two quarters. All earnings, taxes, and financial aid awards are adjusted for inflation using the CPI-U to represent constant 2013 dollars.

Information on parent AGI is available from the THECB beginning in AY 2008. Our analysis sample includes students who first enrolled at public universities in Texas in the 2008 through 2011 school years, which allows us to track all students up to four years after college entry. We observe academic outcomes through the 2016 academic year and, as a result, our measures of student attainment for five, six, and seven years after enrollment will exclude students who entered college in later cohorts.

We focus on first-time college entrants whose family AGI falls within $12,000 of the income eligibility threshold for an automatic zero EFC.[17] We limit our sample to four-year college entrants. This is because the "first stage" change in grant aid at the AGI threshold for an automatic zero EFC is substantially smaller for two year college students, limiting our ability to draw conclusions around the effects of additional grant aid for community college students. We further limit our sample to students classified as dependent because most students classified as independent are ineligible for an automatic zero EFC, irrespective of AGI.[18] Further, as we only observe AGI for FAFSA filers, non-filers are excluded from the analysis sample.[19] The remaining sample includes 36,697 first-time entrants (or approximately 9175 students per cohort).

Table 1 provides information on the characteristics of students in the sample (overall and by income eligibility for an automatic zero EFC).[20] On average, students are 19 years old at college entry and 97

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[15]The unemployment insurance records include employers who pay at least $1500 in gross wages to employees or have at least one employee during twenty different weeks in a calendar year regardless of the wages paid. Students employed by their college or university are not included in reporting for the Unemployment Insurance system.

[16]Unfortunately, we do not observe family structure, potential deductions, and non-UI earnings. Earnings are rounded to the nearest $1000 for the purpose of calculating tax liabilities because TWC earnings data cannot leave a dedicated, non-networked machine. See Feenberg and Coutts (1993) and http://users.nber.org/~taxsim/taxsim-calc9/index.html for additional information on TAXSIM.

[17]We examine effects of eligibility for additional grant aid on returning college students in a set of supplementary analysis; details and results are provided in Online Appendix B.

[18]Only independent students with dependents are eligible for an automatic zero EFC. These students' eligibility is based on their own AGI. Other independent students (those who are 24 or older and those who are married) do not qualify. Nationwide, only 3.6 percent of first-time undergraduates entering public four-year institutions had dependents. Authors' calculations using the 2012/14 Beginning Postsecondary Students (BPS) study via PowerStats.

[19]Nationwide, 89 percent of 2012 first-time dependent students entering public four-year institutions with AGIs within $12,000 of the automatic zero EFC cut-off filed a FAFSA. (Authors' calculations using the 2012/14 Beginning Postsecondary Students (BPS) study via PowerStats.)

[20]Sample characteristics are largely similar to those of dependent, first-time, bachelor's degree seeking public college entrants nationwide in 2008 (Online Appendix Table C.1).

percent are Texas residents. Racial/ethnic minorities comprise a substantial fraction of the sample with 46 percent identifying as Black or Hispanic and 46 percent identifying as White. Most students do not have parents who attended college: just 23 percent report having a father with a college degree and 29 percent report having a college-educated mother. Students in the analysis sample receive a substantial amount of grant aid in their first year of enrollment – approximately $9700 – with the largest source being the Pell Grant ($4053) and the second largest the TEXAS Grant ($3365). On average, students borrow $2740 through federal and state loan programs and earn $3844 in their first year of college. Students in the analysis sample come from relatively low-income families, especially compared to students near the eligibility threshold for grant aid programs that are commonly studied.[21]

Students with AGIs below the automatic zero EFC threshold receive more grant aid, take on less student loan debt, and earn less compared to students above the threshold. Summing across grants, loans, work-study income, and earnings from employment, sample members who were income-eligible for an automatic zero EFC had approximately $800 more in total observed first-year resources than ineligible students.

4   Identification Strategy

We identify Pell Grant effects by exploiting the nonlinear relationship between family AGI and qualification for the automatic zero EFC, which results in a discontinuity in grant aid. Let agi_t^0 represent the value of the automatic zero EFC cutoff in year t. For student i entering college in year t, $\widetilde{AGI}_{it} = AGI_{it} - agi_t^0$ represents the distance her family's income falls from the year-specific threshold. In general, a student's EFC is a complicated nonlinear function of family income, assets, and many other characteristics that are both observable ($\mathbf{X_i}$) and unobservable (U_{it}) to the econometrician: $EFC_{it} = \mathbf{1}\left[\widetilde{AGI}_{it} > 0\right] \times f\left(AGI_{it}, \mathbf{X_i}, U_{it}\right)$. The automatic zero income threshold generates a discontinuous relationship between EFC and AGI for a subset of students, resulting in a discrete increase in the probability of receiving a zero EFC when income falls below the year-specific AGI threshold.

Figure 2 displays this relationship for dependent students entering a Texas public four-year institution in the 2008 through 2011 academic years. We use a larger window of $20,000 around the automatic zero EFC threshold for descriptive purposes. As discussed in Section 2.1, some students who are income-eligible (hereafter, "eligible") for an automatic zero are disqualified based on other requirements (in most cases, related to family assets and non-earned income). Likewise, students who are ineligible for an automatic zero

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[21]Carruthers and Welch (2015) and Marx and Turner (forthcoming) examine the cutoff for the minimum Pell Grant (roughly $40,000-$60,0000 in family AGI). Castleman and Long (2016) examine a change in Florida state grant aid for students with an EFC of $1590 corresponding to an income of $40,000 (in 2011 dollars). Eligibility for the Cal Grant studied by Bettinger et al. (2016) involves both income and high school GPA thresholds, with the former corresponding to approximately $60,000 in family income.

EFC based on AGI may still qualify based on other FAFSA inputs. Thus, income eligibility (hereafter, "eligibility") imperfectly predicts whether a given student has a zero EFC. Students with AGIs falling below the eligibility threshold are 51 percentage points more likely to receive a zero EFC. Given that only 33 percent of ineligible students receive a zero EFC, this change represents a 155 percent increase in the likelihood of qualifying for the maximum Pell Grant.

A student's EFC directly determines much of her financial aid package. Most importantly, students with a zero EFC are eligible for the maximum Pell Grant. No other federal grants are explicitly linked to a zero EFC, but many federal and state programs target students with high levels of unmet need (see Online Appendix A for additional details).

Panel A of Figure 3 displays the discontinuous relationship between total grant aid and the distance to the automatic zero threshold. Eligibility results in an approximately $700 increase in grant aid. Panels B through D replicate this exercise for Pell Grant aid, TEXAS Grant aid, and other grant aid, respectively. Most of the increase in grants received by eligible students comes from increases in Pell Grant aid (approximately $500, relative to ineligible students), but eligible students also experience a discontinuous increase in TEXAS Grant aid (approximately $125). There is no evidence that other sources of grant aid change at the eligibility threshold. While the relationship between eligibility and Pell Grant aid (Panel B) is mechanical, the relationship in Panels C and D represent any mechanical effects due to state policies and the endogenous response of institutions to changes in a given student's EFC and financial aid package.

To quantify the effect of eligibility for an automatic zero EFC, we estimate ordinary least squares (OLS) regressions of the form:

$$Y_{it} = \beta \mathbf{1} \left[\widetilde{AGI}_{it} > 0 \right] + f \left(\widetilde{AGI}_{it} \right) + \mathbf{X_i} \gamma + \delta_t + \epsilon_{it} \tag{2}$$

Where Y_{it} represents the outcome of student i belonging to entry cohort t, $\mathbf{1} \left[\widetilde{AGI}_{it} > 0 \right]$ indicates automatic zero EFC eligibility, $f \left(\widetilde{AGI}_{it} \right)$ is a function of normalized AGI (allowed to vary on either side of the eligibility threshold), $\mathbf{X_i}$ is a vector of observable student characteristics, and δ_t is a set of entry-cohort fixed effects. Under the identifying assumption that, in the neighborhood of the eligibility threshold, all unobservable factors that are correlated with both Y and receipt of a zero EFC vary continuously through the threshold, estimates of β will represent the causal effect of automatic zero eligibility on student outcomes (Hahn et al. 2001). This assumption is fundamentally untestable, but generates testable predictions relating to continuity of the density and predetermined observable characteristics through the threshold (Lee and Lemieux 2010). Section 4.1 provides evidence that in our setting, these conditions are satisfied.

In practice, we estimate local linear regression models with a uniform kernel, bandwidth of $12,000, and control for parent education categories, race categories, age, gender, and Texas residency. The $12,000

bandwidth is approximately the midpoint of the optimal bandwidths chosen across outcomes by the Imbens and Kalyanaraman (2012) procedure. However, we show that our estimates are robust to larger and smaller bandwidths and higher order polynomials in $\widetilde{AGI}$. Standard errors are clustered at the entry cohort by institution level to account for correlated outcomes within cohort-institution groups.

Under the assumption that eligibility for a zero EFC only directly affects student outcomes by increasing grant aid, we can also estimate instrumental variables (IV) regressions of the effect of grant aid on attainment. In this case, $\mathbf{1}\left[\widetilde{AGI}_{it} > 0\right]$ serves as the excluded instrument for grants received by student i in her first year. Given monotonic responses of grant aid to eligibility for a zero EFC (e.g., eligibility weakly increases grant aid for all students), IV estimates represent the local average treatment effect (LATE) of a marginal increase in grants on student outcomes for the set of students induced to receive a zero EFC due to meeting the AGI eligibility requirement (Imbens and Angrist 1994).

4.1 Evaluating the RDD identifying assumptions

To test for discontinuities in the density of recentered AGI, we examine the number of students in $100 AGI bins on either side of the eligibility threshold (Figure 4). Panel A excludes students who report an AGI that is a multiple of $1000, while Panel B includes all students. In both cases, there is no observable change in density below the automatic zero EFC eligibility threshold. Our preferred specification excludes students who report EFCs at multiples of $1000 for two reasons. First, Barreca et al. (2016) demonstrate that with non-random heaping at set values of the running variable, regression discontinuity estimates may be biased. Second, the cutoff for the automatic zero EFC occurs at a multiple of $1000 in all years. If parents precisely manipulate or misreport AGI to gain access to the automatic zero threshold, the assumptions necessary for identification using the regression discontinuity design would be violated. This does not appear to be the case in Panel B of Figure 4; there is heaping at all multiples of $1000 and the number of students at the threshold is not substantially larger than heaping at other values.[22]

Other potential concerns for our identification strategy include behavioral responses that exploit the income eligibility rule (e.g., misreporting of income) and enrollment responses. Though income may be under-reported generally, in recent years, over half of all Pell Grant eligible students have been selected for FAFSA verification, and income is one of the main FASFA components that is audited during this process. Furthermore, general under-reporting will not threaten identification unless students and their families are

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[22]One explanation for the heaping at $1000 intervals is that students are allowed to submit their FAFSA before their parents have filed their taxes and report an estimated AGI (that will later be updated with a revised FAFSA submission). Our data only contain information from a single submitted FAFSA (not necessarily the final FAFSA). As shown in Online Appendix Table C.2, which compares the characteristics of heapers and nonheapers within an $18,000 window around the automatic zero eligibility threshold, these two groups have similar characteristics, but heapers are less likely to be Texas residents, less likely to be white, and more likely to have college educated parents. In Section 5.3, we show that the inclusion of students with parent AGIs at multiples of $1000 does not substantively alter estimated effects.

more likely to under-report when they income falls just above the threshold which is unlikely, given that the existence of this cutoff is not well known or publicized. To formally test for additional density we use the McCrary (2008) test, which yields a point estimate of 0.032, with standard error of 0.029, and fails to reject the hypothesis of no change in density. Thus, we find no evidence of behavioral responses to exploit the income eligibility rule, consistent with other studies that find no enrollment effects arising from Pell Grant eligibility (Kane 1995; Rubin 2011; Turner 2014; Carruthers and Welch 2015).

We next examine the relationship between predetermined characteristics and eligibility for an automatic zero EFC. We test for discontinuities in all available predetermined student characteristics, and point estimates for selected characteristics are presented in Table 2. Results for all other characteristics are available in Online Appendix Table C.3. We first combine all of the covariates into a single composite predicting the probability of graduating within four years of college entry via a logistic regression. While two of the 8 regressions shown in Table 2 yields statistically significant differences in student characteristics across the eligibility threshold, there is no significant change in the predicted probability of four-year graduation, and the 95 percent confidence interval rules out effects larger than a 0.007 percentage point increase. Eligible students are 1.2 percentage points (1 percent) significantly more likely to be Texas residents than ineligible students ($p < 0.05$) and 3.2 percentage points (12 percent) less likely to be Black ($p < 0.1$). When using the Imbens and Kalyanaraman (2012) optimal bandwidth for Texas residency ($6200) and race ($8300), the estimated discontinuities are smaller and statistically insignificant. Given the number of hypotheses tested in Table 2 and Appendix Table C.3 (16) and the lack of significant effects on the composite index of student characteristics, we interpret these estimates as providing evidence in support of continuity in predetermined characteristics through the threshold.

5   Empirical Results

To preview our key findings, we present graphical evidence of the reduced form relationship between standardized AGI and student outcomes. In the year of college entry, income eligibility for an automatic zero EFC appears to have only negligible effects on credit hours attempted, GPA, and the probability of reenrollment in the following year (Figure 5). Figure 6 shows little evidence of changes in annual earnings received in students' year of entry and a significant decrease in the amount borrowed. Income eligibility for an automatic zero EFC leads to an increase in probability of graduation within four years of entry (Figures 7). The increase in graduation rates persists for the duration of our panel, up to 7 years after college entry. We find evidence of increased earnings starting four years after entry and persisting for the remainder of our panel (Figure 8). Summing across all years in which we observe sample members, we calculate

total grants, loans, earnings, and tax liabilities. Figure 9 shows that automatic-zero eligibility is correlated with discrete increases in total grant aid received, total earnings, and total estimated federal income taxes. Despite the reduction in first-year borrowing, eligibility for an automatic zero EFC at college entry does not generate significant changes in cumulative loans by the end of our panel. In the remainder of this section, we quantify these effects by estimating OLS and IV models.

5.1 Short-run effects on finances and academics

We first examine the effect of eligibility for an automatic zero EFC on students' financial resources. Past research suggests that endogenous decisions by students and institutions may diminish changes to cash on hand generated by eligibility for additional grant aid. The $510 increase in Pell Grant aid crowds in grant aid provided through the TEXAS Grant program (Table 3). There are no statistically significant effects on other sources of grant aid. Eligibility also leads to a statistically significant $333 decrease in the amount borrowed and a negative but statistically insignificant reduction in earnings from employment received during eligible students' first year of college.

Effects on first-year academic outcomes are small and insignificant. Automatic zero eligibility has no significant effect on credits attempted, GPA, and reenrollment in the following academic year (Table 4). Estimated 95-percent confidence intervals exclude an increase greater than 0.5 credits attempted (2 percent), a 0.02 percentage point (3 percent) increase in returning the following academic year, and a 0.098 (5 percent) GPA increase. Given the change in grant aid received by eligible students (an approximately 9 percent increase), we cannot rule out modest responses of short-run attainment to additional aid, although the effects are smaller than those generated by increases in borrowing due to loan packaging in Marx and Turner (2017). Modest increases in first-year academic outcomes could lead to larger long-run gains if attainment is characterized by dynamic complementarities. In a randomized controlled trial of privately-funded financial aid on student outcomes, Goldrick-Rab et al. (2016) find similarly small effects on contemporary outcomes accompanied by significant increases in graduation rates.

5.2 Longer-run effects on graduation and earnings

We observe attainment and labor market outcomes for students in our sample up to seven years after college entry and observe all cohorts for at least four years after entry. We first examine effects on academic outcomes including reenrollment, credits attempted, and degree receipt. Figure 10 displays point estimates and corresponding 95 percent confidence intervals from equation (2), which represent the reduced-form

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effects of automatic zero EFC eligibility.[23] We find no evidence of effects on enrollment in Texas public four-year institutions that are significant at the 5 percent level at any point after college entry (Panel A), though point estimates are positive through the first four years.[24] Panel B shows that eligibility generates significant increases in credits attempted two and three years after entry of 0.6 and 0.8 additional credits attempted, respectively.

Panel C of Figure 10 shows that eligibility significantly increases the probability of graduation within four, five, and six years of college entry. Eligible students are approximately 2 percentage-points more likely to receive a bachelor's degree within four years (a 13 percent increase relative to the mean completion rate for students with income just above the AGI threshold) and a 3.6 and 3.4 percentage-points more likely to graduate within five and six years of entry, respectively (representing 12 and 9 percent increases relative to ineligible students' graduation rates). The change in the probability of graduation within seven years of entry is similar in magnitude to estimated effects on the five- and six-year graduation rates and larger in magnitude than the increase in the probability of graduating within four years, but the estimate is imprecise because we only observe two entry cohorts for this length of time.

It is unclear whether, in the longer-run, increases in graduation rates will persist (as in Bettinger et al. 2016) or fade (as in Scott-Clayton and Zafar 2016). Approximately 7 percent of ineligible students and 8 percent of eligible students are still enrolled 7 years after college entry (Online Appendix Table C.4). To close the gap in the overall graduation rate, the difference in the probability of graduation conditional on being enrolled 7 years after entry between eligible and ineligible students would have to exceed 50 percentage points (e.g., 100 percent of still-enrolled ineligible students and less than 45 percent of still-enrolled eligible students eventually graduate).[25] Thus, while there is scope for the the changes in graduation we identify to represent retiming of degree receipt rather than increases in new graduates, there would need to be large improvements in the outcomes of ineligible students to diminish the gains in degree receipt we observe over the short-run.

We repeat this exercise for labor market outcomes including annual earnings and estimated federal income and payroll taxes; results are shown in Figure 11 and Online Appendix Table C.5. Automatic zero eligibility results in significant earnings gains beginning four years after college entry. Estimated impacts on earnings continue to increase for the remainder of our panel at seven years after entry.[26]

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[23]Corresponding point estimates and standard errors are displayed in Online Appendix Table C.4.

[24]As shown in Online Appendix Table C.4, the estimate effect of eligibility on enrollment two years after entry (a 2 percentage point increase) is significant at the 10 percent level. Online Appendix Figure C.1 displays estimated effects on the probability of transferring to a Texas community college. We find no evidence that transfer rates changed in response to eligibility for an automatic zero EFC.

[25]Among prior cohorts of four-year degree-seeking students in Texas, close to 70 percent of students still enrolled 6 years after entry would go on to graduate within 10 years of entry.

[26]Estimated impacts on earnings are quite similar when we use non-winsorized earnings except at 7 years post-entry when one automatic zero EFC eligible student earned over $1 million (Online Appendix Table C.6).

Under the assumption that income eligibility for an automatic zero EFC at college entry only affects student outcomes by weakly increasing grant aid, we can identify the causal effect of increases in grants on attainment and labor market outcomes. To do so, we estimate instrumental variables (IV) models in which the indicator for income below the eligibility cutoff serves as the excluded instrument. As shown in Panels A and B of Table 5, an additional $1000 in first year grant aid generates significant increases in graduation within four through seven years of entry. These are substantial increases relative to mean completion rates of ineligible students, ranging from a 10 to 16 percent, and are comparable to the estimated effects of Cal Grant eligibility on the long-run probability of earning a bachelor's degree found by Bettinger et al. (2016).[27]

A $1000 increase in grant aid at college entry also generates statistically significant increases in annual earnings beginning four, five, six, and seven years after initial enrollment. Estimated earnings gains grow over this period, from of $978 at four-years post-entry to $3584 seven years after entry. Impacts on imputed federal income taxes are positive and statistically significant starting five years after entry, while positive effects on predicted payroll tax liabilities are statistically significant within four years of entry. These gains could theoretically increase or decrease over time, depending on factors such as the timing of returns to a bachelor's degree and the extent that the control group's rate of degree receipt catches up to the rate of the treatment group. As discussed above, complete convergence in the graduation rates of eligible and ineligible students is unlikely. Furthermore, evidence that estimated returns to education are decreasing in time-to-degree suggests that the earnings gains we find are most likely persistent over the long-run (e.g., Flores-Lagunes and Light 2010; Aina and Casalone 2011).

5.3 Robustness

Interpretation of the effect on earnings is complicated by the fact that we only observe earnings for jobs covered by the Texas UI system. If eligibility for an automatic zero EFC affects the probability that a student remains in state (or in a UI-covered job), the increases in earnings that we find may not represent the causal effect of additional grant aid. To be explicit, if someone does not work, moves out of state to work, or works for a job not covered by Texas unemployment insurance, they will appear to have no earnings.[28]

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[27]Control group mean outcomes at the Cal Grant GPA eligibility threshold in Bettinger et al. (2016) are similar to those in our setting (e.g. 48.5 percent complete a bachelors degree compared to 43 percent within seven years in our setting). The change in total grant aid at the GPA eligibility threshold is about $4000, roughly three times the magnitude of the increase in grant aid at the automatic zero EFC threshold. Estimated effects of initial eligibility on degree receipt are roughly proportional: Bettinger et al. (2016) find increases in bachelor's degree receipt that are roughly twice as large as the effects in our setting, and impacts on log labor income due to Cal Grant eligibility translates to a $1630 increase in annual earnings, about 1.5 larger than the effect on annual earnings from automatic zero EFC eligibility five and six years after entry.

[28]Past research suggests that college educated young adults are more likely to move between states than those with less education (Wozniak 2010; Malamud and Wozniak 2012). However, Texas is very large state with a population of more than 25 million in 2010, and even young college educated adults are relatively unlikely to leave the state. Using the IPUMS-CPS (Flood et al. 2015), we estimate that the baseline annual interstate migration rate for young adults (20-24 years old) with some college in Texas between 2010 and 2016 was 3.2 percent. There is some evidence that *state* grant aid eligibility affects the probability of remaining in state. Fitzpatrick and Jones 2016 examine the effect of eligibility for state merit aid on the probability of remaining in the original state of birth. Effects are

Using Census data, Andrews et al. (2016) rule out systematic differences in earnings for students who leave the state of Texas and those who remain in-state. For our sample, we examine whether automatic-zero eligibility affects the probability of being observed "in state," defined as either have earnings records in the state UI system or records of enrollment in a public universities or community college. We find no significant effect of income eligibility for an automatic zero EFC on the probability of being in state. Point estimates only exceed a 1 percentage-point increase in this probability at the seven-year horizon, when the underlying sample is smallest (Figure 12).[29]

We also estimate bounds on eligible students' earnings gains, following Lee (2009). Specifically, we "trim" the earnings of automatic zero EFC eligible students at the top of the distribution of reported earnings by setting these students' earnings to $0. We use the years-since-entry-specific estimated change in the probability of remaining "in-state" (e.g., Figure 12) to determine the share of eligible students to trim. This exercise will produce bounds under the extreme assumption that the entirety of the (insignificant) difference in the probability of being in-state comes from eligible students with the highest earnings who would have otherwise moved out of Texas (rather than, for instance, an increase in the probability of employment). The estimated lower bounds on earnings gains in years 4 through 7 average to approximately one quarter of the effect size in our main specification. If the lower bound of estimated earnings gains for eligible students seven years after entry ($602) persists over a 35-year career, the lifetime earnings effect would be roughly 30 times the size of the initial grant.

Table 6 show that our main findings are robust to several alternative specifications. Results in Panel A come from models that exclude predetermined student covariates and are quite similar to those produced when these covariates are included. Likewise, including students "heaping" at AGI multiples of $1000 does not alter our findings (Panel B). Our results are not substantially altered when we use a smaller bandwidth of $6000 (Panel C) or a larger bandwidth of $18,000 (Panel D). Finally, Panel E shows that estimates from models that use a bandwidth of $18,000 and a quadratic in $\widetilde{AGI}$ are quite similar to those produced by our preferred specification.

statistically significant but economically negligible in magnitude. Bettinger et al. 2016 estimate that eligibility for need-based state grant aid in California leads to a 3 percentage point (an approximately 4 percent) increase in the probability of remaining in California 10 to 14 years after high school graduation. It is not clear whether these findings can be generalized to the effects of federal grant aid on the probability remaining in state after attending college.

[29] Automatic zero eligible students are significantly more likely to have UI-covered earnings 4 and 7 years after college entry, and point estimates are of a similar magnitude in years 5 and 6 (Online Appendix Table C.6). Combined with the positive effects of automatic zero eligibility on the probability of graduation for the same time period (Figure 7), this result suggests that automatic zero eligibility leads students to both finish school and enter the labor market sooner than they otherwise would have.

5.4 Channels for earnings gains

There are several channels through which eligibility for additional grant aid could increase earnings. First, as shown in the preceding sections, eligibility for an automatic zero EFC increases the probability of degree receipt within four and up to seven years after entry and such gains likely represent permanent increases in graduation rates. There is abundance evidence of substantial earnings returns to college degree receipt (see Barrow and Malamud (2015) for a review). Second, eligible students may accumulate more student loan debt which could, in turn, increase the likelihood that they choose a higher paying job, as in Rothstein and Rouse (2011). We can rule out this channel, as eligibility for an automatic zero EFC has an insignificant effect on cumulative student loan debt (e.g., Panel B of Figure 9). Finally, eligibility for additional grant aid could induce students to upgrade to institutions or majors that generate higher earnings.

To investigate whether eligibility for additional grant aid leads to upgrading within the four-year sector, we estimate effects of automatic-zero eligibility on measures of institutional quality. Institutional quality is correlated with students' attainment and labor market outcomes. Hoekstra (2009) finds that marginal applicants admitted to a flagship public institution received higher earnings, Bound et al. (2012) argue that decreases in public institutions' resources contributed to the increases in time-to-degree, and Cohodes and Goodman (2014) show that when high achieving Massachusetts students were induced to attend schools with lower graduation rates due to receipt of a state scholarship, their own graduation rates suffered. We examine effects on inputs (e.g., characteristics of the student body, selectivity), resources (e.g., costs, expenditures, student-faculty ratios), and outputs (e.g, retention and graduation rates). All measures of institutional quality come from the Integrated Postsecondary Education Data System (IPEDS). To create a summary of the numerous measures of institutional quality and to deal with concerns of spurious significant estimates due to the number of hypotheses being tested, we also examine effects on the first component from a principal component analysis of these quality measures.

As shown in Table 7, we find no statistically significant effects of eligibility on any of the institutional quality measures beyond a 0.9 percentage point (2 percent) increase in the average admissions yield of institutions attended by eligible students ($p < 0.1$).[30] The largest percentage change is the 0.8 percentage-point increase in the average four-year graduation rate of the institution attended by eligible students, a 3.7 percent increase relative to the average graduation rate at institutions attended by ineligible students.[31]

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[30]In the specifications shown in Table 7, standard errors are clustered by institution, as these measures do not vary across entry cohorts.

[31]Cohodes and Goodman (2014) provide evidence that graduation rates of students induced to attend public schools by a merit-based scholarship in Massachusetts have a greater than one-to-one correlation with the average four-year graduation rate at the institution they attend. To fully explain the estimated increase in four-year graduation rates generated by automatic zero eligibility, each percentage-point increase in the institutional graduation rate would need to generate a 2.4 percentage-point increase in graduation at the individual level.

Estimated effects on the first principle component (FPC) are small and statistically insignificant. The mean difference between consecutively ranked Texas public four-year institutions is 0.46, roughly three times larger than the increase in quality (as measured by the FPC) at the eligibility threshold.

To test whether eligibility for additional grant aid affected students' field of study, we estimate impacts on graduation in STEM (Science Technology Engineering Math) and non-STEM fields (Table 8). Estimated impacts on STEM and non-STEM degree receipt within four and six years of entry are similar in magnitude. However, STEM degree receipt is less common and so a similar increase in percentage points represents a larger percent increase over ineligible students' attainment. Eligibility increases STEM degree receipt within four years of entry by 33 percent and by 16 percent within six years of entry. These increases are larger than most of the estimated impacts of federal SMART grants, which explicitly subsidized STEM degree completion (e.g., Denning and Turley 2017; Evans 2017) and similar to the findings of Castleman et al. (2017), who study the effect of a state need-based grant that did not explicitly incentivize STEM. We find a marginally significant ($p < 0.1$) increase in the share of students who declare a STEM major during their time in college (Online Appendix Table C.7), which could arise if treatment effects on attainment are larger for STEM majors or if a maximum Pell Grant affects sorting into and/or out of STEM majors.

5.5 Evidence of borrowing constraints

Theoretically, grant aid should increase the attainment of students who face liquidity constraints (Lochner and Monge-Naranjo 2012).[32] Even students who are not constrained in the traditional sense may not fully smooth consumption due to fixed borrowing costs or aversion to taking on debt (e.g., Marx and Turner forthcoming; Boatman et al. 2017). The importance of credit constraints appears to have grown with increases in costs and returns to college (Lochner and Monge-Naranjo 2011) and a substantial share of U.S. college students and Canadian high school students report a desire to borrow above and beyond their current eligibility (Stinebrickner and Stinebrickner 2008; Belzil et al. 2017).

Few low-income undergraduate students in the U.S. have access to private loans. Thus, we proxy for whether a student faces credit constraints with a dummy indicating that she has borrowed the maximum allowed federal Direct Loan.[33] In order to avoid mechanical reductions in federal loan eligibility that could

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[32]Structural estimates of the importance of credit constraints in the U.S. college students' decisions have generally found that find that relaxing such constraints would have small effects on educational attainment (Cameron and Taber 2004; Keane and Wolpin 2001; Johnson 2013). However, as Lochner and Monge-Naranjo (2012) note in their review of the literature, effects on current consumption could be substantial even in the absence of attainment effects. Brown et al. (2011) model credit constrained youth as those whose parents do not contribute the amount expected by the federal government to their childrens' postsecondary education and estimate that around half of all youth were constrained in previous decades.

[33]Loan amounts reported in the data often exclude small origination fees. As a result we define a student as borrowing the maximum allowed federal loan if she borrows within $100 of the federal Direct Loan limit for first-year dependent students. Changing the definition to be exactly the maximum reduces the coefficients slightly but the results are qualitatively similar. Students are considered to borrow the maximum allowed federal loan if they take-up either the federal maximum for dependent students or the federal maximum for dependent students whose parents are denied a PLUS loan. See Online Appendix A for details.

arise from the increase in grant aid generated by automatic zero EFC eligibility, we focus on a subsample of students who should qualify for the maximum loan whether or not they receive an automatic zero EFC.[34] Only 12 percent of students with family AGIs just above the automatic zero EFC cutoff take-up the maximum allowed Direct Loan (Table 9). Automatic zero eligibility reduces the share of students who have exhausted their federal loan eligibility by 3.3 percentage points (28 percent), suggesting that additional grant aid may relax credit constraints for a number of students in our sample.

Students may also face internal credit constraints. Approximately 27 percent of ineligible students do not borrow at all, and automatic zero EFC eligibility leads to a statistically significant 4 percentage point reduction in the probability of borrowing. The unconditional amount borrowed in eligible students' first year falls by $620 in response to a $544 increase in total grant aid in the restricted sample, implying that every dollar of grant aid crowds-out over $1 of loans. Crowd-out for "would-be-borrowers" - students who would have borrowed had they not been eligible for an automatic zero EFC - is even larger ($1.57). As described in Marx and Turner (forthcoming), crowd-out of loans in response to grant aid in excess of 100 percent would indicate that some students face a fixed cost of borrowing. This fixed cost can reduce attainment in the same manner as external credit constraints, even though such students technically have access to additional loan aid.

These results suggest that grants may have increased attainment by relaxing traditional credit constraints, self-imposed constraints, or a combination of the two. As we show in the next section, knowing the exact mechanism that prevents students from fully smoothing consumption is not necessary to draw inference about the welfare effects of increasing grant aid.

6   Theoretical Framework

In our setting, eligibility for the maximum Pell Grant increases cumulative government expenditures on grant aid while also increasing eligible students' earnings and federal tax liabilities (Figure 9). To interpret the implications of these findings for social welfare, in this section, we present a general model and derive sufficient statistics for the welfare implications of changes in the price of schooling. Our model closely follows Chetty (2006a), generalizing from a constant unemployment insurance benefit to a nonlinear college pricing scheme, introducing student choices over which college (if any) to attend, and allowing for with multiple forms of externalities.

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[34]The sample is defined by students who have unmet need (cost of attendance - EFC - grants) + TEXAS grants exceeding $13,500. For these students, even if the additional Pell Grant aid were to crowd in $8000 of TEXAS Grant aid (the 99th percentile in the sample), then the student would still have over $5500 of unmet need and be able to borrow the maximum federal Direct Loan. Estimated effects on academic and financial outcomes are quite similar for this restricted sample (Online Appendix Tables C.8 and C.9).

6.1 The individual's problem

An individual lives for up to $T+1$ periods, indexed by $t \in \{0, 1, 2, ..., T\}$. In each period, she chooses consumption $c_t \geq 0$, a vector s_t of schooling investments $s_t^k \geq 0$ at colleges $k \in \{1, 2, 3, ..., K\}$, and a length-$X$ vector x_t of other choices. For example, schooling investment might be denominated in credits attempted, and other choices could include the amount of leisure to consume and the number of hours to study or to work. Each college k charges tuition and fees η_t^{km} when schooling investment s_t^k falls within a range μ^{km}, of which there are $M^k \geq 1$.[35] Heterogeneous individuals i have a set of characteristics that are continuously distributed, though to reduce notation we omit i subscripts. Choices are made for each value of a state variable ω_t that evolves according to an arbitrary stochastic process and may govern factors such as wages and the cost of schooling. Expectations $E[\cdot]$ are taken with respect to this state variable as well as over individuals. Let $c = \{c_t(\omega_t)\}_{0 \leq t \leq T}$, $s = \{s_t(\omega_t)\}_{0 \leq t \leq T}$, and $x = \{x_t(\omega_t)\}_{0 \leq t \leq T}$, denote an individual's full set of state-contingent choices for each period.

In each period, the individual chooses consumption, schooling, and labor supply to maximize her utility $u_t(c_t, x_t, s_t)$ subject to several constraints. Each period's utility function is strictly quasi-concave, and we assume Inada conditions with respect to consumption to ensure an interior solution. Any and all components of x_t and s_t can take the value of zero; an individual need not ever attend college. The budget constraint in each period t is: $c_t = a_t - \sum_{k=1}^{K} \sum_{m=1}^{M^k} \left(\eta_t^{km} \mathbf{1}\left(s_t^k \in \mu^{km}\right) \right) + f_t(s, x) + \theta_t + g_t - \tau_t(s, x) - \frac{1}{R} a_{t+1}$, where:

- a_t is the level of assets at the beginning of the period,

- η_t^{km} is the student's price of enrollment at college k at intensity μ^{km}, indicated by the dummy $\mathbf{1}\left(s_t^k \in \mu^{km}\right)$,

- $f_t(s, x)$ is income received in the period (possibly negative) from the choices s and x,

- θ_t is a transfer received from the government,

- g_t is the consumption value of public goods,

- $\tau_t(s, x)$ is the tax paid to the government, and

- $R \geq 1$ is the gross interest rate.

The individual faces asset constraints $a_t \geq \underline{a_t}$, which imply that borrowing may be constrained. Such constraints may be imposed by the market or by the individual. In addition to the budget and asset constraints, we allow for $J < X - 2$ generic constraints, $g_{jt}\left(c_t + \sum_{k=1}^{K} \sum_{m=1}^{M^k} \left(\eta_t^{km} \mathbf{1}\left(s_t^k \in \mu^{km}\right)\right) - \theta_t, x_t, s_t\right) \geq 0$, in each

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[35]This structure accounts comes from the fact that most postsecondary institutions have flat pricing within a set range of credits attempted (e.g., 0-6, 6-12, 12 or more) and that some grant programs adjust aid for recipients' courseloads (e.g., the Pell Grant Program).

period.[36] As examples, such constraints might include restrictions on the number of hours spent working or rules relating to income-based loan repayment. Lagrange multipliers on all constraints are denoted with λ_{ω_t} and a relevant superscript (c, a, or g_j). Indirect utility will depend on the price of schooling across colleges and years, which we denote by $\boldsymbol{\eta}$, defined analogously to the other such vectors.

The indirect utility function at time $t = 0$ is

$$V\left(a_0 | \boldsymbol{\eta}\right) = \max_{\mathbf{c,s,x}} \left\{ \sum_{t=0}^{T} E u_t\left(c_t, \boldsymbol{x}_t, s_t\right) \right.$$

$$+ \sum_{t=0}^{T} E\left[\lambda_{\omega_t}^c \left(a_t - \sum_{k=1}^{K}\sum_{m=1}^{M^k} \left(\eta_t^{km}\mathbf{1}\left(s_t^k \in \mu^{km}\right)\right) + f_t\left(\boldsymbol{s}, \boldsymbol{x}\right) + \theta_t + g_t - \tau_t\left(\boldsymbol{s}, \boldsymbol{x}\right) - \frac{1}{R}a_{t+1} - c_t \right) \right]$$

$$\left. + \sum_{t=1}^{T} E\left[\lambda_{\omega_t}^a \left(\underline{a_t} - a_t\right)\right] + \sum_{t=0}^{T}\sum_{j=1}^{J} E\left[\lambda_{\omega_t}^{g_j} g_{jt}\left(c_t + \sum_{k=1}^{K}\sum_{m=1}^{M^k} \left(\eta_t^{km}\mathbf{1}\left(s_t^k \in \mu^{km}\right)\right) - \theta_t, \boldsymbol{x}_t, s_t \right)\right] \right\}$$

And the first-order condition with respect to consumption in period t' for each value of $\omega_{t'}$ is

$$0 = \frac{\partial}{\partial c_{t'}} u_{t'}\left(c_{t'}, \boldsymbol{x}_{t'}, s_{t'}\right) - \lambda_{\omega_{t'}}^c + \sum_{j=1}^{J} \lambda_{\omega_{t'}}^{g_j} \frac{\partial}{\partial c_{t'}} g_{jt'}. \tag{3}$$

6.2 The government's problem

The government must balance its budget in expectation, thus, expected government revenue equals expected tax revenue. On the expenditure side, the government makes transfers θ_t and spends G_t on public goods, the level of which can be affected by educational investment externalities. The government must cover any difference between the social (resource) cost $v_t^{km}\mathbf{1}\left(s_t^k \in \mu_t^{km}\right)$ of schooling level s_t^k and the payments made by the student. This requirement is most intuitive for public institutions, but we also require that it hold for private institutions. In U.S. higher education, the for-profit sector is relatively small with students' tuition payments disproportionately funded through federal grant aid, while the nonprofit sector is publicly supported through exemption from corporate income tax and through donations that alternatively could purchase other resources. Our formulation follows Andreoni (2006) and Diamond (2006) in excluding from welfare analysis the utility obtained from making donations and, in our case, providing nonprofit schooling.

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[36]The structure of these constraints requires that schooling expenditures enter into the individual's optimization problem everywhere that consumption expenditures enter, which rules out subsistence constraints on consumption but not constraints on schooling itself. With this structure, the constraints in our framework satisfy the assumptions required by Chetty (2006a).

We are interested in a policy reform that reduces the cost of educational investment through the parameters η_t^{km}. This formulation is applicable to a variety of reforms, including changes to the pricing of public institutions or changes in generosity of student grant aid, and such reforms may apply equally to all enrolled students or vary in generosity with the number of credits attempted. Grants may be portable across all colleges, as is the case with Pell Grant aid, or they may only be relevant for certain institutions, as is often the case with state grants that can only be applied at public institutions.

To allow for these variants, we consider a policy change that reduces a student's cost of enrolling at one or more institutions at intensity μ_t^{km}. Policy reforms could affect multiple credit ranges across multiple institutions. Therefore, we parameterize a multi-faceted policy using a scalar p that we define as representing units of the present-value expected cost to the government. We do so by denoting the reductions to the values of μ_t^{km} by $\Delta_t^{km} p$ and requiring that $p = \sum\limits_{t=0}^{T} R^{T-t} \sum\limits_{k=1}^{K} \sum\limits_{m=1}^{M^k} \Delta_t^{km} E\left[\mathbf{1}\left(s_t^k \in \mu_t^{km} \right) \right].^{37}$

We require that the reform maintain budget neutrality and a fixed level of public goods to capture the full welfare effect of both receiving and paying for any change in schooling expenses. For notational simplicity, we consider a policy that offsets changes to expected education costs by adjusting the final transfer θ_T; we will note how the resulting formula for welfare effects would differ if instead the government spread any offsets to transfers over multiple years.

The government's budget constraint is

$$
\theta_T = \sum_{t=0}^{T} R^{T-t} \left(E\left[\tau_t(\boldsymbol{s}, \boldsymbol{x}) - \theta_t - G_t - \sum_{k=1}^{K} \sum_{m=1}^{M^k} \left(v_t^{km} - \eta_t^{km} \right) \mathbf{1}\left(s_t^k \in \mu_t^{km} \right) \right] \right).
$$

Differentiating the budget constraint with respect to the school-price-reducing parameter p yields

$$
\frac{d\theta}{dp} = -R^T p + \sum_{t=0}^{T} R^{T-t} E\left[\frac{d}{dp} \tau_t(\boldsymbol{s}, \boldsymbol{x}) - \frac{d}{dp_t} G_t - \sum_{k=1}^{K} \sum_{m=1}^{M^k} \left(v_t^{km} - \eta_t^{km} \right) \frac{d}{dp} Pr\left(s_t^k \in \mu_t^{km} \right) \right] \tag{4}
$$

Equation (4) represents the changes in future transfers needed to offset any budgetary impacts of changing a student's cost of schooling. The first term captures the direct impact on the government's budget – the transfer to inframarginal students – which will depend on the amount of educational investment at affected schools under the status quo. The remaining terms capture the effects of behavioral responses, which may occur in any year. For example, the reform might increase schooling and reduce tax payments in one year

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[37] As an example, suppose there is a single period, a single college, and students who are evenly split between full-time and part-time enrollment with respective tuition levels of \$2000 and \$1000. A policy to eliminate tuition for all students would have an expected cost of $1500 = .5(1000) + .5(2000)$ per student. In this example we would have $\Delta^1 = \frac{1000}{1500} \approx 0.67$, and $\Delta^2 = \frac{2000}{1500} \approx 1.33$, and $p \in [0, 1500]$, so that a one-unit increase in p reduces μ^1 by \$0.67 and μ^2 by \$1.33, yielding an expected cost to the government of \$1.

but increase tax revenues and the level of public goods in later years. In addition, induced changes in schooling will affect the government's budget if there is a difference between the private and social costs of educational investments. For example, students may be induced to switch between colleges that differ in the degree to which they are subsidized, or they may increase the number of credits they attempt if generosity increases with enrollment intensity.[38]

The government maximizes the individual's indirect utility. By invoking the Envelope Theorem, we can ignore behavioral responses other than those that arise through the government budget constraint. The standard assumptions of basic versions of the Envelope Theorem are violated by the fact that educational expenses are lumpy, including fixed costs that arise when making a nonzero investment an discrete jumps when exceeding threshold numbers of credits, which will generally create kinked points of non-differentiability in the value function at these levels of investment. Clausen and Strub (2016) offer a set of conditions under which the Envelope Theorem holds at agents' optima, and in Online Appendix D we show that these conditions are satisfied in our setting.[39]

The welfare effect of reducing prices through parameter p (and offsetting the budgetary effects through transfers in period T) is

$$\frac{dV\left(a_0|\boldsymbol{\eta}\right)}{dp} = \left\{ -\sum_{t=0}^{T} E\left[\left(\sum_{j=1}^{J} \lambda_{\omega_t}^{g_j} \frac{\partial}{\partial c_0} g_{jt} - \lambda_{\omega_t}^{c} \right) \sum_{k=1}^{K} \sum_{m=1}^{M^k} \Delta_t^{km} \mathbf{1}\left(s_t^k \in \mu^{km} \right) \right] \right.$$

$$\left. + \frac{d\theta}{dp} E\left[\left(\lambda_{\omega_T}^{c} - \sum_{j=1}^{J} \lambda_{\omega_T}^{g_j} \frac{\partial}{\partial c_0} g_{jT} \right) \right] \right\}.$$

Using the first-order condition for consumption in equation (3), we can rewrite this as

$$\frac{dV\left(a_0|\boldsymbol{\eta}\right)}{dp} = \sum_{t=0}^{T} E\left[\left(\sum_{k=1}^{K} \sum_{m=1}^{M^k} \Delta_t^{km} \mathbf{1}\left(s_t^k \in \mu^{km} \right) \right) \frac{\partial}{\partial c_t} u_t \right] + \frac{d\theta}{dp} E\left[\frac{\partial}{\partial c_T} u_T \right].$$

Substituting in the expression from the budget constraint in equation (4) and normalizing by expected marginal utility at time T yields

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[38] At the student level there may be discrete changes in institution attended, which would create points of nondifferentiability, but continuity of the distribution of student characteristics ensures differentiability and gives the change in the probability of enrollment (over states of the world) as the derivative.

[39] Milgrom and Segal (2002) offer alternative assumptions that would mostly hold in this setting but would preclude the Inada condition that would ensure nonzero consumption in all periods.

$$\frac{dV(a_0|\eta)/dp}{R^T E\left[\frac{\partial}{\partial c_T}u_T\right]} = \left\{\sum_{t=0}^{T} E\left[\left(\sum_{k=1}^{K}\sum_{m=1}^{M^k}\Delta_t^{km}\mathbf{1}\left(s_t^k \in \mu^{km}\right)\right)\left(\frac{\frac{\partial}{\partial c_0}u_0}{R^T E\left[\frac{\partial}{\partial c_T}u_T\right]} - 1\right)\right]\right.$$

$$\left. + \sum_{t=0}^{T} R^{-t}E\left[\frac{d}{dp}\tau_t\left(\boldsymbol{s},\boldsymbol{x}\right) - \frac{d}{dp_t}G_t + \sum_{k=1}^{K}\sum_{m=1}^{M^k}\left(\eta_t^{km} - \nu_t^{km}\right)\frac{d}{dp}Pr\left(s_t^k \in \mu^{km}\right)\right]\right\}. \tag{5}$$

Equation (5) describes the welfare effects of a marginal change in the price of school. The first expectation captures direct utility effects from the policy change. The dollars that a student receives in school are transfers that will have to be paid back in the future. Multiplying the current value of the in-school transfer by marginal utility in the year of receipt or in the future provides the relative utility value of those dollars at each of these points in time. Two observations about the terms in this sum offer further intuition. First, if $s_t = 0$ then the entire term for that period is equal to zero; a change in the price of schooling for any particular period only directly affects students who would be enrolled with some probability in that period. Second, if there is no uncertainty, and if the individual's asset and other constraints never bind, then the first-order conditions for future assets can be used to show that $\frac{\partial}{\partial c_t}u_t = R^{T-t}\frac{\partial}{\partial c_T}u_T$, in which case the entire term is again equal to zero. Because the policy is a transfer from one year to another, an unconstrained individual has already adjusted borrowing and saving so as to be indifferent to the timing of a marginal dollar. Thus, lowering the cost of schooling will only have a direct benefit to students who face constraints, such as borrowing constraints, that elevate their in-school marginal utility of consumption.

The remaining sum in equation (5) captures the externalities generated by behavioral responses to the policy change. As described above, these include both traditional externalities on the level of public goods and fiscal externalities through taxes and public spending on education. The externalities could theoretically be either positive or negative on net, and they may arise through changes in behavior in years other than the year of policy change (e.g., if changing the cost of schooling in one year affects government-subsidized schooling investment for multiple years). For our expositionally-simple policy, these effects are all incorporated into period-T transfers and therefore valued according to the marginal utility in that period. If instead the fiscal externalities were spread over multiple periods, then the change in each year's transfer would be multiplied by marginal utility in that year.

In our empirical setting, the general welfare formula in equation (5) can be simplified. First, we treat the marginal grant aid as equal for all students at the threshold because (a) the amount of grant aid received is directly affected in only one year and does not depend on credits attempted as long as the student attempts at least 12 credits per semester, (b) the vast majority of students in the sample attempt sufficient credits, and (c) we find economically and statistically insignificant effects of the grant on the probability of attempting 12 credits per semester. Second, we consider current students at the automatic zero EFC eligibility threshold.

Together, these assumptions imply that $\Delta_t^{km} = 1$ for the student's actual college and enrollment intensity, simplifying the expression for the direct welfare effect. Third, we will assume away non-fiscal externalities, for which we do not have estimates. Assuming such externalities are positive on net, as prior literature would suggest, this simplification works against finding that increasing grants would increase welfare.

The resulting simplified condition for a welfare gain from providing income to current students is:

$$\frac{dV(a_0|\boldsymbol{\eta})/dp}{R^T E\left[\frac{\partial}{\partial c_T} u_T\right]} = \left\{ \sum_{t=0}^{T} E\left[\frac{\frac{\partial}{\partial c_t} u_t}{R^T E\left[\frac{\partial}{\partial c_T} u_T\right]} - R^{-t}\right] \right.$$

$$\left. \sum_{t=0}^{T} R^{-t} E\left[\frac{d}{dp}\tau_t\left(\boldsymbol{s}, \boldsymbol{x}\right) - \sum_{k=1}^{K}\sum_{m=1}^{M^k}\left(\eta_t^{km} - \nu_t^{km}\right)\frac{d}{dp}Pr\left(s_t^k \in \mu^{km}\right)\right]\right\}. \tag{6}$$

This condition is necessary and sufficient for a welfare gain. If we further assume that $\frac{\partial}{\partial c_{t'}} u_t \geq R^{T-t'} E\left[\frac{\partial}{\partial c_T} u_T\right]$, as would be the case if only intertemporal budget constraints bind, then it is sufficient to show that net externalities of the increase in grant aid are positive. Showing that this holds for fiscal externalities alone will be sufficient if nonfiscal externalities are non-negative.

7 Welfare Evaluation

7.1 Indirect effects

According to equation (6), a revenue-neutral increase in grant aid enhances welfare if net externalities are positive and students are not over-consuming while in college. We now assess the net non-fiscal externalities of the additional grant aid provided to students who qualify for an automatic zero EFC based on their family AGI. We estimate local average treatment effects from available policy variation instead of a marginal change, as is common in empirical applications that involve welfare analysis. This provides a first-order approximation to the welfare effect; estimating local effects at the the pre- or post-reform level of the policy requires additional policy variation or parametric assumptions (Chetty 2009).

We first consider the cost of the program. We take into account total cash flows between students and the public sector, abstracting from issues related to transfers between the federal government, state government, and public educational institutions. An advantage of our setting is that we observe all grants that students receive, whether from the Pell program or other sources. As such, we are able to directly estimate the effect of automatic zero eligibility on grant aid received in later years, which turns out to be one of the two large fiscal externalities generated by behavioral responses to eligibility.

Table 10 shows the effect of eligibility for an automatic zero EFC on total financial aid flows over seven

years, a proxy that likely captures most of the lifetime effects on financial aid receipt. The $711 increase in grants received by eligible students at college entry (Table 3) leads to a $1310 increase in total grant aid received over the duration of our panel, a period over which the majority of students have completed a degree or dropped out of college. The increase in cumulative grant aid beyond the initial $711 is likely generated by increased persistence and the increase in the probability of qualifying for a TEXAS Grant in the year of entry, as continued eligibility for TEXAS Grant aid does not depend on family income or need after the first year of receipt. Impacts on cumulative federal borrowing are small and statistically insignificant. Despite the significant reduction in first-year borrowing among eligible students, increased persistence in later years and resultant borrowing offsets this initial decrease. We also find no evidence of statistically significant effects on years of attendance or expenditures on direct subsidies to public institutions attended by eligible students.[40] Point estimates are small, negative, and statistically insignificant.

Public revenue arising from the incremental grant aid exceeds the costs under relatively weak assumptions. As shown in Table 10, summing over the estimated effects of initial eligibility for an automatic zero EFC on federal income tax liabilities suggests that an additional $707 in federal tax revenue was generated in the seven years following college entry. To recover the remaining cost of the grant requires an additional $705. We cannot say whether the earnings effects (and resulting income tax gains) will continue to grow over the long-run, but if earnings gains simply remain at the level we observe at the end of our panel, the additional grant will be fully recouped in nine years and will continue to produce additional revenue for many more years. Indeed, the effect on subsequent years' earnings could be two-thirds as large, and the grant would pay for itself within ten years. Earnings gains need not even persist if we include the $721 increase in FICA taxes collected.

According to the sufficient condition in equation (6), increasing grant aid generosity would be welfare improving in our setting. Of the $1310 increase in public expenditures, $711 was due to the mechanical increase in initial grant aid. This change in student resources was simply a transfer and does not appear directly in equation (6). The behavioral effect on subsidies received by the student is $\frac{1310-711}{711} = \$0.84$ per dollar of initial aid. The behavioral effect on income taxes paid by the student within seven years is $\frac{707}{711} = \$0.99$, giving a net externality of approximately $0.15 over the first seven years following initial grant receipt. At least some portion of the effects on income likely are permanent, and if students work an additional 30 years and pay an additional $707 in income taxes every 3 years then the net externality per dollar of initial aid rises to $9.95. Thus, even if we ignore the private return on the educational investment (which appears to be large) and any nonfiscal externalities (which we expect to be positive on net), our results

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[40]We approximate the value of the direct subsidy provided to a given institution using data from the IPEDS and calculating average student-year expenditures on "core expenses" in excess of tuition payments.

indicate that such transfers raise welfare if direct effects are positive or sufficiently small in magnitude.

7.2 Direct effects

We now address the first sum in equation (6). This sum captures direct welfare effects that arise when marginal utility in college, when the grant is received, differs from marginal utility in later years, when transfers are used to satisfy the government's budget constraint. Marginal utility should increase after college if credit constraints or other factors prevent students from fully smoothing their consumption over time. As our model indicates, we do not need to know the underlying cause of any failures to smooth consumption; the ratio of marginal utilities within and after college is a sufficient statistic for the direct welfare effects of the grant.

We measure consumption over different ages for current and former college students using data from the 2011 through 2015 interview panels of the Consumer Expenditure Survey (CEX). We focus on two groups: current college students aged 18-24 and former students who have completed at least some college and are 25 to 30 years old.[41] By restricting our attention to this relatively young group, instead of individuals at peak earnings ages, we will likely generate an underestimate of the welfare gains of grant aid that moves income from later to earlier periods. Following Meyer and Sullivan (2011), we define consumption to include all expenditures except educational investments, medical expenses, charitable contributions, and retirement savings. We also exclude home production expenditures and use the expected rental value reported by homeowners as a proxy for housing consumption in place of expenditures on mortgage payments, interest, and home maintenance and repairs.[42] We adjust consumption to account for household size, also following Meyer and Sullivan (2011).[43]

In the case of a one-time increase in grant aid provided to first-time college freshmen, the first sum in equation (6) simplifies to a single term so that the direct welfare gain is equal to $\left(\frac{\frac{\partial}{\partial c_0} u_0}{R^T E\left[\frac{\partial}{\partial c_T} u_T\right]} - 1 \right)$. Calibration is straightforward with the constant relative risk aversion (CRRA) utility function. If we assume that utility exhibits CRRA with risk aversion parameter γ and discount rate β then marginal utility is $\beta^t c_t^{-\gamma}$. We allow for uncertainty by calculating the average marginal utility of consumption (rather than the marginal utility of average consumption) for a given level of risk aversion. Online Appendix Table C.11 contains estimated mean marginal utility of consumption in the college student population (Panel A) and the post-college population (Panel B).

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[41]We exclude students with advanced degrees from the latter group. Approximately 52 percent of the remaining sample has a bachelor's degree while the remainder have an associate degree, other credential, or left college without receiving a credential.

[42]Mean and median consumption, expenditures, and household AGI for 18-24 year old students and former students within 5-year age groups are reported in Online Appendix Table C.10.

[43]Adjusted household consumption is equal to annual household consumption divided by $(adults + 0.7 * children)^{0.07}$.

Expected future marginal utility may vary across students, and is likely positively correlated with current marginal utility, but this correlation cannot be observed without panel data on consumption. We therefore calculate upper and lower and bounds for this ratio by assuming zero and perfect correlation, respectively. For the upper bound we calculate $\left(\frac{\frac{1}{N_{coll}} \sum c_{coll}^{-\gamma}}{R\beta^t \left(\frac{1}{N_{postcoll}} \sum c_{postcoll}^{-\gamma} \right)} \right) - 1$ where $\frac{1}{N_{coll}} \sum c_{coll}^{-\gamma}$ is the average marginal utility of consumption for the college population, $\frac{1}{N_{postcoll}} \sum c_{postcoll}^{-\gamma}$ is average marginal utility for the college-educated in the next age group (25-30 years old), and t is the difference in average age between the two groups (6 years). For the lower bound we separate both the student and post-college samples into centiles of consumption, calculate the same statistic for each centile (effectively assuming no mobility or uncertainty), and take the average over centiles.

Following Carroll (2004), Chetty (2006b), and Card et al. (2007), we present welfare calculations for multiple values of the CRRA parameter γ. The welfare gain is increasing in the degree of risk aversion; if an individual's utility function is highly curved, then marginal utility will be much greater when consumption is held at a below-optimal value. Furthermore, we allow the net discount rate $R\beta$ to vary. With $R\beta = 1$, we would expect a constant level of consumption over time, which is consistent with the behavior of the college-educated population in the CEX between the ages of 46 and 65 (Online Appendix Table C.10). When $R\beta > 1$, individuals are patient and prefer to consume more in the future, which reduces the value of additional consumption while in college. The converse applies when $R\beta < 1$.

Table 11 presents estimated upper and lower bounds for the direct effect of grant aid on welfare for $\gamma \in \{1, 2, 3\}$ and $R\beta \in \{0.97, 1, 1.03\}$. We also estimate the direct welfare gains for students from low- and high-income families to account for variation in the targeting of grant programs. Panel A provides estimates for the average college student with average post-college attainment, while Panels B and C adjust in-college consumption to better represent students from families with lower-than-average and higher-than-average income, respectively.[44]

For low-income students like those in our empirical setting, direct welfare gains are positive and sizable for most parameter values, ranging from $0.40 to $1.94 per dollar increase in grant aid with $\gamma = 2$. For most parameter values, average and high-income students also receive fairly substantial, positive direct welfare gains from grant aid increases. With $\gamma = 2$ and $R\beta = 1$, the direct utility gain for the average college student exceeds $0.50 per $1 of grant aid, and effects are at least 30 percent larger for students with family income resembling that of our Texas sample.[45]

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[44]We adjust college-age consumption for low-income students to mimic the fact that those in our sample come from families with incomes around $20,000. Specifically, we scale by the ratio of average consumption among students from families with AGIs between $10,000 and $30,000 to average consumption among all students (0.81). Likewise, to approximate the high-income college student population, we use the ratio of average consumption of students from families with AGIs between $50,000 and $85,000 to average consumption of all students as the adjustment factor (1.10).

[45]Jacob et al. (forthcoming) show that, in addition to academic spending, four-year institutions spend a considerable amount on

Future research on the welfare effects of grant aid can select from values in Table 11 or work towards more precise and tailored estimates. The magnitudes of both the direct and indirect effects of transfers such as grant aid will vary with the characteristics of the affected population and the incentives created by the transfer. The following subsection illustrates how our welfare framework and estimates of direct welfare effects can be applied in different settings.

7.3 Welfare evaluation in other settings

Equation 5 shows that the welfare effects of changing college prices depend on two components: direct effects for students who are unable to smooth consumption and indirect effects arising from the externalities of behavioral responses. The magnitudes of both components will vary across settings, as will the particular types of externalities that arise. To illustrate how our framework could be applied to other settings, we perform rough calculations of the welfare effects of grant aid programs studied by Marx and Turner (forthcoming) and Bettinger et al. (2016), in both cases relying on credible causal estimates generated by regression discontinuity designs.

Our back-of-the-envelope calculations should be viewed as illustrative. The relevant parameters have not all been estimated, and we make strong assumptions about impacts on long-run income and tax revenue and, in the case of Bettinger et al. (2016), the resource cost of educating students at different schools. We also ignore non-fiscal externalities, which would likely improve the welfare effects of the grants that increase educational attainment. These calculations serve as a rough example of the parameters that empirical researchers can estimate, and how they can connect the estimates of various outcomes, to obtain estimates of the welfare effects of grants and changes in tuition rates. Additional details regarding our assumptions and intermediate calculations are available in Online Appendix E.

We first focus on the findings of Marx and Turner (forthcoming), who study the effect of additional grant aid provided to students at the Pell Grant Program's eligibility threshold within the City University of New York (CUNY) system. Students at this threshold have higher family income – with an average AGI of approximately $48,000 – than students at the automatic zero EFC threshold. Eligibility for Pell Grant aid had no effect on college attendance or choice of institution. At entry, eligible students received an additional $389 in Pell Grant aid, were given an additional $33 in other grant aid, and reduced student loans by $224. In contrast to our estimates pertaining to the effect of grant aid on the outcomes of students

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what might be considered consumption amenities. To the extent that the consumption value of college is captured by the cost of on-campus room and board, it will be accounted for in our measure of consumption. However, institutional spending on student activities such as athletics will not be captured. As reported in Jacob et al. (forthcoming), the average public four-year institution charged $5490 in tuition and provided $3602 in consumption amenities in 2004, a ratio of 0.66. We impute the consumption value of college using this ratio and the expenditures on higher education reported in the CEX and report results in Online Appendix Table C.12. Estimate direct welfare effects remain similar to those reported in Table 11.

near the automatic zero EFC eligibility threshold, Marx and Turner (forthcoming) find no evidence that the additional Pell Grant aid increased attainment. As a result, Pell Grant eligibility at college entry had no effect on grant aid received beyond students' first year of enrollment.

The initial increase in Pell Grant aid is simply a transfer to eligible students, while additional grant aid that is crowded-in represents an increase in social costs of $0.08 per dollar of Pell Grant aid. Accounting for the welfare implications of the reduction in borrowing requires additional assumptions, specifically, the fraction of the foregone loan dollars that would not have been repaid to the federal government. Data from the federal College Scorecard suggest that, on average, 26 percent of Pell Grant recipients who attended a CUNY institution had either defaulted on their loans or had failed to make a payment of at least $1 towards their loan debt five years after leaving college.[46] Under the assumption that this average also applies to the students studied by Marx and Turner (forthcoming), Pell Grant eligibility generated a $58 reduction in loan debt that would not have been repaid, representing a $0.15 reduction in (short-run) social costs per $1 of Pell Grant aid. Thus, at least in the short-run, increases in Pell Grant generosity for students on the margin of eligibility improves welfare by reducing social expenditures. Taking into account the consumption-smoothing benefits from providing additional grant aid to middle-income students would generate larger net welfare benefits, in the range of $0.52 to $0.61 per $1 increase in Pell Grant aid (e.g., Table 11, Panel A with $\gamma = 2$ and $R\beta = 1$). Even using the lowest estimated direct effect of $0.03 in direct benefits per $1 increase in Pell Grant generosity, the reduction in borrowing would only have to generate a $0.05 reduction in social expenditures (corresponding to a loan repayment rate of over 90 percent) for additional grant aid to be welfare increasing despite the fact that grant aid had no effects on educational attainment.

In our second example, Bettinger et al. (2016) examine the short- and long-run effects of the Cal Grant Program on college choice, degree receipt, and earnings. The program covers tuition and fees at four-year public institutions and heavily subsidizes tuition at four-year nonprofit schools. Cal Grant eligibility requirements created two different discontinuities, and estimated local average treatment effects and the characteristics of grant aid recipients differ at these thresholds. Thus, we separately calculate welfare implications of changes in grant generosity for each of these populations.

We first consider the income threshold, which induces a change in Cal Grant eligibility for families with a relatively high average income of $60,500. At this threshold, eligibility had no effect on college enrollment but generated changes of 0.057, -0.048, and -0.035 in the respective probabilities of attending a private four-year college, a public four-year college, and a community college. Eligibility had no effect on years of college attendance and impacts on both earnings and AGI 10 to 14 years after college entry are small, negative, and statistically insignificant.

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[46]Institution-level College Scorecard data is available at https://collegescorecard.ed.gov/data/.

Given these results, indirect welfare effects should be limited to changes in the social cost of educating students who were induced to switch higher education sectors by Cal Grant eligibility. Switches from public into nonprofit schools will generate two fiscal externalities: changes in the public subsidy to the institution attended, and increases in the amount of Cal Grant payments relative to what would have been paid if students did not switch. For simplicity, we assume that grants provided to four-year public school students equaled average tuition ($2500) and that average grant aid received by private-school attendees equaled the reported maximum amount available at these schools ($9388). We assume that marginal Cal Grant recipients are evenly split between public and private schools and that the average student obtains three years of schooling, which generates estimated average total Cal Grant aid received by marginal students equal to $9129, matching the reported results. Shifting the shares of public- and private-attending students by the reported effect sizes suggests that marginal students would have received $7911 had there been no change in sector attended. This implies that of the $8129 change in grants at the threshold, $1218 was a negative externality due to these endogenous responses, and absent these responses the increase in grant aid would have been $6911.

The second externality from changes in choice of institution arises due to changes to public subsidies that are provided directly to institutions. Using the IPEDS, we estimate that the net per-student-year subsidy at four-year institutions in California is nearly the same in the public and private sectors and about $9769 less in the average community college. Multiplied by the share of students induced to leave community colleges (0.035) and an average of three years of schooling gives a fiscal externality of -$1026. The sum of the two fiscal externalities is therefore -$3244, or -$0.47 per $1 increase in grant generosity.

For the direct welfare gains, we use the estimate for high-income students (Table 11, Panel C, $\gamma = 2$, $R\beta = 1$), which suggests a benefit of $0.16 to $0.33 per $1 increase in grant aid generosity. For this value of the direct effect and our back-of-the-envelope calculations of net fiscal externalities, we conclude that the welfare effects of increasing grant aid at this margin are negative, on the order of -$0.14 to -$0.31 per $1 increase in grant generosity.

At the Cal Grant GPA eligibility threshold, Bettinger et al. (2016) find no effect on enrollment or sector of institution attended. Eligibility leads to a roughly 0.08 increase in years of attendance and significant increases in earnings and insignificant increases in AGI. At the GPA threshold, marginally-eligible students receive an additional $4307 in Cal Grant aid. Indirect welfare effects will be driven by changes in social costs due to additional years of college attendance and increases in tax revenue paid by eligible students who experience earnings gains.

The average per-student subsidy to California four-year institutions (weighted by the enrollment proportions of 0.57 in public and 0.12 in private in this population at entry) is $13,172 per year. With students

obtaining an additional 0.08 years of education, this amounts to a $1054 increase in social costs or $0.24 per $1 increase in Cal Grant generosity. To estimate the increased tax revenue from eligible students' earnings gains, we assume the annual AGI increase of $469 accrues in each year of a 35-year career and is taxed at the 8 percent rate that we obtain for our low-income Texas sample. This generates a positive fiscal externality of $1312, or $0.30 per $1 of Cal Grant aid. Thus, even if students perfectly smooth consumption, these calculations suggest that increases in grant generosity for students at the GPA threshold for Cal Grant eligibility would increase welfare. This calculation should be viewed with extra caution, however, as it relies on a statistically-insignificant effects on AGI.

Even if net externalities were slightly negative the direct benefits to students at the Cal Grant GPA threshold would likely ensure a welfare gain. For this sample the mean family income at the time of application was $35,100. The lower bound for our middle estimate of the direct effect for low-income college students in Table 11 is 0.67. For net externalities in the range of -0.67, the effect on log AGI would need to be roughly -0.014, which is lower than the reported estimate by nearly two times its standard error.

8   Conclusion

Using student-level administrative data from Texas and a regression discontinuity design, we show that eligibility for additional grant aid at college entry - approximately $700 on average - substantially increases poor students' postsecondary attainment and earnings. Eligibility potentially generates earnings gains through a combination of increasing the likelihood of degree completion and/or decreasing time to degree, and shifting students into STEM majors. Graduation and earnings effects remain positive for the duration of our panel, seven years after college entry, and the estimated increase in federal tax payments is large enough that government expenditures on grant aid are fully recouped within ten years of college entry.

Economists have studied a variety of grant programs for higher education and estimated a range of attainment effects. We present a general model that generates sufficient statistics for evaluating the welfare effects of changes in the price of schooling. These statistics include a direct consumption smoothing effect, which can be estimated from marginal utilities without knowledge about potential underlying frictions, and an indirect effect of externalities generated by behavioral responses to aid. We apply our framework and estimated direct effects to multiple settings and find that while welfare effects cannot be inferred from examining attainment outcomes in isolation, grants that target low-income students are most likely to increase welfare. The benefits to students at the automatic zero threshold for Pell Grant aid are substantial, and increasing support for these students pays for itself through financial gains for the public.

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Figures and Tables

Figure 1: Trends in the Automatic Zero EFC Cut-Off and Maximum Pell Grant
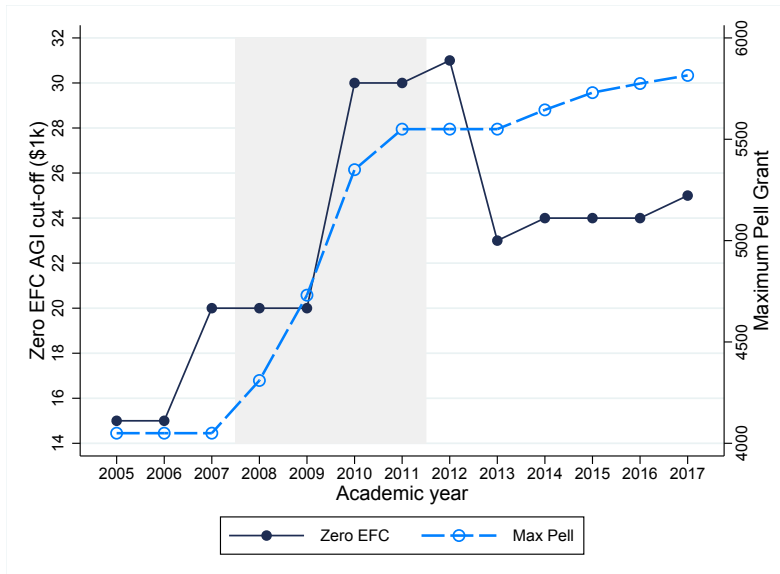
*Note*s: Markers indicate the nominal value of the maximum Pell Grant (light blue hollow circles) and the nominal value of the AGI cut-off for automatic zero EFC eligibility (navy circles) for the specified academic year. The gray shaded area represents the academic years over which students in the analysis sample entered college.

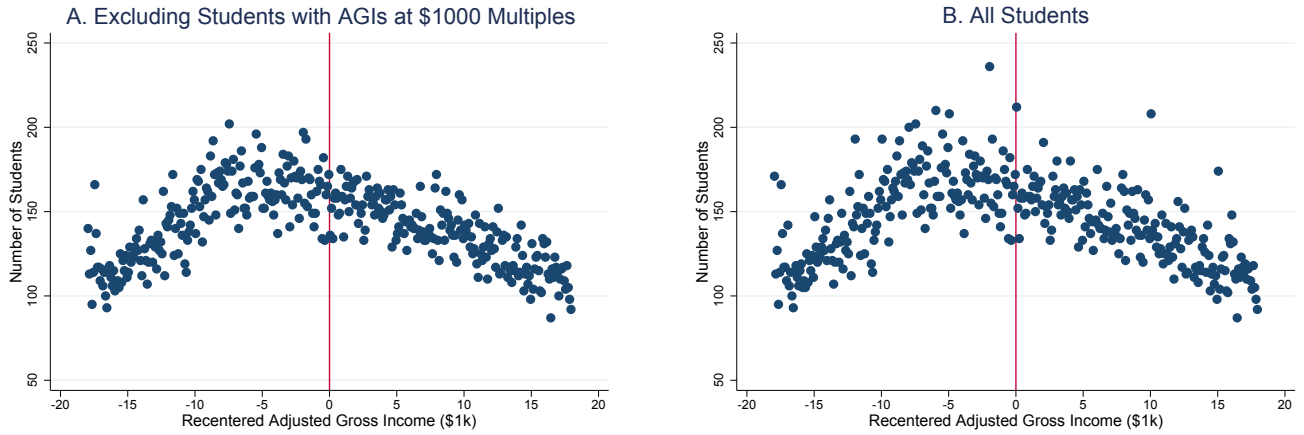Figure 2: Probability of Zero EFC by Distance to the Automatic Zero AGI Threshold
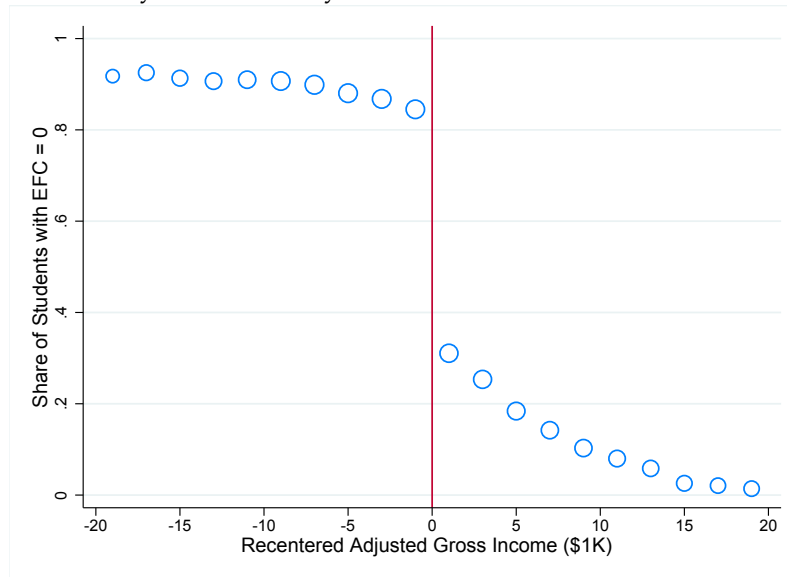
Notes: First-time dependent undergraduate students who enrolled in a four-year Texas public institution in 2008 through 2011 and whose family AGI fell within $20,000 of the income eligibility threshold for an automatic zero EFC (see Figure 1). Students with AGIs at multiples of $1000 are excluded. $2000 AGI bins. Each marker represents the average percent of students with a zero EFC within the bin. Larger circles represent a larger underlying sample size.

Figure 3: Pell Grant Aid and Total Grant Aid by Distance to the Automatic Zero EFC AGI Threshold
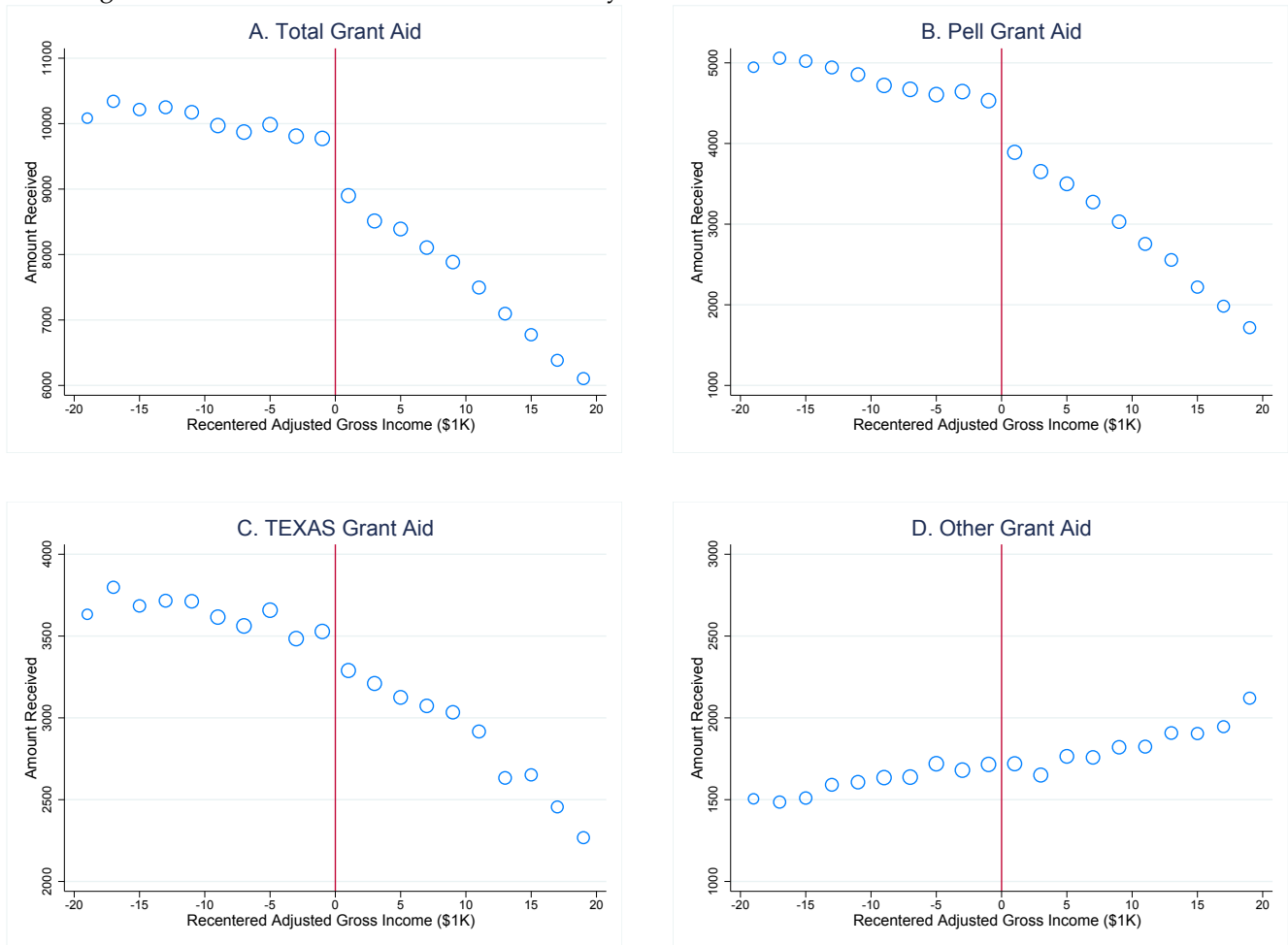
*Note*s: See Figure 2 for sample description. Each marker represents the average amount of total grant aid (Panel A), Pell Grant aid (Panel B), TEXAS Grant aid (Panel C), or other grant aid (Panel D) received by students within the bin. Total grant aid includes Pell, Texas, other state, other federal, and institutional grant aid. $2000 AGI bins. Larger circles represent a larger underlying sample size. All dollar amounts adjusted to represent constant 2013$.

Figure 4: Number of Students by Distance to the Automatic Zero EFC AGI Threshold

*Note*s: First-time dependent undergraduate students who enrolled in a four-year Texas public institution in 2008 through 2011 and whose family AGI fell within $18,000 of the income eligibility threshold for an automatic zero EFC (see Figure 1). Students with AGIs at $1000 intervals are excluded in Panel A. Each marker represents the number of students within a given $100 bin.

Figure 5: Short-Run Academic Outcomes by Distance to the Automatic Zero EFC AGI Threshold
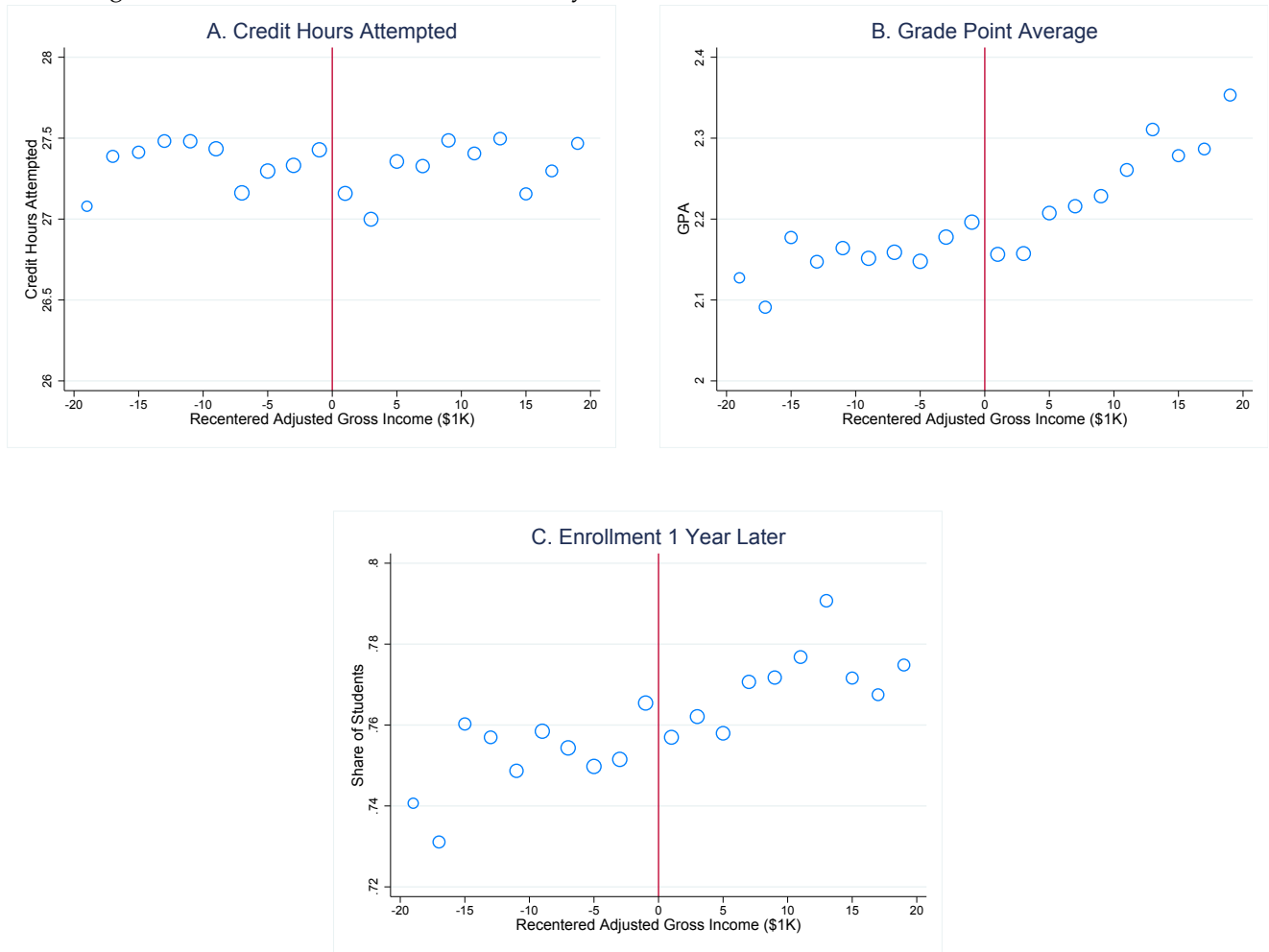
Notes: See Figure 2 notes for sample description. Each marker represents the average number of credit hours attempted in the year of college entry (Panel A), average GPA in the year of college entry (Panel B), or share of students who reenrolled the year after college entry (Panel C) within a given $2000 AGI bin. Larger circles represent a larger underlying sample size.

Figure 6: Short-Run Financial Outcomes by Distance to the Automatic Zero EFC AGI Threshold

A. Earnings

B. Loans
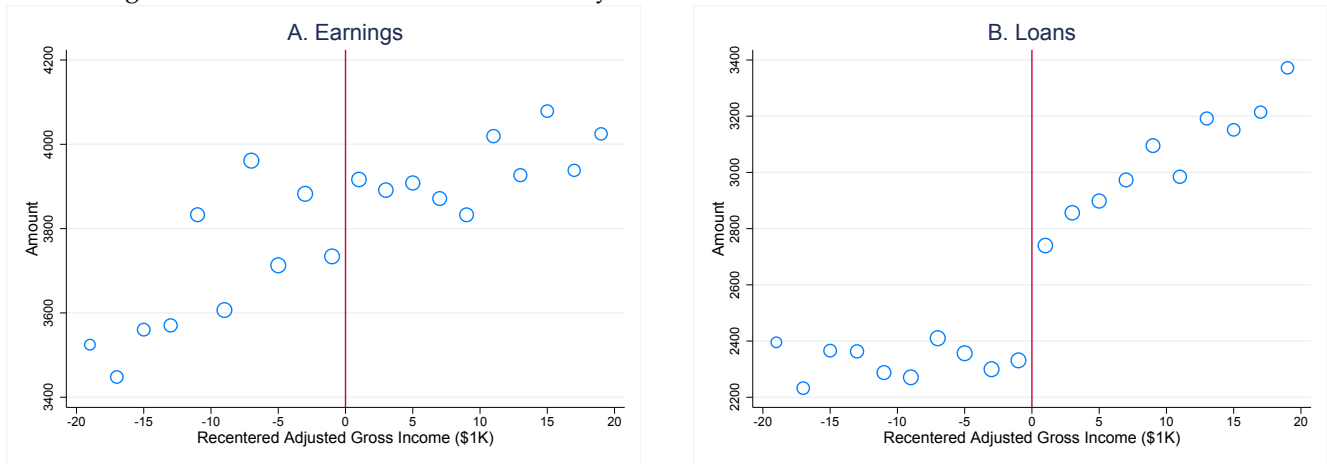
Notes: See Figure 2 notes for sample description. Each marker represents the average earnings in the year of college entry (Panel A) or average federal loan aid received in the year of college entry (Panel B) within a given $2000 AGI bin. Earnings are limited to those received in UI-covered jobs in Texas. Larger circles represent a larger underlying sample size. All dollar amounts adjusted to represent constant 2013$.

Figure 7: Graduation Rates by Distance to the Automatic Zero EFC AGI Threshold
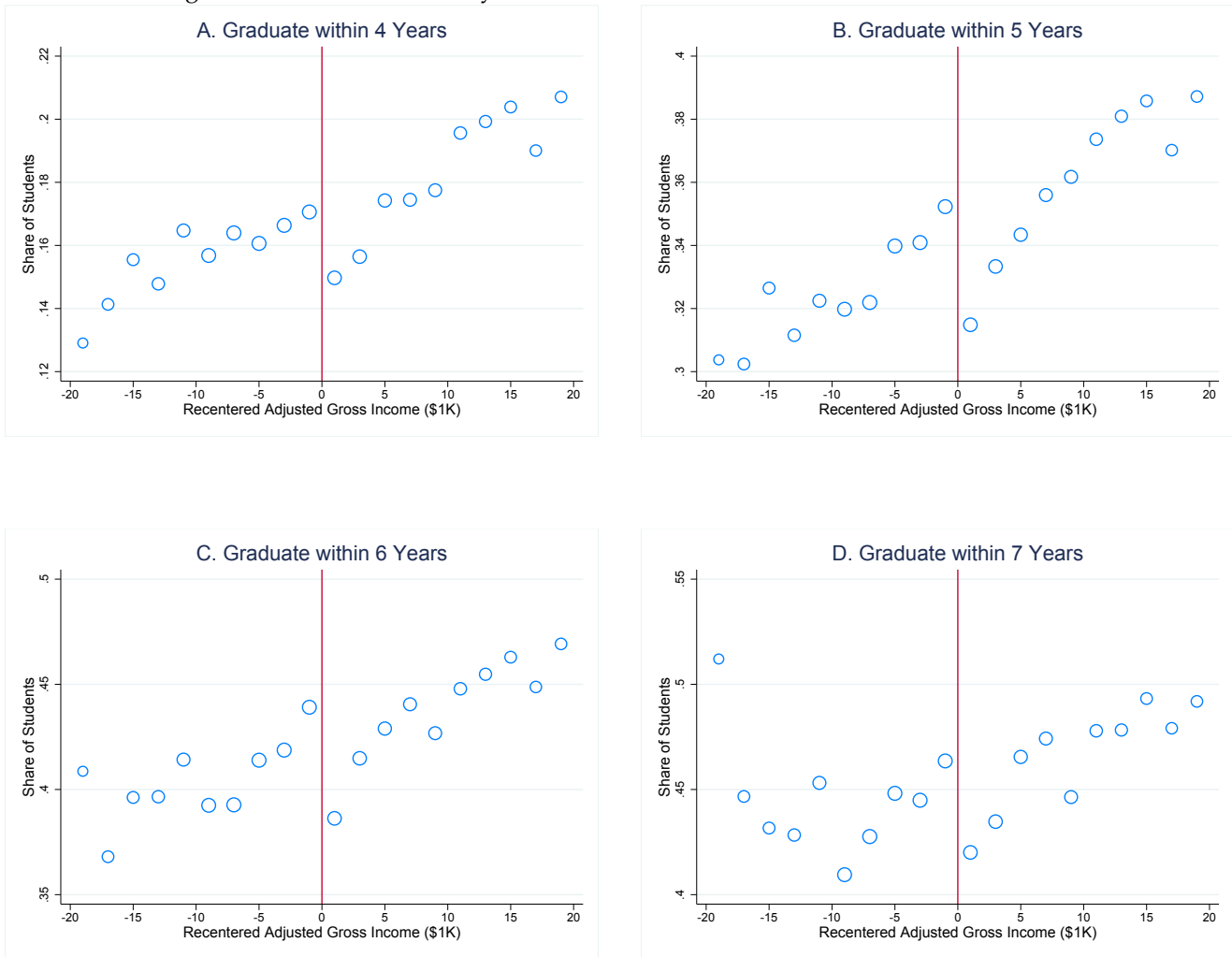
Notes: See Figure 2 notes for sample description. Each marker represents the share of students receiving a bachelor's degree within the specified number of years since entry within a given $2000 AGI bin. Standardized AGI represents the distance from the automatic zero EFC cut-off in the year of college entry. Larger circles represent a larger underlying sample size.

Figure 8: Annual Earnings by Distance to the Automatic Zero EFC AGI Threshold
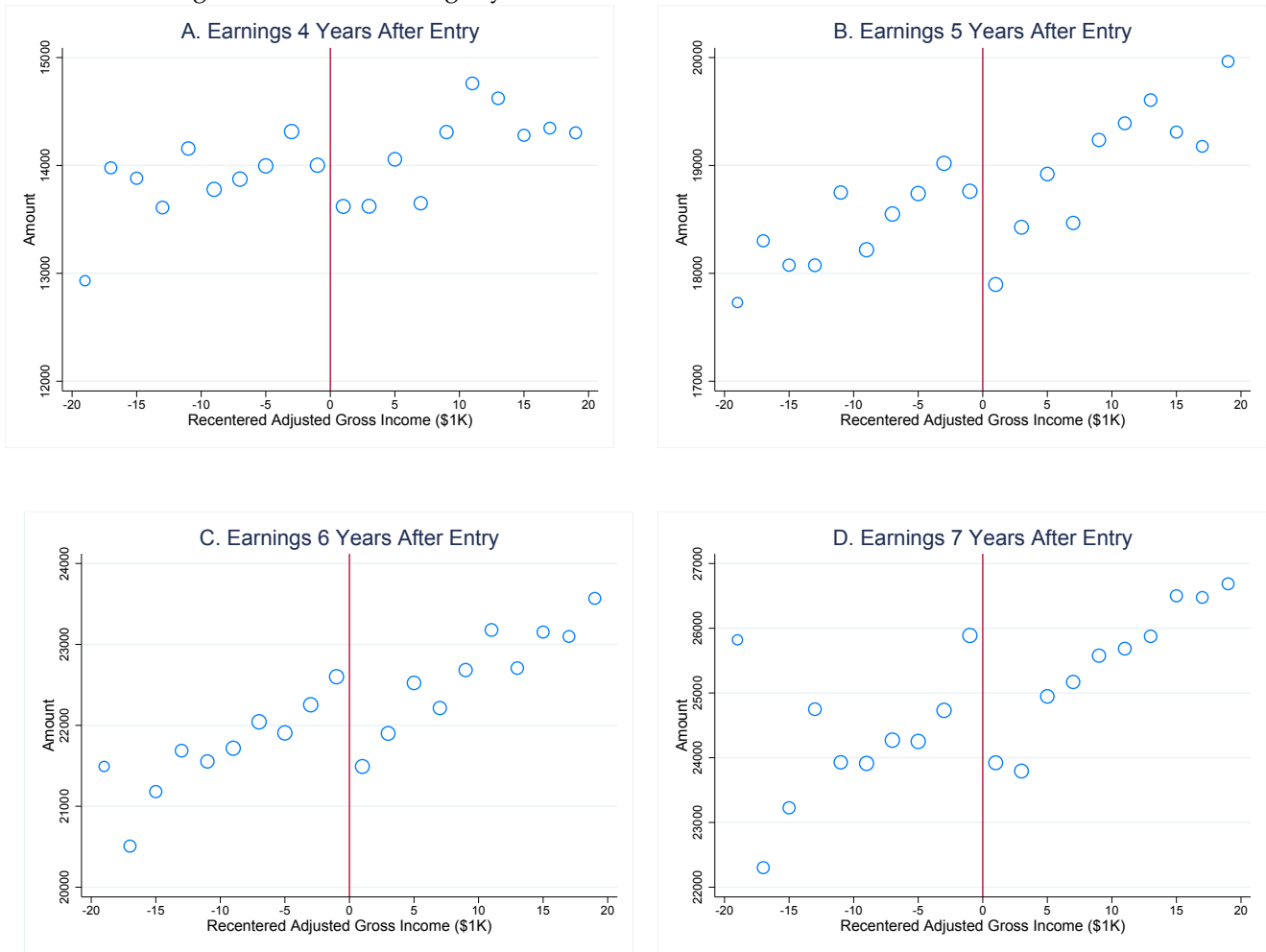
Notes: See Figure 2 notes for sample description. Each marker represents average earnings received by students in the specified number of years since entry within a given $2000 AGI bin. Standardized AGI represents the distance from the automatic zero EFC cut-off in the year of college entry. Earnings are limited to those received in UI-covered jobs in Texas. Larger circles represent a larger underlying sample size. All dollar amounts adjusted to represent constant 2013$.

Figure 9: Total Grants, Loans, and Earnings by Distance to the Automatic Zero EFC Threshold
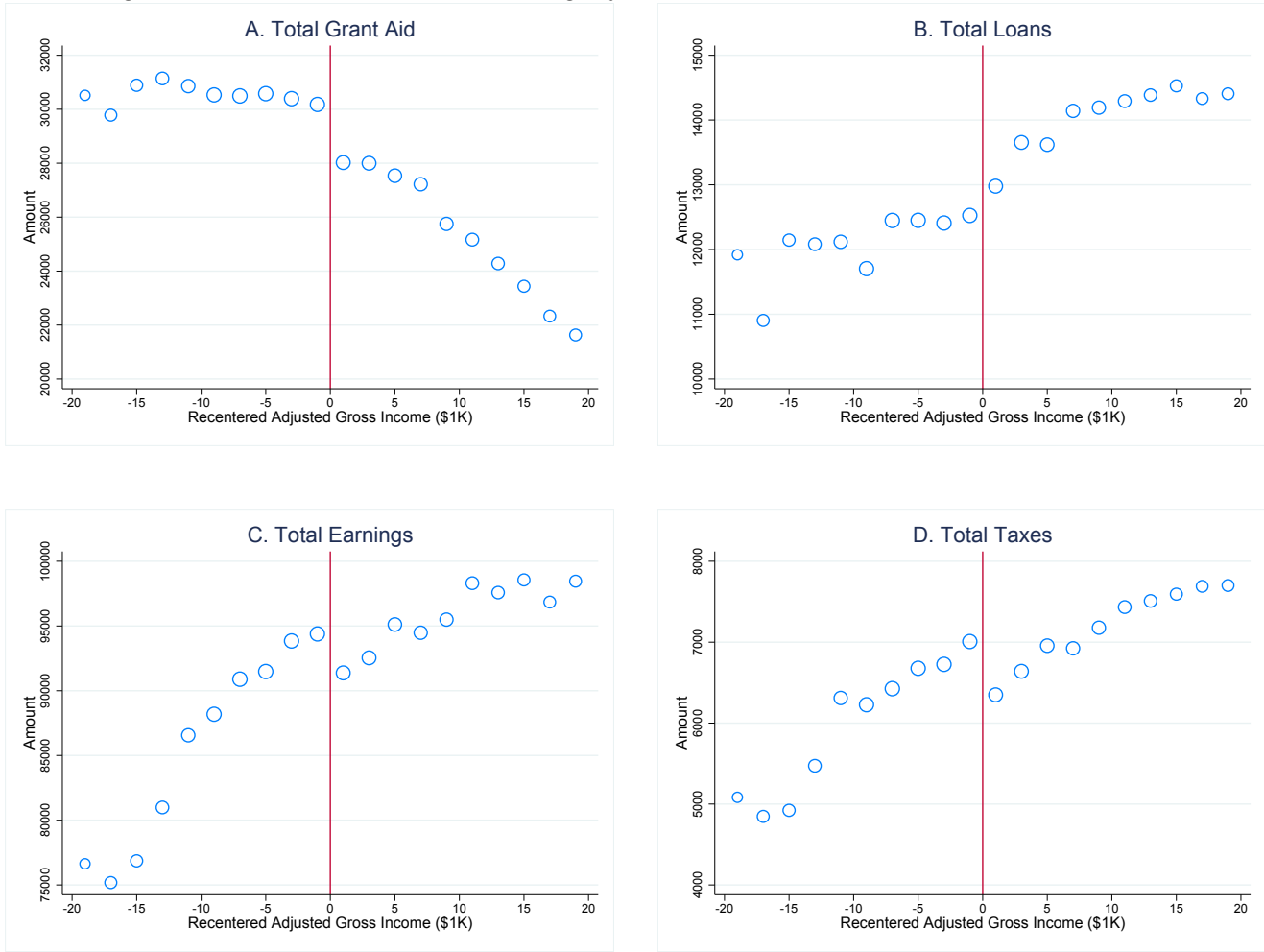
*Note*s: See Figure 2 notes for sample description. Each marker represents average cumulative grant aid (Panel A), federal loans (Panel B), earnings (Panel C), or estimated federal income and FICA taxes (Panel D) received by students over the duration of years in which they are observed within a given $1000 AGI bin. Standardized AGI represents the distance from the automatic zero EFC cut-off in the year of college entry. Earnings are limited to those received in UI-covered jobs in Texas. Federal income and payroll taxes imputed using NBER TAXSIM (see Section 3 for details). Larger circles represent a larger underlying sample size. All dollar amounts adjusted to represent constant 2013$.

Figure 10: Effects of Automatic Zero EFC Eligibility on Academic Outcomes by Years Since Entry
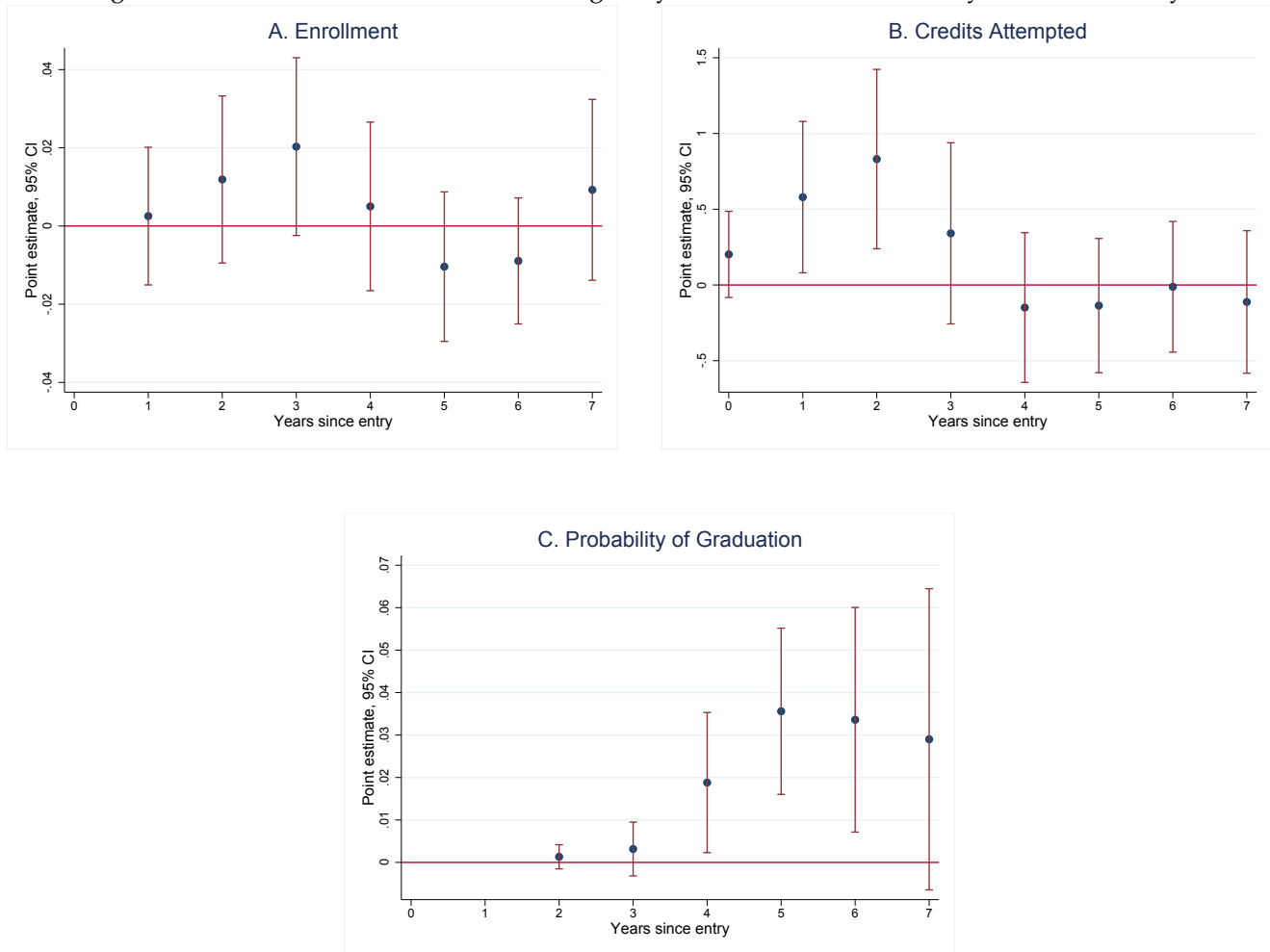
*Note*s: First-time dependent undergraduate students who enrolled in a four-year Texas public institution in 2008 through 2011 and whose family adjusted gross income fell within $12,000 of the income eligibility threshold for an automatic zero EFC (see Figure 1). Students with AGIs at $1000 intervals are excluded. Point estimates and 95% CI from regressions of the probability of reenrollment (Panel A), academic year credits attempted (Panel B), or probability of bachelor's degree receipt within the specified number of years since entry (Panel C) on income-eligibility for the automatic zero EFC, a linear term in distance from the threshold (allowed to vary on either side), and indicators for parent education, race, gender, age, Texas residency, and cohort. Confidence intervals constructed using robust standard errors clustered at initial institution by entry cohort level.

Figure 11: Effects of Automatic Zero Eligibility on Labor Market Outcomes by Years Since Entry
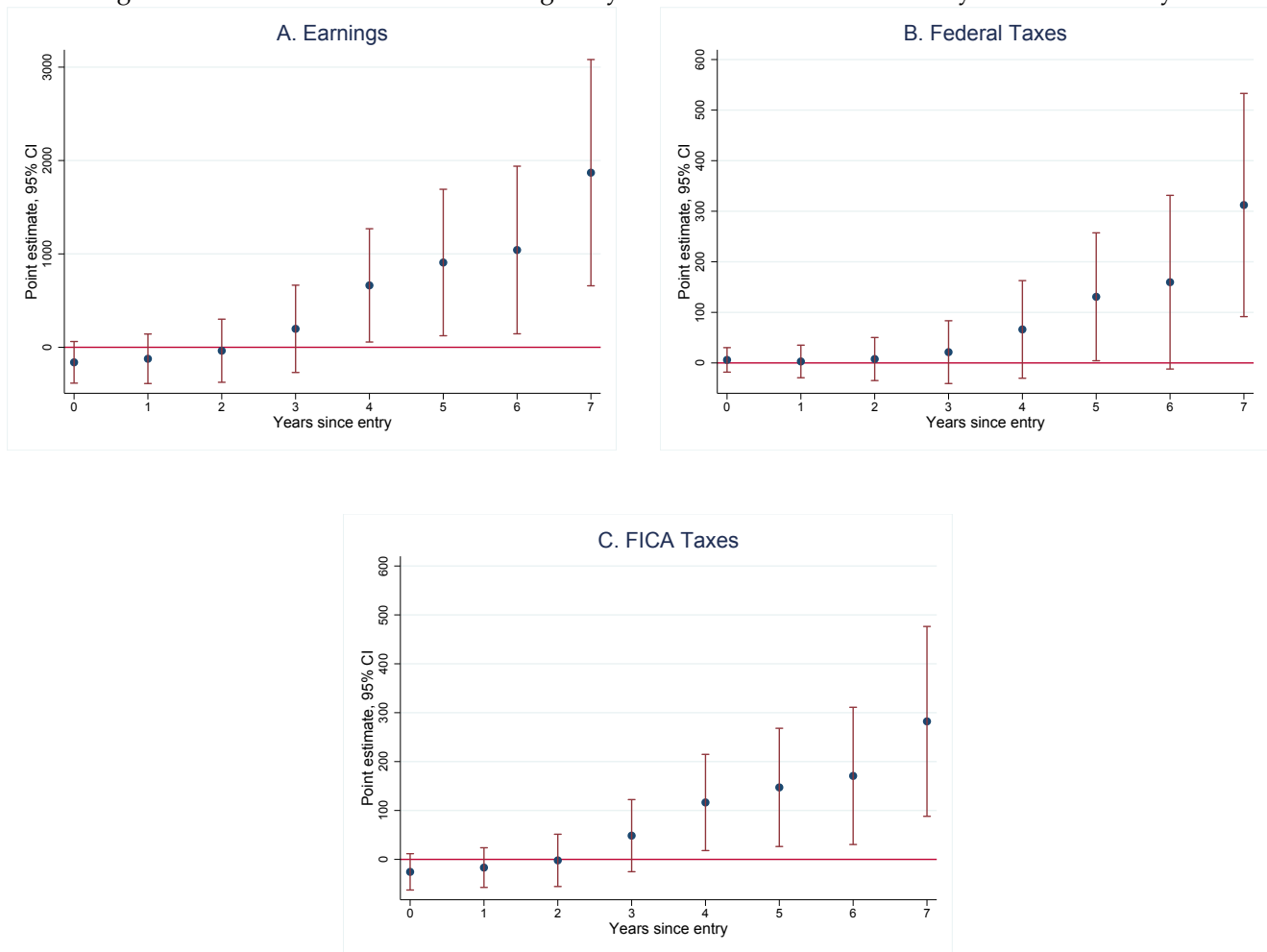
*Note*s: See Figure 10 notes for sample description. Point estimates and 95% CI from regressions of annual earnings (Panel A), estimated federal income taxes (Panel B), or estimated federal payroll taxes (Panel C) on income-eligibility for the automatic zero EFC, a linear term in distance from the threshold (allowed to vary on either side), and indicators for parent education, race, gender, age, Texas residency, and cohort. Confidence intervals constructed using robust standard errors clustered at initial institution by entry cohort level. Earnings are limited to those received in UI-covered jobs in Texas. Federal income and payroll taxes imputed using NBER TAXSIM (see Section 3 for details). All dollar amounts adjusted to represent constant 2013$.

Figure 12: Share of Students with Earnings or Enrollment
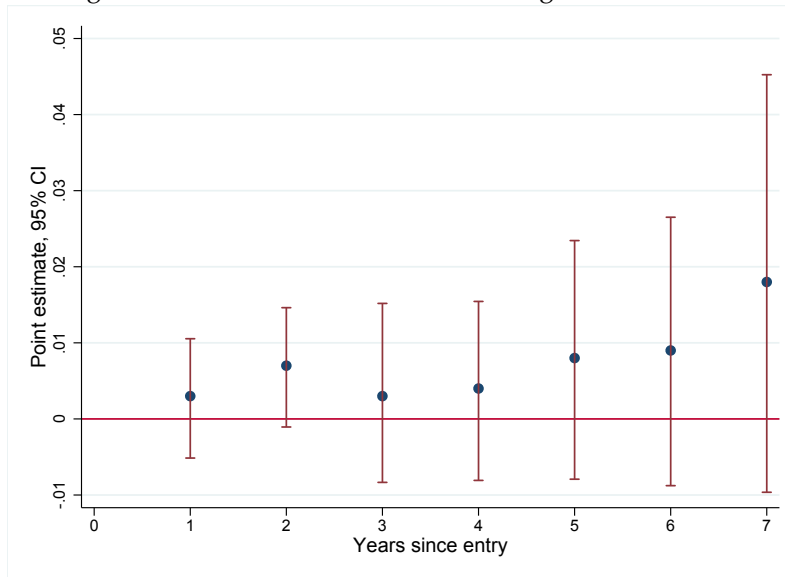
Notes: See Figure 10 notes for sample description. Dependent variable is the probability of having any earnings in a UI covered sector in Texas or any enrollment in a Texas public higher education institution (2- or 4-year). Point estimates and 95% CI from regressions of the dependent variable on income-eligibility for the automatic zero EFC, a linear term in distance from the threshold (allowed to vary on either side), and indicators for parent education, race, gender, age, Texas residency, and cohort. Confidence intervals constructed using robust standard errors clustered at initial institution by entry cohort level.

Table 1: Sample Demographics and Contemporaneous Finances

	(1) Full sample	(2) Auto-zero eligible	(3) Auto-zero ineligible
A. Student demographics			
Male	0.46	0.45	0.46
Age	18.6	18.6	18.6
Texas Resident	0.97	0.97	0.96
Race			
Asian	0.05	0.05	0.05
Black	0.24	0.23	0.26
Hispanic	0.22	0.20	0.25
White	0.46	0.50	0.42
Parental education			
Father: <HS	0.13	0.15	0.12
Father: HS degree	0.46	0.45	0.47
Father: college degree	0.23	0.21	0.25
Mother: <HS	0.12	0.14	0.10
Mother: HS degree	0.49	0.49	0.48
Mother: college degree	0.29	0.26	0.32
B. Financial aid			
EFC = 0	0.55	0.88	0.18
Pell Grant aid	$4,053	$4,667	$3,372
Texas Grant aid	$3,365	$3,591	$3,115
Total Grants	$9,676	$10,413	$8,860
Loans	$2,740	$2,421	$3,094
Earnings	$3,844	$3,788	$3,905
Work Study	$141	$137	$145
Observations	36,697	19,275	17,422

*Note*s: First-time dependent undergraduate students who enrolled in a four-year Texas public institution in 2008 through 2011 and whose family adjusted gross income fell within $12,000 of the income eligibility threshold for an automatic zero EFC (see Figure 1). Students with AGIs at $1000 intervals are excluded. Students with family AGI below the year specific threshold are income-eligible for an automatic zero EFC. Race and parent education categories will not sum to 100 percent due to missing values. All dollar amounts adjusted for inflation (2013$).

Table 2: Correlations between Automatic Zero Eligibility and Selected Student Characteristics

	(1) Linear prediction	(2) Father college deg.	(3) Mother college deg.	(4) White	(5) Black	(6) Hispanic	(7) Asian	(8) Age	(9) Texas resident
Automatic zero eligible	0.003	-0.003	-0.002	0.013	-0.032*	0.015	0.002	-0.018	0.012**
	(0.002)	(0.009)	(0.009)	(0.014)	(0.017)	(0.009)	(0.005)	(0.013)	(0.005)
Mean | ineligible	0.16	0.22	0.28	0.46	0.27	0.20	0.05	18.6	0.96
Observations	36,697	36,697	36,697	36,697	36,697	36,697	36,697	36,697	36,697

*Note*s: First-time dependent undergraduate students who enrolled in a four-year Texas public institution in 2008 through 2011 and whose family adjusted gross income fell within $9000 of the income eligibility threshold for an automatic zero EFC. Students with AGIs at $1000 intervals are excluded. Point estimates from OLS regressions of the dependent variable specified in each column on income-eligibility for the automatic zero EFC. All models also include controls for a linear term in distance from the AGI threshold (allowed to vary on either side of the threshold). Robust standard errors, clustered by initial institution by entry cohort, in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$. "Mean | ineligible" represents the limit of the expected value of the dependent variable as the AGI threshold is approached from above the threshold.

Table 3: The Effect of Automatic Zero Eligibility on First Year Financial Outcomes

	(1) EFC=0	(2) Total grant aid	(3) Pell Grant aid	(4) TEXAS Grant aid	(5) Other grant aid	(6) Earnings	(7) Loans
Automatic zero eligible	0.522***	711***	510***	122*	78	-161	-333***
	(0.014)	(94)	(37)	(63)	(66)	(114)	(65)
Mean | ineligible	0.32	$9,008	$4,020	$3,319	$1,669	$3,882	$2,887
Observations	36,697	36,697	36,697	36,697	36,697	36,697	36,697

*Note*s: See Table 1 notes for sample description. Point estimates from OLS regressions of the dependent variable specified in each column on income-eligibility for the automatic zero EFC. All models also include controls for a linear term in distance from the AGI threshold (allowed to vary on either side of the threshold), parent education, race, gender, age, Texas residency, and entry cohort. Robust standard errors, clustered by initial institution by entry cohort, in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$. "Mean | ineligible" represents the limit of the expected value of the dependent variable as the AGI threshold is approached from above. All dollar amounts adjusted for inflation (2013$).

Table 4: The Effect of Automatic Zero Eligibility on Contemporaneous Academic Outcomes

	(1) Credit hours attempted	(2) Persistence	(3) GPA
Automatic zero eligible	0.202	0.003	0.032
	(0.145)	(0.009)	(0.027)
Mean | ineligible	27.1	0.76	2.14
Observations	36,697	36,697	36,697

*Note*s: See Table 1 notes for sample description. See Table 3 notes for specification. Robust standard errors, clustered by initial institution by entry cohort, in parentheses; *** p<0.01, ** p<0.05, * p<0.1. "Mean | ineligible" represents the limit of the expected value of the dependent variable as the AGI threshold is approached from above the threshold.

Table 5: IV Estimates of the Effect of Grant Aid on Longer-Run Outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Enrollment by years since entry							
First year grant aid ($1k)	0.004	0.018	0.030*	0.007	-0.015	-0.017	0.023
	(0.013)	(0.015)	(0.017)	(0.016)	(0.014)	(0.016)	(0.034)
Mean | ineligible	0.76	0.62	0.55	0.38	0.20	0.10	0.07
Observations	36,697	36,697	36,697	36,697	26,389	17,109	8,163
B. Graduate within X years							
First year grant aid ($1k)	--	0.002	0.005	0.028**	0.053***	0.050**	0.057*
	--	(0.002)	(0.005)	(0.012)	(0.015)	(0.020)	(0.034)
Mean | ineligible	--	<0.01	0.02	0.15	0.31	0.39	0.43
Observations	--	36,697	36,697	36,697	36,697	26,389	17,109
C. Earnings by years since entry							
First year grant aid ($1k)	-182	-54	292	978**	1334**	1545**	3584**
	(204)	(254)	(343)	(438)	(576)	(702)	(1522)
Mean | ineligible	$5,657	$7,522	$9,605	$13,413	$17,944	$21,488	$23,583
Observations	36,697	36,697	36,697	36,697	36,697	26,389	17,109
D. Federal income tax liabilities by years since entry							
First year grant aid ($1k)	4	11	32	98	193**	236*	610**
	(24)	(32)	(46)	(70)	(94)	(134)	(260)
Mean | ineligible	-$85	$122	$454	$1,012	$1,604	$2,126	$2,479
Observations	36,697	36,697	36,697	36,697	36,697	26,389	17,109
E. FICA tax liabilities by years since entry							
First year grant aid ($1k)	-25	-3	72	172**	217**	252**	551**
	(31)	(40)	(53)	(71)	(90)	(110)	(244)
Mean | ineligible	$881	$1,152	$1,517	$2,205	$2,886	$3,382	$3,675
Observations	36,697	36,697	36,697	36,697	36,697	26,389	17,109

*Note*s: See Table 1 notes for sample description. Each cell within a panel displays 2SLS estimates of the impact of an additional $1000 in first-year grant aid on the specified outcome by the number of years since entry specified in the column headings. The indicator for first-year income eligibility for the automatic zero EFC serves as the excluded instrument. All models also include controls for a linear term in distance from the AGI threshold (allowed to vary on either side of the threshold). Robust standard errors, clustered by initial institution by entry cohort, in parentheses; *** p<0.01, ** p<0.05, * p<0.1. "Mean | ineligible" represents the limit of the expected value of the dependent variable as the AGI threshold is approached from above the threshold. All dollar amounts adjusted for inflation (2013$).

Table 6: Robustness of Estimated Effects of Automatic Zero Eligibility on Graduation and Earnings

	Contemporaneous outcomes:				Graduate within:				Earnings after			
	(1) EFC = 0	(2) Total Grants	(3) Credits attempted	(4) GPA	(5) 4 years	(6) 5 years	(7) 6 years	(8) 7 years	(9) 4 years	(10) 5 years	(11) 6 years	(12) 7 years
A. No covariates												
Automatic zero eligible	0.523***	673***	0.246	0.043	0.022**	0.041***	0.039**	0.035*	733**	1011**	1148**	1978***
	(0.014)	(111)	(0.150)	(0.030)	(0.009)	(0.011)	(0.015)	(0.020)	(323)	(415)	(472)	(633)
Observations	36,697	36,697	36,697	36,697	36,697	36,697	26,389	17,109	36,697	36,697	26,389	17,109
B. Including students with AGIs at $1000 multiples												
Automatic zero eligible	0.521***	673***	0.184	0.034	0.019**	0.035***	0.032**	0.027	623**	931**	1064**	1805***
	(0.014)	(99)	(0.140)	(0.026)	(0.008)	(0.010)	(0.014)	(0.018)	(311)	(399)	(456)	(623)
Observations	37,488	37,488	37,488	37,488	37,488	37,488	26,954	17,452	37,488	37,488	26,954	17,452
C. $6K bandwidth												
Automatic zero eligible	0.488***	648***	0.196	0.055	0.029**	0.039***	0.052***	0.045**	889**	1364***	1575**	2551**
	(0.018)	(137)	(0.210)	(0.037)	(0.011)	(0.013)	(0.017)	(0.020)	(441)	(509)	(674)	(975)
Observations	18,996	18,996	18,996	18,996	18,996	18,996	13,809	9,051	18,996	18,996	13,809	9,051
D. $18K bandwidth												
Automatic zero eligible	0.556***	596***	0.103	0.027	0.017**	0.023***	0.025**	0.016	519**	724**	825**	1525***
	(0.014)	(89)	(0.110)	(0.023)	(0.007)	(0.008)	(0.011)	(0.015)	(233)	(304)	(315)	(538)
Observations	51,034	51,034	51,034	51,034	51,034	51,034	35,844	22,175	51,034	51,034	35,844	22,175
E. $18K bandwidth, quadratic in AGI												
Automatic zero eligible	0.492***	760***	0.270	0.041	0.024**	0.046***	0.046***	0.045**	861**	1250**	1128*	2189**
	(0.016)	(107)	(0.188)	(0.033)	(0.010)	(0.012)	(0.016)	(0.021)	(380)	(494)	(642)	(861)
Observations	51,034	51,034	51,034	51,034	51,034	51,034	35,844	22,175	51,034	51,034	35,844	22,175

*Note*s: First-time dependent undergraduate students who enrolled in a four-year Texas public institution in 2008 through 2011 and whose family adjusted gross income fell within $12,000 (Panels A and B), $6000 (Panel C), or $18,000 (Panels D and E) of the income eligibility threshold for an automatic zero EFC (see Figure 1). Students with AGIs at $1000 intervals are excluded from sample in Panels A, C, D, and E. Point estimates from OLS regressions of the dependent variable specified in each column on income-eligibility for the automatic zero EFC. All models include a linear term in the distance from the AGI threshold (allowed to vary on either side of the threshold). Panels B through E models also include controls for parent education, race, gender, age, Texas residency, and entry cohort. Panel E models also include controls for a quadratic in the distance from the AGI threshold (allowed to vary on either side of the threshold). Robust standard errors, clustered by initial institution by entry cohort, in parentheses; *** p<0.01, ** p<0.05, * p<0.1. "Mean | ineligible" represents the limit of the expected value of the dependent variable as the AGI threshold is approached from above. All dollar amounts adjusted for inflation (2013$).

Table 7: The Effect of Automatic Zero Eligibility on Measures of Institutional Quality

A. Summary and inputs

	(1) First principal component	(2) Verbal, 25th percentile	SAT scores (3) Verbal 75th, percentile	(4) Math, 25th percentile	(5) Math, 75th percentile	Share of students: (6) Receiving Pell	(7) Borrowing	Admissions (8) Applicants admitted	(9) Yield
Automatic zero eligible	0.175	4.818	6.156	5.378	6.035	-1.039	-0.979	0.695	0.862*
	(0.134)	(3.793)	(4.909)	(4.300)	(4.781)	(0.947)	(0.853)	(0.685)	(0.487)
Mean | ineligible	1.044	443	548	466	566	45.4	51.1	67.5	40.2
Observations	36,556	33,277	33,277	33,611	33,611	36,556	36,556	36,211	36,211

B. Resources and outputs

	(1) Tuition and Fees	(2) Student-faculty ratio	Retention rate (3) Full-time students	(4) Part-time students	Graduation rate (5) Within 4 years	(6) Within 6 years	Expenditures per FTE: (7) Instruction	(8) Academic support svc.	(9) Student services
Automatic zero eligible	-16	0.136	0.878	1.751	0.806	1.301	-42	-1	-3
	(41)	(0.121)	(0.779)	(1.591)	(0.683)	(1.153)	(93)	(43)	(16)
Mean | ineligible	6945	20.9	71.9	52.1	21.8	43.8	7635	2536	1451
Observations	36,553	36,556	36,553	36,553	36,483	36,483	36,556	36,556	36,556

*Note*s: See Table 1 notes for sample description. Students who initially enrolled in schools missing a given measure of institutional quality are also omitted. Point estimates from OLS regressions of the dependent variable specified in each column on income-eligibility for the automatic zero EFC. All models also include controls for a linear term in distance from the AGI threshold (allowed to vary on either side of the threshold), parent education, race, gender, age, Texas residency, and entry cohort. Robust standard errors, clustered by initial institution by entry cohort, in parentheses; *** p<0.01, ** p<0.05, * p<0.1. "Mean | ineligible" represents the limit of the expected value of the dependent variable as the AGI threshold is approached from above. Panel A, column 1 dependent variable is the first principal component of the set of displayed measures of institutional quality. Institutional quality measures come from the IPEDS.

Table 8: The Effect of Automatic Zero Eligibility on Degree Receipt: STEM and Other Degree Completion

	Graduate in 4 years			Graduate in 6 years		
	(1) All majors	(2) STEM major	(3) Non-STEM major	(4) All majors	(5) STEM major	(6) Non-STEM major
Automatic zero eligible	0.019**	0.010***	0.009	0.034**	0.011*	0.023**
	(0.008)	(0.004)	(0.007)	(0.014)	(0.006)	(0.011)
Mean | ineligible	0.15	0.03	0.12	0.40	0.07	0.32
Observations	36,697	36,697	36,697	26,389	26,389	26,389

*Note*s: See Table 1 notes for sample description. See Table 3 notes for specification. Robust standard errors, clustered by initial institution by entry cohort, in parentheses; *** p<0.01, ** p<0.05, * p<0.1. "Mean | ineligible" represents the limit of the expected value of the dependent variable as the AGI threshold is approached from above the threshold. STEM majors are those with CIP codes included in the National Science Foundation's list of STEM disciplines (available at: https://www.lsamp.org/help/help_stem_cip_2010.cfm). Non-STEM majors are all other majors. Categories are not mutually exclusive (double majors may receive both STEM and non-STEM degrees).

Table 9: The Effect of Automatic Zero Eligibility on the Probability of Constrained Borrowing

	(1) Max loan	(2) Any loan	(3) Total grants	(4) Total loans
Automatic zero eligible	-0.033**	-0.040**	544***	-620***
	(0.015)	(0.015)	(144)	(140)
Mean | ineligible	0.119	0.727	$8,880	$4,308
Crowd-out | would-be-borrower				-1.57
Observations	11,375	11,375	11,375	11,375

*Note*s: See Table 1 notes for sample description. Students are considered to have maximized their federal loan if their total loan aid at entry equals either the maximum Direct Loan available to dependent first-year undergraduate students ($3500 in 2008 and $5500 in 2009-2011) or the maximum Direct Loan available to dependent first-year undergraduate students' whose parents have been denied a PLUS loan ($7500 in 2008 and $9500 in 2009-2011). Students with unmet need less than $13,500 are also excluded. Point estimates from OLS regressions of the dependent variable specified in each column on income-eligibility for the automatic zero EFC. All models also include controls for a linear term in distance from the AGI threshold (allowed to vary on either side of the threshold) and entry cohort. Robust standard errors, clustered by initial institution by entry cohort, in parentheses; *** p<0.01, ** p<0.05, * p<0.1. "Mean | ineligible" represents the limit of the expected value of the dependent variable as the AGI threshold is approached from above. Crowd-out | would-be-borrower equals the change in amount borrowed per dollar increase in grant aid divided by the share of ineligible students who borrow (see Marx and Turner (forthcoming) for details). All dollar amounts adjusted for inflation (2013$).

Table 10: Impacts on Cumulative Financial Aid, Earnings, and Estimated Federal Taxes

| | (1) Cumulative grant aid | (2) Cumulative loans | Sum of estimated effects on: | | |
			(3) Earnings	(4) Fed. income taxes	(5) FICA taxes
Automatic zero eligible	1310***	-39	4327**	707***	721***
	(458)	(298)	(1736)	(273)	(276)
Mean | ineligible	$28,759	$12,712	$103,063	$7,538	$16,369
Observations	36,697	36,697			

Notes: See Table 1 notes for sample description. See Table 3 notes for specification. The sum of estimated effects on cumulative earnings is equal to the sum of point estimates displayed in Figure 8. Robust standard errors, clustered by initial institution by entry cohort, in parentheses; *** p<0.01, ** p<0.05, * p<0.1. The sum of estimated effects on imputed federal taxes is equal to the sum of point estimates from regressions of estimated federal income or payroll taxes on an indicator for income-eligibility for the automatic zero EFC in models that also include controls for a linear term in distance from the AGI threshold (allowed to vary on either side of the threshold), parent education, race, gender, age, Texas residency, and entry cohort. All dollar amounts adjusted for inflation (2013$).

Table 11: Direct Utility Gain from $1 Increase in Grant Aid

| | Risk aversion parameter (γ) = | | |
	1	2	3
A. All college students			
Net discount rate ($R\beta$) =			
1.03	[0.03, 0.05]	[0.27, 0.35]	[0.57, 0.77]
1	[0.23, 0.25]	[0.52, 0.61]	[0.88, 1.11]
0.97	[0.48, 0.50]	[0.82, 0.94]	[1.25, 1.53]
B. Low AGI college students			
Net discount rate ($R\beta$) =			
1.03	[0.07, 0.29]	[0.40, 1.05]	[0.84, 2.31]
1	[0.28, 0.54]	[0.67, 1.45]	[1.19, 2.95]
0.97	[0.54, 0.85]	[1.00, 1.94]	[1.63, 3.74]
C. High AGI college students			
Net discount rate ($R\beta$) =			
1.03	[-0.10, -0.05]	[-0.03, 0.11]	[0.07, 0.32]
1	[0.07, 0.13]	[0.16, 0.33]	[0.27, 0.58]
0.97	[0.28, 0.36]	[0.39, 0.59]	[0.53, 0.89]

Notes: Lower and upper bounds for the normalized present value of the direct welfare effect in equation 6 as a function of the risk aversion parameter (γ), college student sample, and $R\beta$. See Section 7 for details. All dollar amounts adjusted for inflation (2013$).