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ABSTRACT

Monthly government transfer programs create cycles of consumption that track the timing of benefit receipt. In this paper, we exploit state-level variation in the staggered timing of nutritional assistance benefit issuance across households to analyze how this monthly cyclicality in food availability affects academic achievement. Using individual-level score data from a large national college admissions exam in the United States linked to national college enrollment data, we find that taking this high-stakes exam in the last two weeks of the SNAP benefit cycle reduces test scores and lowers the probability of attending a 4-year college for low-income high school students.

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1 Introduction

There is a strong link between income inequality and nutritional inequality. More than 35 percent of families under the federal poverty line are food insecure, compared to less than 10 percent for those with incomes more than three times the federal poverty line (Schanzenbach, Bauer, and Nantz, 2016). This inequality extends to and perhaps perpetuates inequality in human capital accumulation. Low socioeconomic status (SES) students perform increasingly worse on achievement tests relative to their higher-income peers, exacerbating gaps in high-school completion and college attendance (Reardon, 2011).

In this paper we exploit a natural experiment in the timing of Supplemental Nutrition Assistance Program (SNAP) benefits and show that the timing of benefits has substantial impacts on student achievement for low-income high school students. SNAP, formerly known as the Food Stamp Program, provides food-purchasing assistance to 41 million low-income Americans each year. Because states have authority to determine their own distribution schedules, there is significant variation in when households receive benefits. For example, while many states use case ID numbers to determine the monthly disbursement date, some use the first letter of a family's surname. For each household, benefits are issued on the same day each month, and no household currently receives SNAP benefits more than once per month. As a result, recent studies have shown that households increase the quantity and quality of food expenditures right after SNAP receipt and subsequently decrease consumption, creating a "calorie crunch" just before their next disbursement (Shapiro, 2005; Kuhn, 2018; Tarasuk, McIntyre, and Li, 2007; Castner and Henke, 2011; Todd, 2015; Laurito and Schwartz, 2019).

To identify families most likely to experience food insecurity due to the "calorie crunch", we first use student data from 7 states and Washington DC that determine benefit timing by surname.[1] Then, we match SNAP schedules to the administration dates of the SAT, a high-stakes exam used for college admission decisions in the United States, to estimate how the timing of benefits affects test scores and college enrollment. Since the SAT date varies from year to year, we are able to measure effects of SNAP benefit disbursement across cohorts, states, and years.

Using detailed, individual-level data on SAT scores and college attendance, we find that low-

[1] These data contain information on a student's potential benefit cycle, based on the first letter of their surname, and measures of low-income status.

income students who sit for the exam two weeks after their assigned SNAP issuance date score around 6 points, or 0.06 standard deviations, lower than those who sit in the two weeks following disbursement.[2] We also find some evidence that low-income students scoring comparatively lower on their SAT are 0.7 percentage points less likely to initially attend a 4-year college, and those who do attend college attend less-selective universities. Because we are not able to directly link students receiving SNAP to those taking the SAT, we note that these effects are intent-to-treat estimates and represent a lower bound of the effects of nutritional resource scarcity on student performance. Moreover, we note that stress, family conflict, and hunger may all play a role in affecting academic achievement when households exhaust their SNAP benefits, and our estimates are unable to disentangle each contributing effect. Even so, we estimate in our subset of 7 states plus DC that this relative performance loss results in over 1,150 students not initially enrolling in a 4-year college.

Our findings expand on and contribute to the current literature in a number of ways. We build on a body of work showing that short-run environmental and psychological shocks, including sleep, temperature, pollution, local violence, and stress, can affect students' cognitive performance, to provide new evidence of the effects of nutritional shocks on academic performance and longer-run outcomes.[3] Previous research on the relationship between nutritional quality and educational outcomes has generally focused on long-term measures of food security or program participation, rather than the causal effect of immediate nutritional shortages.[4] While there is some evidence

[2]We note that these effects are smaller than the standard error of measurement calculated by the College Board (approximately 32 points), but fit within the 0.002–0.3 standard deviations range of estimates of related SAT interventions, discussed in further detail below.

[3]In particular, Alhola and Polo-Kantola (2007) provides a literature review showing sleep deprivation impairs attention and long-term memory. Zivin, Hsiang, and Neidell (2017) finds that changing the temperature 10 degrees Celsius decreases math scores by 0.12 standard deviations, while Garg, Jagnani, and Taraz (2019) finds that high temperatures similarly reduce math and reading scores. Ebenstein, Lavy, and Roth (2016) uses data on Israeli students and finds that a 10-unit increase in PM2.5 exposure decreases student performance by 0.083 standard deviations, lowers educational attainment by 3 percentage points and earnings by 2.1 percent. Chang and Padilla-Romo (2019) use data from Mexico and determine that exposure to nearby violent crime the week before a high-stakes test reduces test scores for female students (but not male students) by 0.11 standard deviations. Heissell, Adam, Doleac, Figlio, and Meer (2019) shows that low-income students in grades 3–8 experiencing high levels of cortisol during high-stakes standardized exam score 0.4 standard deviations lower than expected. Mani, Mullainathan, Shafir, and Zhao (2013) run a randomized controlled trial and show that inducing thoughts about finances reduces cognitive performance among the low-income individuals.

[4]For example, Winicki and Jemison (2003) report that the children of parents who report frequently worrying about food running out due to lack of income, or that their children have skipped at least one meal in the last 12 months because money was not available, perform worse on kindergarten assessments. Beharie, Mercado, and McKay (2017) find that among children who are living in poverty, SNAP participants have lower rates of grade retention. Laurito and Schwartz (2019) find that SNAP households are more likely to participate in school lunch at the end of the SNAP benefit cycle. Aurino, Fledderjohann, and Vellakkal (2019) find that adolescents in food-insecure households

that school-sponsored lunch programs can mitigate these effects for elementary-aged and middle-school children, there is less evidence on how food availability affects educational attainment for high-school students (Figlio and Winicki, 2005; Schwartz and Rothbart, 2019; Mangrum, 2019).[5]

Two recent studies focus on performance on single-state assessments in young children.[6] Gassman-Pines and Bellows (2018) estimate the relationship between days since SNAP receipt and test scores using OLS and find that for third through eighth graders in North Carolina end-of-grade test scores peak by 0.021–0.022 standard deviations 17–19 days after benefit issuance. They interpret these relatively small effects on test scores as a delayed effect of the improved nutrition and reduced household stress induced by the receipt of a SNAP payment. Cotti, Gordanier, and Ozturk (2015) exploit variations in SNAP disbursement schedules and exam testing dates in South Carolina and find a negative effect of taking the exam towards the end of the benefit cycle on third through eighth grade standardized math test scores, particularly for African American boys. However, we note that these results vary depending based on subgroup.

Our study has several key differences relative to the existing literature. First, the aforementioned studies focus on standardized tests that were high-stakes for the schools but not the students. Schools thus had incentives to mitigate factors, nutritional or otherwise, that would hurt student test scores, while the students themselves suffered no potential consequences of the calendar-induced inequality. In particular, these state standardized tests are taken each year on a weekday, when school lunch and breakfast programs may help fill gaps in a student's nutritional intake, and schools may alter caloric offerings to boost scores. In contrast, the SAT is high-stakes for students but does not affect funding or hiring decisions for schools and is generally taken on the weekend, further lessening the ability for schools to reduce nutritional gaps with free or reduced-price breakfast and lunch. Second, using college attendance data, we measure long-term consequences of food scarcity using information on college matriculation rates and college quality, which more closely reflect

in India score lower on vocabulary, reading, math, and language tests.

[5]Specifically, Figlio and Winicki (2005) finds that increasing calories on school menus on testing days increases math and English pass rates by 11.1 percent and 5.8 percent, respectively. Schwartz and Rothbart (2019) estimates the impact of providing universal free lunch to middle-school students in New York City and finds that school lunch participation increases test scores by 0.08 standard deviations in math and 0.07 standard deviations in reading. Mangrum (2019) analyzes a program that provided low-income elementary students with take-home meals at school on Fridays and finds that treated students scored 0.16–0.28 standard deviations higher on reading and math tests.

[6]Other work provides evidence that the SNAP benefit cycle has important effects on students beyond test scores as well. For example, Gennetian, Seshadri, Hess, Winn, and George (2016) finds that participating students in grades 5–8 are more likely to receive a disciplinary infraction at the end of the benefit month, as compared to non-SNAP students.

achievement gaps in adults, as best as these outcomes can be measured by cognitive test scores. In doing so, we link the cyclicality of in-kind food benefits in adolescence with determinants of adult earnings through the mechanism of underperformance on high-stakes exams.

The remainder of the paper is organized as follows. In the next section, we discuss in more detail how SNAP issuance schedules present a natural experiment for studying the effects of food insecurity on adolescent outcomes. We then describe our data and empirical approach and present the results of our analysis on test scores and college outcomes. We conclude by providing evidence against the existence of strategic test-scheduling behavior by students and discuss the costs of nutritional resource scarcity in lost wages.

2 Background on SNAP Issuance Schedules

SNAP is a means-tested entitlement program administered and funded by the United States Department of Agriculture (USDA).[7] Each month participating households receive cash-like electronic food vouchers to be spent at authorized SNAP retailers. Although SNAP is federally funded, and the USDA sets minimum allotment standards, state public assistance agencies run the program through their local offices and determine the organization and timing of benefits. As a result, there is significant variation in state SNAP disbursement schedules. While seven states currently distribute all benefits on one day of the month, a majority of states stagger issuance throughout the month, allocating different households benefits on different days of the month.

We focus on students in DC as well as 7 states that assign benefit dates by last name: Arizona, Indiana, Iowa, Kansas, Maryland, Utah, and West Virginia.[8] Table A1 provides these schedules of SNAP issuance days throughout the month based on the first letter of the last name, and we will henceforth refer to these separate groups as "letter groups." Since states vary in the assignment of letter groups and receipt day, and SAT test date opportunities are the same for all students, we use this last name-based benefit issuance scheme to isolate as-good-as-random variation in the timing of receipt in our empirical models, which we discuss in further detail below.

[7] For more details on the program and its administration, see `https://www.fns.usda.gov/snap/facts`.

[8] Although Connecticut, Hawaii, and Wyoming also stagger benefits by last name, SNAP issuance dates are closely clustered within 2–3 days, which does not provide enough variation to differentiate between potentially "SNAP scarce" or "not SNAP scarce" students for this analysis. Delaware was the only state to change its SNAP schedule timing during this period; we drop Delaware from the analysis (because the schedule is at times ambiguous), but its inclusion does not impact results.

3 Data

3.1 SAT and College Attendance Data

To measure how SNAP timing affects academic performance and post-secondary enrollment, we use administrative data on SAT scores, college attendance, and college selectivity from three main data sets for students in high school cohorts between 2009 and 2014. Data on student characteristics, including race, ethnicity, gender, and grade, as well as high-school characteristics, and SAT scores are from College Board. The SAT is a college admissions exam, administered by College Board, intended to test college readiness. Across the US, high-school students voluntarily sit for the 3-hour exam on 1 of 7 annual offered test dates, typically in their junior or senior year. The SAT consists of math and verbal sections scored on a 200 to 800 point scale, with a highest possible composite score of 1600. The scores are scaled by College Board depending on test difficulty. In 2014, the average SAT score among college-bound seniors was 1010 (The College Board, 2016).

Students are allowed to retake the SAT as many times as they wish. However, retakers vary from other students along important unobservable dimensions like race and socioeconomic status (see Goodman, Guarntz, and Smith, 2020), and in this context, low-income students who experience SNAP scarcity are more likely to retake the exam. We keep only first-time SAT scores to avoid the issues created by this endogenous sample selection.[9] For similar reasons, we also use only test takers in their junior or senior year of high school.

College attendance data are from the National Student Clearinghouse (NSC) for 2009–2014 cohorts. These data contain information on college going, including enrollment and information on whether the institution is considered a 2-year or 4-year college. As of 2015, over 3,600 colleges and universities participate in the NSC, comprising over 98 percent of all students enrolled in American postsecondary institutions.[10] Despite the fact that the NSC tracks each college and university that a student attends, we only consider the first destination, and we do not consider graduation as an outcome due to the fact that the cohorts observed in our data have not had enough time to graduate by the end of our sample period. Importantly, the NSC tracks students' outcomes at all institutions of higher education, so we retain outcomes for students who attend an out-of-state

[9] This precludes us from leveraging students who take multiple tests to exploit within student variation in SNAP scarcity via student fixed effects.

[10] See Dynarski, Hemelt, and Hyman (2015) for information regarding deficiencies in NSC data.

or private institution, despite only looking at students who take the exam in a limited number of states.

We measure college selectivity using data from the National Center for Education Statistics Integrated Postsecondary Education Data System (IPEDS). These data include institution-level information on admissions, 12-month enrollment, graduation rates, flagship status, and whether the institution is classified as "selective" according to the Barron's Profiles of American Colleges.[11] We do not observe college quality measures for students who do not attend college, but we do know where every SAT-taker attends college if they do. In our main models we use the same sample throughout, controlling for whether a student did not attend college when the outcome of interest is a measure of college quality.

3.2 Potential SNAP Eligibility

SNAP is a means-tested program. We cannot directly observe in our data whether any student is a SNAP participant, but can use multiple income measures to classify those who likely would be eligible. First, we observe the student's reported household income on the questionnaire given to SAT-takers, categorized into $10,000 or $20,000 income bins. Our preferred approach uses this binned income to judge whether a student is a likely SNAP participant. Although SNAP eligibility limits vary based on state and federal regulations, it is very unlikely that any family earning more than $60,000 per year would be able to participate in the program. Indeed, based on data from the SNAP Quality Control Database, a nationally representative survey of SNAP participants, all SNAP households in our 7 sample states and Washington DC with one or more 16- and/or 17-year olds reported having a household income below $50,000 in 2014, although approximately one percent of respondents reported an income of more than $40,000.[12] This provides us with reason to believe that some students reporting a household income of $40,000–$60,000 are participating in the program, and none over $60,000 should be participating. In our preferred specifications, we classify students as low-income if they select a bin below $60,000, although we additionally present

[11]For Barron's selectivity categories, "1" indicates colleges that are "most competitive," "2" is "highly competitive plus," "3" is "highly competitive," and "4 is "very competitive plus." See `https://archive.nytimes.com/www.nytimes.com/interactive/2013/04/04/business/economy/economix-selectivity-table.html` for a list of colleges ranked by their selectivity score.

[12]These publicly available data contain information on 48,250 households categorically eligible for SNAP or eligible via applicable income and asset tests, and are accessible here: `https://host76.mathematica-mpr.com/fns/Download.aspx?`.

results for households earning below $40,000.

3.3 Defining Household Income

Because household income data are self-reported by students, we additionally use several alternative definitions of whether a student is low-income. We consider College Board fee waivers as a measure of low-income status, as waivers are available upon request to students who qualify for Free or Reduced Price Lunch (FRPL). In practice, the granting of fee waivers is not guaranteed due to the request process, making this an imperfect measure as well.[13] We also create both school-level and geographic measures to get a better sense of students who are most likely to be affected by SNAP cyclicality. In our school-level measures we classify students as attending a low-income school if 50% of students who report an income select a bin below $60,000.

Moreover, students report their resident zip code which we merge with Census data from the 2012 American Community Survey to track levels of income and SNAP participation within the area that a student lives. Therefore, we define a student's zip code as low-income if the median income is below $60,000 and define a zip code as high SNAP usage if more than 15% of residents participate in SNAP.[14]

Because we selected these cutoffs among other options, we also report treatment effects for individual bins that we expect to be treated and not treated to show that results are concentrated among low-income students. Overall, we focus on students who reported income in the College Board survey, match to a zip code, and attend a school containing observations from at least 50 students.[15]

4 Implementing the Natural Experiment

In our main analysis, we adopt a fixed effects approach that exploits variation in state-level SNAP benefit schedules and accounts for the recurring timing of benefits, individual characteristics that

[13]For reference, in our sample 160,089 students report an income below $60,000, but only 39 percent of these students use a fee waiver for the SAT. Out of the students reporting a household income below $40,000, approximately half use a fee waiver.

[14]This SNAP usage cutoff, although seemingly low is around 1 standard deviation above the mean in our sample, and nearly the 90th percentile.

[15]When we do not condition on students answering this survey question, in an effort to include more observations, and focus only on zip code definitions of low-income status, our results are similar in sign and magnitude across outcomes.

are correlated with benefit timing, and unobserved school characteristics.

We begin by considering a model of the following form:

$$y_{icst} = \beta_0 + \beta_1 SNAP_{icst} + \pi_c + \psi_d + \gamma_s + \lambda_t + X_{icst} + u_{icst}, \tag{1}$$

where i, c, s, t represent the student, cohort, school, and test, respectively. y represents outcome variables of interest: SAT score, no college attendance, 2-year college attendance, 4-year college attendance, and college selectivity measures.[16] We use two different measures of SNAP-induced scarcity, represented in the above equation as $SNAP_{icst}$. First, we consider a student i to be "SNAP scarce" if student i sits for SAT exam t 15 days or more after SNAP issuance. This measure is an indicator variable equal to one if a student meets that criteria and zero otherwise. Based on the literature on SNAP families' consumption decisions, 15 days is a reasonable estimate for when families begin to experience SNAP-induced scarcity, as a majority of households exhaust all of their benefits before that point (Castner and Henke, 2011). Alternatively, we measure scarcity more continuously as the number of days since an individual could have been issued SNAP benefits, based on a student's last name.[17] π_c are cohort fixed effects to account for unobserved characteristics across graduation cohorts, λ_t are test fixed effects to control for differences in SAT exam difficulty common to a particular test, and γ_s are high-school fixed effects to control for any systematic differences across schools. ψ_d represent state-by- disbursement day-of-month fixed effects. These are akin to first letter of last name group fixed effects to control for common characteristics of students with the same disbursement date and state, and are especially important to include if last name letter corresponds to race or other factors related to average test scores. Although controlling for first letter of last name would be more accurate, we do not have first letter of last name for privacy reasons.

In some specifications, we include X_{icst}, which contains dummy variables for ethnicity, and

[16] Math and verbal scores contribute nearly equally to the overall effect, so we present combined scores throughout the paper. Appendix Table A2 and Appendix Figure A2 contain scores for math and verbal sections separately for reference.

[17] Appendix Figure A3 plots the residuals of SAT scores, and college attendance variables (after removing the standard set of controls and fixed effects) by the number of days since SNAP benefit disbursement day. We plot the low- and high-income students separately to show that downward trends in outcomes for low-income students are generally not present for higher-income students.

gender. Finally, u_{icst} is a random error term that we allow to be correlated across time within a state-by-cohort-by day of disbursement.[18]

There are a number of reasons that we opt to use this specification. We recognize that first letter of last name may be related to race or ethnicity, as some surnames are more common within a given race or ethnicity. This implies that last name letters may be predicted by race and/or ethnicity, and therefore the effects of such benefit schedules are not totally random (e.g. see Tables 1 and A3). Outside of controlling for race and ethnicity directly, we also include the state-by-disbursement day-of-month fixed effects to account for this or any other impacts of first letter of last name on academic achievement.[19] We also note that, based on the states' distribution schedules and the limited number of SAT dates, many students sit for the SAT either near the beginning or near the very end of their potential SNAP benefit month, with fewer students receiving benefits in days 10–20.[20]

Because SAT exam dates vary across months and within months across cohorts, causal identification in this context relies on comparisons between students within cohort, exam, school, and last name letter group. Our approach implies that, once accounting for the extensive set of fixed effects listed above, there is as-good-as-random variation in students taking the test while experiencing SNAP-induced scarcity. In Section 5, we discuss this idea further and provide additional tests to support the validity of our identification assumption.

As discussed above, it is very unlikely that a student with household income above \$60,000 would be able to participate in SNAP. Exploiting the fact that SNAP is a means-tested program, we consider those students who report an income below that threshold to be the potential treatment group in a difference-in-differences style model as our main specification. We focus on this approach for two reasons. First, although effects are still intent-to-treat in this model, this coefficient will be closer to capturing the treatment-on-the-treated than the full sample approach of Equation (1). Second, using higher-income students as a control group helps to address any lingering concerns that our set of fixed effects cannot fully account for endogeneity between scores and taking the exam

[18]While we cluster on state-by-disbursement day-of-month-by-cohort level because that determines for which test a student is considered "SNAP scarce," our estimates are not sensitive to this choice. Clustering by state and state-by-cohort yield similar results, and results can be found in Table A4.

[19]Another possibility is that a student has a different name than the parent receiving benefits. We note that while this would result in measurement error, it should bias our estimates towards zero.

[20]Refer to Figure A1 for a density plot of the number of students in each potential SNAP benefit day bin.

more than 15 days after potential disbursement. We estimate the following:

$$y_{icst} = \beta_0 + \beta_1 SNAP_{icst} * lowincome_{icst} + \beta_2 SNAP_{icst} + \beta_3 lowincome_{icst} + \pi_c + \psi_d + \gamma_s + \lambda_t + X_{icst} + u_{icst}, \tag{2}$$

where and $lowincome_{icst}$ is an indicator variable equal to one if a student is identified as low income and all other variables remain unchanged from Equation (1). In our preferred specification, we consider a student low income if their reported household income is below \$60,000, but we also compare other measures of this, including student-level and community-level income measures. Our coefficients of interest in Equations (1) and (2) are both β_1. These coefficients identify the effect of nutritional resource scarcity off of differences in the change in performance of individuals with the same letter group sitting for the exam at different times between high-income (non-SNAP participant) and low-income (likely SNAP participant) students.

5 Estimating the Effects of Nutritional Shortfalls on Cognitive Performance and College Attendance

5.1 Effects on SAT Scores

Table 1 separately presents summary statistics. In the first two columns, we report means and standard deviations for all students, then in Columns 3 and 4 we report means for students within 15–31 days of potential SNAP receipt (i.e. "SNAP scarce" students), based on last name, and those within 0–14 days of SNAP issuance (i.e. "Not SNAP scarce" students). In the last column, we present estimates from a *t*-test showing whether the means for these two groups of students are statistically different for each outcome.[21] These statistics show that, on average, SAT scores are approximately 5 points lower for the SNAP scarce students. (Math and verbal scores are approximately 3.7 and 1.3 points lower, respectively.) Moreover, these students are more likely to attend no college or attend a 2-year college, while students who take the SAT for the first time while not experiencing SNAP scarcity are more likely to attend a 4-year college but less likely to

[21] Similarly, we provide summary statistics by a student's reported household income level in Table A3.

attend a flagship or more selective college. Although this simple comparison provides some useful descriptive evidence on the relationship between SNAP issuance, SAT scores and college attendance, the empirical analyses below address a wide set of potential confounders, including differences in demographics, economic conditions, and state-wide policies. Some of these confounders are related to a student's first letter of their last name, which is an important source of underlying variation in SNAP scarcity. This relationship is an important factor in our preference for using the difference-in-difference model described in Equation (2), and it means that a balance test is likely to be uninformative as it will not account for the endogeneity related to first letter of last name and other confounders.

In Figure 1 we analyze the effects of SNAP scarcity across household income levels, using an adaptation of Equation (2). We include indicator variables for each family income bin in the SAT survey and their interactions with our "treatment" variable indicating SNAP scarcity.[22] We present coefficients and 95% confidence intervals for each of the interactions.

As discussed previously, it is highly unlikely that any student in a household reporting over $60,000 in annual income would be a SNAP participant. In Figure 1, we find statistically significant effects for SAT scores in income ranges below this cutoff (with the exception of the $10,000 to $20,000 bin). Point estimates indicate that taking the exam in the last two weeks of the benefit cycle reduces SAT scores by 4–8 points for low-income students.

Overall, these estimates imply that the reach of SNAP issuance policies, in terms of having an impact on student testing performance, is concentrated within the population of students reporting household annual income less than $60,000. Therefore, in subsequent analysis we focus on specifications that compare potentially SNAP scarce students in these lower-income households to potentially SNAP scarce students who report household income over $60,000.[23] Because SNAP can serve students with higher incomes, depending on household size, and because some students may not accurately report their household income, this approach can be viewed as estimating a lower bound of the true treatment effect. We also emphasize that any estimates based on this research

[22]Students can select $10,000 bins for incomes below $80,000, but not above. We group all students reporting over $100,00 together.

[23]Dropping students reporting income between $40,000-$120,000 yields estimates that are statistically significant at the 1% level and indicate a 6.6 point decrease in SAT scores. Omitting only students in the somewhat ambiguously treated $40,000–$60,000 bin, we find a 6.3 point decrease in scores, again statistically significant at the 1% level. Estimates of Equation 1 on only students reporting income below $60,000 yield a decrease of 2.3 SAT points. Estimates of Equation 1 for only students with household incomes over $120,000 are small and statistically insignificant.

design will represent intent-to-treat effects, because SNAP participation for eligible households is less than 100 percent. Thus, our estimates will likely understate the effects of SNAP on the students actually served.

In Table 2 we show corresponding effects of SNAP issuance on SAT scores. Beginning with the top panel, which reports estimates from Equation (2), in Column 1 we control for state-specific letter group (i.e. "state-by-disbursement day-of-month"), cohort, and test fixed effects.[24] We find that when students sit for the SAT in the last two weeks of the benefit cycle, scores fall by 10.8 points. As expected, low-income students perform worse on the SAT than their higher-income counterparts.

The inclusion of state-by-disbursement day-of-month (i.e. state-by-letter group) fixed effects should account for any permanent differences in race or socioeconomic status that are correlated within state with last name. In Column 2 we include student-level controls for race, ethnicity and gender. We find that disparities in SAT scores persist across race, ethnicity, and student background, with black students scoring around 140 SAT points lower than white students and Hispanic students scoring around 60 points lower. When including these controls, estimates indicate that SNAP scarcity reduces scores by 7 points for low-income students.

We present our preferred specification in Column 3, which includes school fixed effects. We do so to account for the fact that school interventions, like counselors or other nutritional initiatives, affect SAT performance differentially across students. Importantly, these controls have little impact on our point estimates, suggesting that, all else equal, the effects within schools do not differ from effects across schools. Across all specifications, the coefficient for SNAP scarcity (β_2), which measures the impact on high-income students, is not statistically significant, suggesting our controls are likely capturing confounders for the natural experiment, mirroring findings from Figure 1.

We find that, for low-income students, taking the SAT at the end of the SNAP benefit cycle leads to a reduction in SAT scores of 5.8 points. Overall, these results imply that taking the exam during periods of relative food insecurity reduces scores by approximately 0.06 standard deviations, which suggests that SNAP timing has larger effects on test scores than heat exposure, but smaller effects than retaking the exam (Goodman, Hurwitz, Park, and Smith, 2020; Goodman, Guarntz, and

[24]We have also substituted "SAT opportunity" (i.e. whether it's the first, second, or so on test of the 11 most popular exam choices for a cohort) for exact exam fixed effects and zip code fixed effects for school fixed effects. Estimates are similar to those in Tables 2 and 3, and can be found in Table A4. Moreover, our main estimates are not sensitive to dropping any one state or any one exam, and indicate effects of approximately 4–8 SAT points. See Figure A4.

Smith, 2020). Furthermore, our effects are in line with other work showing that students in grades 3–8 receiving benefits 26 days prior to a standardized exam score 0.014–0.045 standard deviations lower than expected (Cotti, Gordanier, and Ozturk, 2018).[25]

In the lower panel of Table 2, we estimate Equation (2) using a continuous definition of SNAP scarcity that measures the impact of SNAP scarcity as the days since the last eligible disbursement for a student's letter group. Similar to our discrete measure, we find performance decreases as students reach the end of the benefit month. Specifically, we find that SAT scores fall by 0.21 points, respectively, for each day after initial SNAP disbursement. Moreover, in Figure A3, we plot means of residuals for students by high-income and low-income status separately to highlight the day-by-day variation in scores. While SAT scores for higher-income students remain relatively flat over the month, scores for low-income students are highest at the beginning of the benefit month (e.g. days 1–5) and dip to their lowest levels between days 14–20.[26]

There are a number of different ways a 6-point decrease in the average SAT composite score could occur, and not all may be of equal value to students or policymakers.[27] For example, suppose this decrease was driven solely by a large drop in the scores of the highest achievers. While representing a real decrease in cognitive performance, it may have little actual impact on the trajectory of low-income students. High-ability, low-income students rarely apply to the selective schools that require such high scores for entry (Hoxby and Avery, 2013). In contrast, if these losses were driven by a decrease in performance by marginal students who just barely qualified for admission to state flagships, the economic losses could be quite large (Hoekstra, 2009).

We investigate this latter scenario by analyzing changes in the density of scores in Figure 2. Here, we estimate a set of fixed effects models, as specified by Equation (1), considering whether a student scored in a 100-point range on the SAT. We focus on low-income students for simplicity. Our findings suggest that the performance losses are indeed concentrated among marginal students. Students at the end of their potential SNAP benefit cycle are more likely to score between 800–900 points

[25] In particular, Goodman, Hurwitz, Park, and Smith (2020) document that a one standard deviation in heat exposure (or three days about 90 degrees F) reduces test scores by 0.002 standard deviations, while Goodman, Guarntz, and Smith (2020) find that students retaking the SAT improve their scores by 90 points, on average, or 0.3 standard deviations.

[26] Specifically, we present residuals from models based on Equation (1), estimating effects for low- and high-income students separately that include all fixed effects and race and gender controls, and exclude the variable of interest and income variables. We also report coefficients on linear and quadratic functions of days since disbursement for estimates of the continuous form of Equation (2) extended to a quadratic form.

[27] This is because test scores are ordinal measures of achievement. See Bond and Lang (2013).

and less likely to score between 1000–1200 points— well-within the relevant scope for admissions decisions.[28] In the following section, we will look at the effects on these college attendance and quality outcomes directly.

5.2 Effects on College Attendance and Quality

In the above section, we present stark evidence that low-income students perform relatively poorly on the SAT in the two weeks preceding SNAP disbursement. Given that the SAT is a prominently used college admissions exam, and many flagship schools have strict SAT admissions and/or financial aid cutoffs, any effects on SAT scores could have large long-run consequences for underperforming students. In this section, we consider to what extent these effects translate into college attendance and quality.

In Table 3, we estimate the effects of SNAP disbursement on initial college attendance using Equation (2) with a full set of controls (as in Column 3 in Table 2). In general, we note that estimates indicate that low-income students are more likely to forgo college, or enroll in less selective colleges. While we find little evidence that taking the exam during a time of scarcity reduces the rate of post-secondary enrollment for low-income students (Column 2), we do see evidence that it changes the type of colleges where students enroll (Columns 3 and 4). Students taking the exam during a period of potential food scarcity are 0.89 percentage points more likely to attend a 2-year college, and 0.72 percentage points less likely to attend a 4-year college.[29] This corresponds to approximately 1,150 fewer students initially attending a 4-year college as a result of taking the exam during a period of relative resource scarcity over the span of 6 cohorts in our data.[30] Given that many 2-year colleges do not require SAT scores for admission, this result is perhaps unsurprising.

[28]These cutoffs vary by state. For example, the SAT admissions cutoff for West Virginia University is a composite score of 910, while the recommended score at Indiana University is 1140. Moreover, Goodman, Hurwitz, and Smith (2017) find that many colleges use hidden SAT cutoffs, and that these cutoffs substantially affect a student's college-going behavior. In particular, marginal low-income students that just made the cutoff were 10–14 percentage points more likely to attend a 4-year college.

[29]For context, our estimates imply an economically meaningful effect, but are smaller than SAT-focused initiatives. In our sample, 68.1 percent of students who are not experiencing scarcity when they take the exam attend a 4-year college, so the 0.7 percentage point decrease is less than a 1 percent decrease. Specifically, Bulman (2015) analyzes how much SAT taking responds to the distance of an available testing center and finds that opening a testing center corresponds to an increase in 4-year enrollment by 4 percent, while offering free in-school administration of the SAT increases enrollment by nearly 8 percent. Goodman, Guarntz, and Smith (2020) estimate that retaking the SAT increases the probability of enrolling in a 4-year college by 20 percent, and Hurwitz, Smith, Niu, and Howell (2015) document that SAT requirements for high-school juniors increases 4-year enrollment by 4-6 percent.

[30]This calculation is based on the fact that our data contain 169,085 students within a household income below $60,000.

Table 3 Columns 5–8 explore the quality dimension further, by estimating the effect on the overall graduation rate and the average SAT score of the college attended, whether or not the school is classified as "selective" according to Barron's rankings, and if the college is considered a flagship university.[31] We find evidence for a reduction in quality on each of these dimensions. In particular, students who take the SAT for the first time 3–4 weeks after possible SNAP issuance attend colleges with a 2.81 point lower average SAT score. Moreover, these students are 0.93 percentage points less likely to attend a selective college and are 0.51 percentage points (2.9 percent) less likely to attend a flagship.

These estimated magnitudes provide further support for the notion that SNAP cyclicality affects student test scores and longer-run academic outcomes. Based on the underlying data for all students, we estimate that for every increase of 10 SAT points, a student is 0.87 percentage points more likely to attend college. If we rescale our main estimates from Table 2 to capture the impact of 6–11 SAT points using this relationship in the overall data, we should estimate a change in college attendance of 0.52–0.95 percentage points. Our findings indicate that a student sitting for the SAT at the end of the potential benefit cycle is 0.72 percentage points less likely to attend college. Therefore, our college attendance estimates are in line with what would be expected for the corresponding estimated change in SAT scores.

These findings are especially important for informing how immediate resource scarcity can affect student trajectories. For example, Goodman, Hurwitz, and Smith (2017) show that attending a higher quality institution increases college completion for low-income students by 46 percentage points, which is consistent with other work showing the graduation rate penalty associated with students choosing a 2-year over a 4-year college (Long and Kurlaender, 2009; Reynolds, 2012; Brand, Pfeffer, and Goldrick-Rab, 2014). In Section 6 we further discuss the potential costs to students facing these food availability gaps.

[31] For students who do not attend college, we assign 0 for all college selectivity measures and we add a control to Equation (2) indicating that a student did not attend college. If we instead only consider college quality for students who attend some kind of post-secondary education, we find effects are a slightly larger and remain statistically significant.

5.3 Subgroups and Treatment-on-the-Treated Effect

Because we cannot observe whether any student is enrolled in SNAP, all of our findings so far represent intent-to-treat estimates. In this section, we present additional subgroup results for the groups we think are most likely to experience food insecurity. As any of our subgroups approaches 100% SNAP participation, our estimates will approach the treatment-on-the-treated effect for at least that subgroup.[32]

First, in Table 4, we show effects on scores, college attendance, and college selectivity outcomes by neighborhood type.[33] In the first panel, we use a school-level measure indicating that at least half of students in a school who report an income in the SAT survey report one that is below $60,000. In the second panel, we measure low-income status using SNAP usage in the student's zip code, considering all students whose zip codes have at least 15% SNAP participation. Last, we focus on zip codes where the median income is less than $60,000.[34]

Table 4 Column 1 reports effects on SAT scores. Overall, estimates are similar to our main results, but larger. We find that sitting for the exam at the end of the SNAP benefit cycle leads to a decrease in SAT score of approximately 9 points for students in low-income schools, or 0.09 standard deviations. Moreover, students living in zip codes with relatively high levels of SNAP participation experience a decrease of about 4.2 points, while effects for students living in low-income zip codes are relatively imprecise.

In Columns 2–4, we show estimates for college attendance outcomes. Across panels, we find that students in low-income schools, high SNAP usage zip codes, and low-income zip codes are between 0.5–1.2 percentage points less likely to go to any college, and are up to 1.6 percentage points less likely to attend a 4-year college. Estimates for 2-year colleges are statistically insignificant and relatively imprecise.

Additionally, in the last four columns, we show effects of SNAP cyclicality on college selectivity outcomes. In general, we find that students in low-income communities taking the exam when

[32] Alternatively, it is possible that by separating effects by income level, we are picking up heterogeneous effects; that is, higher student-reported income could have smaller or larger Food Stamp cycle impacts. Below we discuss results from models using several different measures of income, which paints a broader picture of the reduced-form effects.

[33] In Figures A2 and A5 we additionally present how these estimates change across these various poverty measures. Overall, estimates indicate that effects are largest for those areas with the most poverty.

[34] Given that school attended and zip code are both determined or defined geographically, we do not include school fixed effects, noting that including school fixed effects has little impact on our baseline estimates, reported in Table 2.

"SNAP scarce" attend less selective colleges with lower average graduation rates. Specifically, students in low-income high schools are 1.4 percentage points less likely to attend a selective college, and attend a college with a 3.5 point lower average SAT score. When analyzing high SNAP and low-income zip codes, these effects are similar; estimates indicate that for those low-income, "SNAP scarce" students attending college choose a school that has a lower average SAT score and are 0.7–0.9 percentage points less likely to choose a selective college.

Furthermore, we take advantage of the continuous nature of the SNAP participation variable by interacting it with $SNAP\ scarce_{icst}$, and we show these results in Table 5. Estimates for SAT scores indicate that students living in zip codes with 100% household SNAP participation score 60 points lower when they take the SAT 15 days or more after their SNAP benefit receipt date. In a zip code where 100% of children receive SNAP benefits, any student we observe must be a SNAP recipient - that means low-income students taking the SAT at the end of their SNAP benefit cycle experience a loss of up to 104 points on the exam. These reductions in SAT scores are mirrored by larger effects on college going and college selectivity outcomes.

That said, there are very few places where SNAP usage is so high, and none in our sample, so we are extrapolating out of sample. Moreover, this large estimate may not represent an average effect because it is possible that the effects are amplified in neighborhoods with high SNAP usage. While we recognize these realities, we submit that the results in Table 5 are a plausible upper bound of the treatment on the treated.[35]

In Tables 6 and 7, we further explore effects by income status to get a better sense of which students are most likely to be affected by SNAP benefit issuance timing. To do so, we interact various income measures used in the above analyses, to estimate effects of SNAP timing on SAT scores and college attendance for students that meet multiple low-income criteria, including reporting a household income below $60,000 and below $40,000, using a fee waiver, and attending a low-income high school (Table 6 Columns 1–4, respectively). Specifically, Columns 5 and 6 display effects for students who are low-income, based on the household income definition, and use a fee waiver. Columns 7–9 display effects for students in low-income households or students using a fee waiver and attending low-income schools. Columns 10 and 11 show effects for students that meet three criteria:

[35] Similarly, when using data on median income from the ACS, we find that a student living in a zip code with an additional $10,000 of median income will score around 2 points lower on the exam when experiencing scarcity. These estimates are consistent with the main models in Table 2.

reported low household income, used a fee waiver, and attended a low-income school. Estimates for our main variable of interest are negative and statistically significant across all columns. Effects are largest for low-income students attending low-income schools, which may indicate that there are spillover effects for these students, and/or fewer school resources to prepare students for SAT test day. Moreover, we note that effects for students using waivers are slightly smaller than the baseline estimates, suggesting that there is non-random selection into which students request a fee waiver.

In Table 7, we further explore effects for this select group of students. In the top panel, we estimate effects on SNAP scarce students using a fee waiver, while in the middle and bottom panel we additionally consider fee waiver students from low-income households as well as those from low-income households attending low-income schools. Overall, estimates indicate that SNAP scarcity does reduce SAT scores by 3–7 points for these students, although we estimate no statistically significant effects on college attendance. However, we note that our estimates indicate that when these students take the SAT at the end of their potential SNAP benefit cycle, they are less likely to attend a selective college, and attend colleges with 0.5–0.6 percentage point lower graduation rates.

Finally, to get a better sense of the treatment variation across student subgroups, in Figure 3 and Table A5, we explore how effects differ across minority status and gender.[36] Specifically, in Figure 3, the left panel of each figure displays point estimates from the labeled coefficient of interest and their corresponding 95 percent confidence intervals from analogues of Equation (2), interacting our main treatment variable ($SNAP\ scarce_{icst}$) with a dummy variable for the 4 most common reported selections for race/ethnicity: white, black, Hispanic, and Asian. We also include dummy variables for race (omitting white) and the interaction between the set of race dummy variables and $lowincome_{icst}$ to capture the effects of race alone and the interaction of race and socioeconomic status. In the right panel of each figure, we do the same for reported gender. Each shaded bar represents the cumulative effect of these three main equation coefficients.

Overall, estimates for Hispanic and Asian students are larger than our main results, with reductions in SAT scores ranging from 8–24 points, and reductions in 4-year college attendance ranging from 4.5–2.1 percentage points. For college attendance outcomes, black students are not impacted

[36]We note that only students who reported an answer to the race/ethnicity survey question are included in this analysis and those who selected "other" are omitted. Moreover, many of our race subgroups are geographically concentrated in our set of states. For example, the majority of the Hispanic students live in Arizona. While these results are interesting and informative, they should be interpreted cautiously.

any more than the general student population by SNAP scarcity. They may even be impacted less for some outcomes, namely whether they attend a 2-year college or attend a selective college. Because underrepresented minorities are less likely to attend high-quality institutions at baseline, this may reflect the fact that the possible magnitude of a reduction is limited.

When separating effects for low-income SNAP scarce students by gender, we find reductions in SAT scores for both male and female students; however, we note that such male students experience a larger overall drop than female students (8.7 versus 3.6 points) and are less likely to attend a four-year college. These findings are especially interesting considering the growing achievement gap, as the college enrollment rate for female students has outnumbered males since 2000, and females currently hold 57 percent of the bachelor's degrees awarded by U.S. institutions (Fry, 2019).[37]

5.4 Effects on Test-Taking

It is possible that students make decisions about whether to register for an exam or show up for an exam for which they are registered based on whether they are experiencing SNAP-induced scarcity on the test date. Based on the strength of norms about which tests students take, and the fact that registration deadlines are a month before the exam, we think that the latter phenomenon is more likely; specifically, students may not show up to take the test when they are experiencing SNAP scarcity. Unfortunately, we do not observe these "no shows" directly. Therefore, to investigate the extent to which SNAP benefit timing affects student selection into test taking, we instead use the even larger population of PSAT-takers to determine whether students are less likely to take the SAT (ever) when the test schedule is such that they are likely experiencing scarcity during the most popular tests.[38]

For each PSAT-taker, we create a measure of likely scarcity using the dates of SAT exams during that student's junior and senior year and their SNAP disbursement date. We determine whether the student would have been classified as "SNAP scarce" during the 4 most common exams: May and June of junior year and October and November of senior year. We then estimate a

[37]We have also considered effects by seniority. When we estimate effects for students taking the SAT as a junior and as a senior separately, estimates for both groups mirror the main results but are more pronounced for students taking the SAT as a senior. See Figure A6.

[38]The PSAT is an exam given only once per year primarily to freshmen-juniors in high school. While often cited as a practice for the SAT, as it is very similar in format, it also plays a primary role in the National Merit Scholars program. Eligibility for this nationwide scholarship program is determined by scores in the junior year of high school, and most college-bound students take it.

model using the proportion of those exams during which the student would have been classified as experiencing SNAP-induced scarcity as our independent variable, like substituting this proportion for $SNAPscarce_{icst}$ in Equation (1). Our outcome of interest is whether students ever take an SAT test. For reference, 10% of students have scarcity for zero exams, 16% have scarcity for 1 exam, 10% have scarcity for 2 exams, 20% have scarcity for 3 exams, and the remaining 44% have scarcity for all of the most common exams. These proportions are the same for students at low-income schools. We take the fact that so many students face scarcity during all of the major exams as further evidence that students are unlikely to intentionally schedule exam-taking during an exam when they do not experience scarcity.

We include controls for race and gender, and the full set of fixed effects as in Column 3 in Table 2. Importantly, we also cannot use a student's reported family income because it will only exist for students who take the SAT, so we instead rely on our measure of school-level socioeconomic status and our two zip code measures as defined in the previous section to focus on the students most likely impacted.

Table 8 contains the results of this analysis. Because the measure of scarcity ranges from zero to one, the coefficient captures the effect of a student experiencing scarcity for all 4 exams relative to experiencing scarcity for none of them. Estimates indicate that there is no perceptible effect on test-taking behavior. In Column 2 we analyze effects for students who attend low-income schools (again measured by the percentage of low-income students). Estimates are statistically insignificant are close to zero, suggesting no meaningful effects on test-taking behavior. Similarly, there are no differential effects related to zip code level poverty measures.[39]

6 Assessing Costs to Students

In this section, we aim to quantify the costs associated with performance losses for students who take the SAT while experiencing scarcity. First, we consider the tradeoffs in wages for attending a 4-year versus a 2-year college. Carnevale, Rose, and Cheah (2011) estimate that an average college

[39] We can also use the PSAT data to estimate whether "SNAP scarce" students perform worse on this exam as well. Overall, effects are smaller and less precise than our main results, indicating a 0.25 point decrease in PSAT scores (or 2.5 points scaled to SAT points) from estimating a model analogous to the first panel of Table 4, using low-income school attendance as an indicator that a student is low income. Estimates remain consistent if we focus only on students taking the PSAT in their junior year.

graduate will earn \$2.8 million over his/her lifetime. Reynolds (2012) estimates that wage penalties for starting at a 2-year college are approximately 3.0 percent for women and 2.3 percent for men, even if a student later matriculates to a 4-year college. Therefore, these estimates suggest that the lifetime penalty of the marginal student attending a 2-year college instead of a 4-year college is \$84,000 for women and \$64,400 for men.[40] If the 0.7 percentage point decrease that we find in 4-year college-going for low-income students is completely transferred to 2-year college attendance (as Table 3 suggests), then the foregone wages are at least \$85.3 million for the 1,150 students who do not attend a 4-year college.

If we instead focus on students who chose to forego college altogether, this wage gap is even higher. For example, the earnings of bachelor's graduates from households with earnings of less than 1.85 times the federal poverty level are 71 percent higher than those of high school graduates, or \$812,250, on average (Bartik and Hershbein, 2018).[41] If the 0.7 percentage point decrease that we find in 4-year college-going for low-income students results in those 1,150 students not attending college (as the geographic subgroups would suggest), the lost earnings are \$934 million.[42]

Next, we can consider the foregone benefits of a student who chooses to attend a 4-year college attending a less selective college. Dale and Krueger (2002) estimate up to a 7 percent wage premium for those attending a college whose students score 100 points higher on the SAT. Following the procedure in Pallais (2015), we use this estimate specifically since Dale and Krueger (2002) analyze a subset of low-income students. Because the students eligible for SNAP are low-income, these estimates will yield an estimate closer to the treatment on the treated. Using these estimates, the average lifetime wage cost of a low-income student scoring 6 points lower on the SAT and attending a less selective 4-year college is \$2,800,000 x 7% x 0.06= \$11,760. For our alternative measure of low-income students based on geography, estimates imply an even larger cost of \$2,800,000 x 7% x 0.09= \$17,640 (based on a 9-point reduction in SAT scores reported in the first panel of Table 4).

Moreover, these estimates will understate the costs of SNAP cyclicality to low-income students

[40] The calculations for men's and women's earnings respectively are \$2,800,000 x 3% and \$2,800,000 x 2.3%. Estimates are calculated in 2008 dollars.

[41] This is based on discounted lifetime earnings of \$475,000 for low-income students who obtain only a high school diploma (Bartik and Hershbein, 2018).

[42] Considering estimates from Bartik and Hershbein (2018) are not plausibly causal, this estimate is likely an upper bound. According to Zimmerman (2014), students just missing the cutoff for a 4-year state university yield total earnings losses of \$12,000 7 years after high-school graduation, although these gaps are expected to grow as workers age.

if graduation is more likely at these higher quality colleges. Indeed, Hoekstra (2009) finds that attending a flagship state university increases earnings by 20 percent. Similarly, Goodman, Hurwitz, and Smith (2017) find that inducing low-income students to attend a 4-year college instead of a 2-year college increases completion by 22 percentage points, suggesting that institutional peer effects play an important role in longer-run outcomes.

We recognize that for a student whose alternative is going straight into the workforce, the opportunity costs of attending college is lost wages at an entry-level job. We also acknowledge that there are additional costs and burdens a student must consider when deciding to attend a 4-year college over a 2-year college or no college at all. These upfront costs include time to complete the application to a 4-year school, the time of the admissions officer evaluating the application, tuition and fees, and potential moving and transitional/psychic costs that a student would otherwise not incur if they lived at home. These costs of attending college are salient for students, but unlikely to outweigh the benefits accrued to students of attending a 4-year college detailed above.

7 Discussion

In this paper we use variation in state SNAP schedules to analyze how nutritional assistance timing can affect high-stakes exam scores and college attendance. We find that when SAT dates fall more than two weeks after a student's SNAP benefit issuance date, SAT scores are 6 points lower for low-income students. This translates into lower 4-year college attendance, and we provide some evidence of substitution to 2-year colleges. Notably, we find large, robust effects indicating that students attend lower quality institutions measured by selectivity rankings and average SATs of admitted students. Effects are largest for students attending low-income schools and living in zip codes with high levels of SNAP participation, and are not driven by changes in test-taking behavior.

Most importantly, these findings are critical for understanding the hurdles to college going that children in poverty face. Taken together, our findings suggest that the documented socioeconomic gap in nutritional intake results in lifelong gaps in human capital formation, and the potential benefits of alleviating resource scarcity at the end of the benefit month could far outweigh administrative transition costs. Considering the evidence that lower SAT scores result in students attending lower-quality colleges, leading to lower lifetime wages, our findings provide evidence that achievement gaps for low-income students may be related to the timing of nutritional assistance (Hoekstra, 2009). We also show that students living in low-income communities perform even worse on the SAT when experiencing resource scarcity.

Finally, we note that there are a number of policy implications that could address the obstacles that low-income children face and ensure that food cyclicality does not stunt the earnings trajectory for these students. Considering that food insecurity, and the household financial and relationship stressors that can accompany it, can affect not only the SAT, but standardized exams throughout a child's schooling career, policymakers should consider the spillover benefits of optimal SNAP timing and/or expanding the scope of school meals. For example, offering the SAT and other high-stakes exams on school days would potentially increase participation and allow students eligible for free school breakfast and lunch to eat prior to the test. Indeed, many school districts have in recent years been moving in this direction; as of 2019, 43 percent of SAT takers took the exam on a school day, up from 36 percent the previous year (The College Board, 2019).

Moreover, expanding SNAP participation or monthly benefit amounts could in and of itself improve gaps in nutritional availability and, subsequently, child health and academic performance (East, 2018). Alternatively, deliberately staggering the electronic delivery of multiple types of transfers over the course of the month would be relatively low cost, but could benefit families and communities more broadly.[43] Given that the cyclicality of SNAP benefits has been shown to affect household conflict (Carr and Packham, 2019b), crime (Carr and Packham, 2019a), alcohol purchases (Castellari, Cotti, Gordanier, and Ozturk, 2017), drunk driving (Cotti, Gordanier, and Ozturk, 2015), and substance use events (Allen, Atwood, Young, Pauly, and Harrington, 2019) our estimates contribute to a broader literature on how the timing of other government transfers can affect total social welfare. In focusing on the timing of public health interventions, policymakers could more directly address the consequences of food insecurity and poverty more generally.

[43]For example, one state in 2014 estimated that delivering benefits to recipients on different days of the month would cost approximately $294,010, of which only $76,500 was due to internal systems staff programming time, while the remainder represents one-time notification costs (House Joint Resolution 43, 2013).

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Table 1: Summary Statistics

	All Students		SNAP Scarce	Not SNAP Scarce	
	Mean	St.Dev.	Mean	Mean	Difference
Student Characteristics					
SAT Score	994.6	192.4	992.6	997.6	5.06***
SAT Math	499.9	105.4	498.4	502.2	3.74***
SAT Verbal	494.7	102.8	494.1	495.5	1.31***
Took >1 SAT	0.47	0.50	0.48	0.44	-0.042***
Black	0.15	0.36	0.17	0.12	-0.053***
Hispanic	0.089	0.29	0.088	0.091	0.0029**
Asian	0.051	0.22	0.056	0.044	-0.013***
Male	0.47	0.50	0.47	0.47	-0.0059***
College Outcomes					
No College	0.13	0.33	0.13	0.13	-0.0050***
Attend 2 Yr College	0.21	0.41	0.22	0.19	-0.032***
Attend 4 Yr College	0.66	0.47	0.65	0.68	0.037***
College Characteristics					
Barrons Top 4	0.58	0.49	0.59	0.58	-0.0085***
Flagship	0.15	0.36	0.15	0.15	0.0066***
College 6 Yr. Grad Rate	57.2	18.6	57.8	56.2	-1.63***
College Avg. SAT	1090.6	123.3	1093.4	1086.7	-6.73***
Observations	420,881		253,773	167,108	

Notes: Data span 2009–2014 cohorts and include the following states: Arizona, District of Columbia, Indiana, Iowa, Kansas, Maryland, Utah, and West Virginia. Data on SAT scores are from The College Board. Data on college attendance are from the National Student Clearinghouse. Data on college characteristics are from IPEDS and are only reported for students who attend college, so the number of observations reported is not accurate for those measures in this table. Students within 15–31 days of potential SNAP receipt, based on state-level SNAP issuance schedules and student last name are the students who may be experiencing scarcity. Students within 0–14 days of potential SNAP receipt are less likely to be experiencing SNAP-related scarcity.

Table 2: Effects of SNAP Timing on SAT Score

Scarcity Indicator			
$\geq$ 15 days since SNAP * Income < 60k	-10.8125***	-6.9949***	-5.7611***
	(2.0209)	(1.6241)	(1.2327)
$\geq$ 15 days since SNAP	-2.3115	-1.4598	-0.5697
	(1.5443)	(1.2916)	(1.0952)
Income < 60k	-63.9966***	-42.8232***	-26.6516***
	(1.7834)	(1.3848)	(1.0646)
Black		-141.5562***	-119.0775***
		(1.5937)	(1.0800)
Hispanic		-61.6905***	-59.2893***
		(1.3974)	(1.1233)
Asian		35.2788***	12.9240***
		(2.8863)	(1.9985)
Native		-55.5515***	-45.2149***
		(3.5267)	(3.3133)
Male		38.1513***	36.9588***
		(0.8258)	(0.7965)
Days Since SNAP			
Days since SNAP * Income < 60k	-0.3549***	-0.2309***	-0.2072***
	(0.0877)	(0.0716)	(0.0555)
Days since SNAP	-0.0552	-0.0227	0.0251
	(0.0557)	(0.0491)	(0.0414)
Income < 60k	-64.6833***	-43.2339***	-26.7080***
	(2.0147)	(1.5713)	(1.2108)
Black		-141.6427***	-119.1100***
		(1.5956)	(1.0812)
Hispanic		-61.7022***	-59.2997***
		(1.3944)	(1.1228)
Asian		35.2376***	12.8950***
		(2.8859)	(1.9979)
Native		-55.5487***	-45.2170***
		(3.5235)	(3.3119)
Male		38.1494***	36.9535***
		(0.8259)	(0.7968)
Observations	420,881	420,881	420,881
State-by-DOM Fixed Effects	Yes	Yes	Yes
Cohort Fixed Effects	Yes	Yes	Yes
Test Fixed Effects	Yes	Yes	Yes
Controls	No	Yes	Yes
School Fixed Effects	No	No	Yes

Notes: Estimates are based on data from The College Board on SAT scores from 2009–2014 cohorts. We estimate Equation (2) with controls including indicator variables for race, ethnicity, and gender. The outcome variable is composite SAT score. Standard errors are clustered on the state-by-disbursement day-of-month-by-cohort level.

*, **, and *** indicate statistical significance at the ten, five, and one percent levels, respectively.

Table 3: Effects of SNAP Timing on SAT and College Outcomes

	SAT Score	No College	Start 2 Yr	Start 4 Yr	Grad Rate	Avg SAT	Selective	Flagship
Scarcity Indicator								
$\geq$ 15 days since SNAP * Income $<$ 60k	-5.7611***	-0.0017	0.0089***	-0.0072**	-0.3527***	-2.8144***	-0.0093***	-0.0051**
	(1.2327)	(0.0025)	(0.0031)	(0.0033)	(0.1161)	(0.7088)	(0.0035)	(0.0022)
$\geq$ 15 days since SNAP	-0.5697	0.0040**	0.0027	-0.0067**	-0.0817	-1.0901*	-0.0013	0.0007
	(1.0952)	(0.0019)	(0.0026)	(0.0031)	(0.0920)	(0.5719)	(0.0028)	(0.0019)
Income $<$ 60k	-26.6516***	0.0383***	0.0257***	-0.0640***	-1.1371***	-6.1809***	-0.0505***	-0.0158***
	(1.0646)	(0.0020)	(0.0025)	(0.0028)	(0.0840)	(0.4956)	(0.0028)	(0.0018)
Days Since SNAP								
Days since SNAP * Income $<$ 60k	-0.2072***	-0.0001	0.0003**	-0.0002	-0.0095*	-0.0749**	-0.0003*	-0.0001
	(0.0555)	(0.0001)	(0.0001)	(0.0002)	(0.0052)	(0.0309)	(0.0002)	(0.0001)
Days since SNAP	0.0251	0.0001	0.0001	-0.0002*	-0.0037	-0.0398*	-0.0001	0.0000
	(0.0414)	(0.0001)	(0.0001)	(0.0001)	(0.0040)	(0.0233)	(0.0001)	(0.0001)
Income $<$ 60k	-26.7080***	0.0383***	0.0261***	-0.0644***	-1.1925***	-6.6378***	-0.0510***	-0.0166***
	(1.2108)	(0.0023)	(0.0029)	(0.0031)	(0.0981)	(0.5746)	(0.0032)	(0.0020)
Observations	420,881	420,881	420,881	420,881	420,881	420,881	420,881	420,881
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-by-DOM Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes		
Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Test Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
School Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Estimates are based on data from The College Board on SAT scores and National Student Clearinghouse data on college attendance from 2009–2014 cohorts. We estimate Equation (2) with controls including indicator variables for race, ethnicity, and gender. We also include a binary indicator for whether a student attended college in Columns 5–8. Graduation rate and average SAT scores are missing for some students who do attend college, and we include a binary indicator for those outcomes when relevant. Standard errors are clustered on the state-by-disbursement day-of-month-by-cohort level.
*, **, and *** indicate statistical significance at the ten, five, and one percent levels, respectively.

Table 4: Effects of SNAP Timing in Low-Income Communities

	SAT Score	No College	Start 2-Year	Start 4-Year	Grad. Rate	Avg SAT	Selective	Flagship
Low-Income Schools								
$\geq$ 15 days since SNAP * Low income school	-8.5738***	0.0118***	0.0041	-0.0159***	-0.4857***	-3.4642***	-0.0142***	-0.0036
	(2.2612)	(0.0036)	(0.0037)	(0.0046)	(0.1627)	(1.0963)	(0.0041)	(0.0026)
$\geq$ 15 days since SNAP	-2.1243*	0.0016	0.0075**	-0.0091***	-0.1468	-2.1228***	-0.0018	-0.0010
	(1.2045)	(0.0019)	(0.0030)	(0.0034)	(0.0892)	(0.6351)	(0.0027)	(0.0018)
Low income school	-45.0186***	0.0331***	0.0070**	-0.0400***	-2.1324***	-11.1913***	-0.0422***	-0.0199***
	(1.7049)	(0.0027)	(0.0028)	(0.0038)	(0.1243)	(0.7481)	(0.0030)	(0.0022)
High SNAP Usage Zip Codes								
$\geq$ 15 days since SNAP * High SNAP zipcode	-4.1927***	0.0068***	-0.0039	-0.0029	-0.5916***	-3.3453***	-0.0094***	-0.0049*
	(1.6194)	(0.0023)	(0.0033)	(0.0037)	(0.1418)	(1.0017)	(0.0035)	(0.0025)
$\geq$ 15 days since SNAP	-2.9071**	0.0022	0.0099***	-0.0121***	-0.0688	-1.8642***	-0.0022	-0.0003
	(1.2992)	(0.0020)	(0.0032)	(0.0036)	(0.0947)	(0.6713)	(0.0028)	(0.0020)
SNAP zipcode	-29.9762***	0.0231***	0.0180***	-0.0411***	-1.1557***	-8.4042***	-0.0337***	-0.0178***
	(1.2286)	(0.0018)	(0.0025)	(0.0028)	(0.1102)	(0.7587)	(0.0030)	(0.0021)
Low-Income Zip Codes								
$\geq$ 15 days since SNAP * Low income zip	-0.2286	0.0058**	-0.0018	-0.0040	-0.2574*	-1.1760	-0.0069*	-0.0017
	(1.5254)	(0.0023)	(0.0033)	(0.0036)	(0.1328)	(0.9099)	(0.0036)	(0.0027)
$\geq$ 15 days since SNAP	-4.3529***	0.0028	0.0092***	-0.0119***	-0.1913**	-2.6562***	-0.0033	-0.0015
	(1.3445)	(0.0020)	(0.0033)	(0.0037)	(0.0957)	(0.6791)	(0.0029)	(0.0020)
Low income zip	-32.5955***	0.0244***	0.0148***	-0.0393***	-1.1713***	-9.3830***	-0.0352***	-0.0196***
	(1.1257)	(0.0019)	(0.0024)	(0.0026)	(0.1016)	(0.6768)	(0.0029)	(0.0023)
Observations	420,881	420,881	420,881	420,881	420,881	420,881	420,881	420,881
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-by-DOM Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Test Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
School Fixed Effects	No	No	No	No	No	No	No	No

Notes: Estimates are based on data from The College Board on SAT scores and National Student Clearinghouse data on college attendance from 2009–2014 cohorts. Zip code-level data on SNAP participation and median family income are from the 2012 American Community Survey. We estimate Equation (2) with controls including indicator variables for race, ethnicity, and gender. We also include a binary indicator for whether a student attended college in Columns 5–8. Graduation rate and average SAT scores are missing for some students who do attend college, and we include a binary indicator for those outcomes when relevant. "Low-Income Schools" includes schools with a majority of students reporting a household income lower than \$60,000. "High SNAP Usage Zip Codes" includes zip codes with over 15 percent of households participating in SNAP. "Low-Income Zip Codes" include zip codes with median income below \$60,000. Standard errors are clustered on the state-by-disbursement day-of-month-by-cohort level.
*, **, and *** indicate statistical significance at the ten, five, and one percent levels, respectively.

Table 5: Effects of SNAP Timing on SAT Scores and College Attendance, by Zip Code SNAP Participation

	% Total Pop. SNAP	% Children SNAP
SAT Score		
≥ 15 days since SNAP * Zip Charactersistic	-59.6668***	-104.2869***
	(6.6201)	(10.4334)
≥ 15 days since SNAP	2.3717*	2.5403**
	(1.2073)	(1.1945)
No College		
≥ 15 days since SNAP * Zip Charactersistic	0.0719***	0.1101***
	(0.0129)	(0.0195)
≥ 15 days since SNAP	-0.0029	-0.0023
	(0.0020)	(0.0019)
Start 2-Year		
≥ 15 days since SNAP * Zip Charactersistic	0.0572***	0.1071***
	(0.0167)	(0.0274)
≥ 15 days since SNAP	0.0011	0.0006
	(0.0030)	(0.0030)
Start 4-Year		
≥ 15 days since SNAP * Zip Charactersistic	-0.1290***	-0.2173***
	(0.0187)	(0.0303)
≥ 15 days since SNAP	0.0017	0.0017
	(0.0034)	(0.0034)
College Graduation Rate		
≥ 15 days since SNAP * Zip Charactersistic	-4.5524***	-7.3179***
	(0.5037)	(0.7734)
≥ 15 days since SNAP	0.1779**	0.1580*
	(0.0867)	(0.0859)
College Average SAT		
≥ 15 days since SNAP * Zip Charactersistic	-27.3478***	-42.0741***
	(3.4728)	(5.1204)
≥ 15 days since SNAP	0.2034	-0.0131
	(0.5954)	(0.5800)
Selective		
≥ 15 days since SNAP * Zip Charactersistic	-0.1531***	-0.2601***
	(0.0168)	(0.0272)
≥ 15 days since SNAP	0.0084***	0.0085***
	(0.0029)	(0.0029)
Flagship		
≥ 15 days since SNAP * Zip Charactersistic	-0.0641***	-0.1058***
	(0.0113)	(0.0176)
≥ 15 days since SNAP	0.0043**	0.0041**
	(0.0021)	(0.0020)
Observations	420,881	420,881
Controls	Yes	Yes
State-by-DOM Fixed Effects	Yes	Yes
Cohort Fixed Effects	Yes	Yes
Test Fixed Effects	Yes	Yes
School Fixed Effects	Yes	Yes

Notes: Estimates are based on data from The College Board on SAT scores and National Student Clearinghouse data on college attendance from 2009–2014 cohorts. Zip code-level data on SNAP participation are from the 2012 American Community Survey. We estimate Equation (2) substituting the indicator that a student is low income with the listed continuous measure. Controls include indicator variables for race, ethnicity, and gender. We also include a binary indicator for whether a student attended college in relevant specifications. Graduation rate and average SAT scores are missing for some students who do attend college, and we include a binary indicator for those outcomes when relevant. Standard errors are clustered on the state-by-disbursement day-of-month-by-cohort level.

Table 6: Effects of SNAP Timing on SAT Score, by Combined Income Measures

	Inc < 60k	Inc < 40k	Waiver	Low-Inc Sch	Inc < 60k * Waiver	Inc < 40k * Waiver	Inc < 60k * Low-Inc Sch	Inc < 40k * Low-Inc Sch	Waiver * Low-Inc Sch	Inc < 60k * Waiver * Low-Inc Sch	Inc < 40k * Waiver * Low-Inc Sch
Scarcity Indicator											
$\geq$ 15 days since SNAP * Measure(s)	-5.7611***	-5.2159***	-3.3175**	-8.5738***	-3.6331**	-3.6938**	-10.5312***	-10.7809***	-8.1737***	-7.8776***	-9.0535***
	(1.2327)	(1.3407)	(1.5573)	(2.2612)	(1.5148)	(1.5932)	(2.5011)	(2.6616)	(2.5722)	(2.5084)	(2.5755)
$\geq$ 15 days since SNAP	-0.5697	-1.6217	-2.3132**	-2.1243*	-2.3527**	-2.4425**	-2.6305**	-3.1148***	-3.4868***	-3.5954***	-3.6501***
	(1.0952)	(1.0289)	(1.0481)	(1.2045)	(1.0445)	(1.0320)	(1.1877)	(1.1713)	(1.2156)	(1.2131)	(1.2069)
Days Since SNAP											
Days since SNAP * Measure(s)	-0.2072***	-0.1827***	-0.0883	-0.2982***	-0.1019	-0.1176*	-0.3616***	-0.3662***	-0.2551**	-0.2444**	-0.3068***
	(0.0555)	(0.0599)	(0.0674)	(0.0975)	(0.0663)	(0.0711)	(0.1085)	(0.1168)	(0.1113)	(0.1080)	(0.1124)
Days since SNAP	0.0251	-0.0164	-0.0445	-0.0407	-0.0456	-0.0461	-0.0621	-0.0805*	-0.0953**	-0.0991**	-0.0988**
	(0.0414)	(0.0374)	(0.0387)	(0.0446)	(0.0384)	(0.0378)	(0.0437)	(0.0433)	(0.0454)	(0.0454)	(0.0453)
Observations	420,881	420,881	420,881	420,881	420,881	420,881	420,881	420,881	420,881	420,881	420,881
State-by-DOM Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Test Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
School Fixed Effects	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No

Notes: Estimates are based on data from The College Board on SAT scores from 2009–2014 cohorts. We estimate Equation (2) with controls including indicator variables for race, ethnicity, and gender. Each column corresponds to a different measure of low-income status that is interacted with the scarcity indicator. "Low-Income Schools" includes schools with a majority of students reporting a household income lower than $60,000. The outcome variable is composite SAT score. Standard errors are clustered on the state-by-disbursement day-of-month-by-cohort level.

*, **, and *** indicate statistical significance at the ten, five, and one percent levels, respectively.

Table 7: Effects of SNAP Timing on College Attendance Outcomes, by Combined Income Measures

	SAT Score	No College	Start 2-Year	Start 4-Year	Grad. Rate	Avg SAT	Selective	Flagship
Waiver								
$\geq$ 15 days since SNAP * Waiver	-3.3175**	-0.0034	-0.0014	0.0048	-0.5181***	-4.0767***	-0.0046	-0.0064**
	(1.5573)	(0.0036)	(0.0038)	(0.0045)	(0.1279)	(0.8156)	(0.0038)	(0.0026)
$\geq$ 15 days since SNAP	-2.3132**	0.0040**	0.0064**	-0.0104***	-0.1314*	-1.4920***	-0.0042*	-0.0002
	(1.0481)	(0.0019)	(0.0027)	(0.0031)	(0.0791)	(0.5068)	(0.0025)	(0.0017)
Waiver on SAT	-31.1823***	0.0325***	0.0117***	-0.0442***	-0.3733***	-1.6190**	-0.0288***	0.0009
	(1.2350)	(0.0030)	(0.0035)	(0.0038)	(0.1022)	(0.6268)	(0.0032)	(0.0023)
Waiver*Income < 60k								
$\geq$ 15 days since SNAP * Waiver * Inc < 60k	-3.6331**	-0.0038	0.0009	0.0029	-0.5260***	-3.8565***	-0.0058	-0.0067**
	(1.5148)	(0.0039)	(0.0041)	(0.0048)	(0.1352)	(0.8248)	(0.0042)	(0.0028)
$\geq$ 15 days since SNAP	-2.3527**	0.0040**	0.0060**	-0.0100***	-0.1402*	-1.6018***	-0.0041	-0.0003
	(1.0445)	(0.0019)	(0.0027)	(0.0031)	(0.0786)	(0.5022)	(0.0025)	(0.0017)
Waiver * Inc < 60k	-30.4738***	0.0361***	0.0108***	-0.0470***	-0.2460**	-0.6748	-0.0265***	0.0022
	(1.2179)	(0.0031)	(0.0035)	(0.0039)	(0.1063)	(0.6247)	(0.0034)	(0.0023)
Waiver*Income < 60k*Low-Income School								
$\geq$ 15 days since SNAP * Waiver * Inc < 60k * Low-inc School	-7.8776***	0.0013	0.0054	-0.0068	-0.6454***	-4.2070***	-0.0111*	-0.0093***
	(2.5084)	(0.0049)	(0.0047)	(0.0060)	(0.2334)	(1.3903)	(0.0056)	(0.0035)
$\geq$ 15 days since SNAP	-3.5954***	0.0044**	0.0080***	-0.0124***	-0.2081**	-2.5888***	-0.0043	-0.0010
	(1.2131)	(0.0020)	(0.0030)	(0.0034)	(0.0870)	(0.6252)	(0.0026)	(0.0017)
Waiver * Inc < 60k * Low-income School	-59.2681***	0.0525***	0.0073**	-0.0598***	-1.3429***	-5.8678***	-0.0461***	0.0030
	(2.0722)	(0.0038)	(0.0037)	(0.0049)	(0.1848)	(1.0074)	(0.0043)	(0.0030)
Observations	420,881	420,881	420,881	420,881	420,881	420,881	420,881	420,881
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-by-DOM Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Test Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Estimates are based on data from The College Board on SAT scores and National Student Clearinghouse data on college attendance from 2009–2014 cohorts. We estimate Equation (2) with controls including indicator variables for race, ethnicity, and gender. School fixed effects are used in the first two panels, but not the third (with “Low-income School"). We also include a binary indicator for whether a student attended college in Columns 5–8. Graduation rate and average SAT scores are missing for some students who do attend college, and we include a binary indicator for those outcomes when relevant. “Low-Income Schools" includes schools with a majority of students reporting a household income lower than $60,000. Standard errors are clustered on the state-by-disbursement day-of-month-by-cohort level.

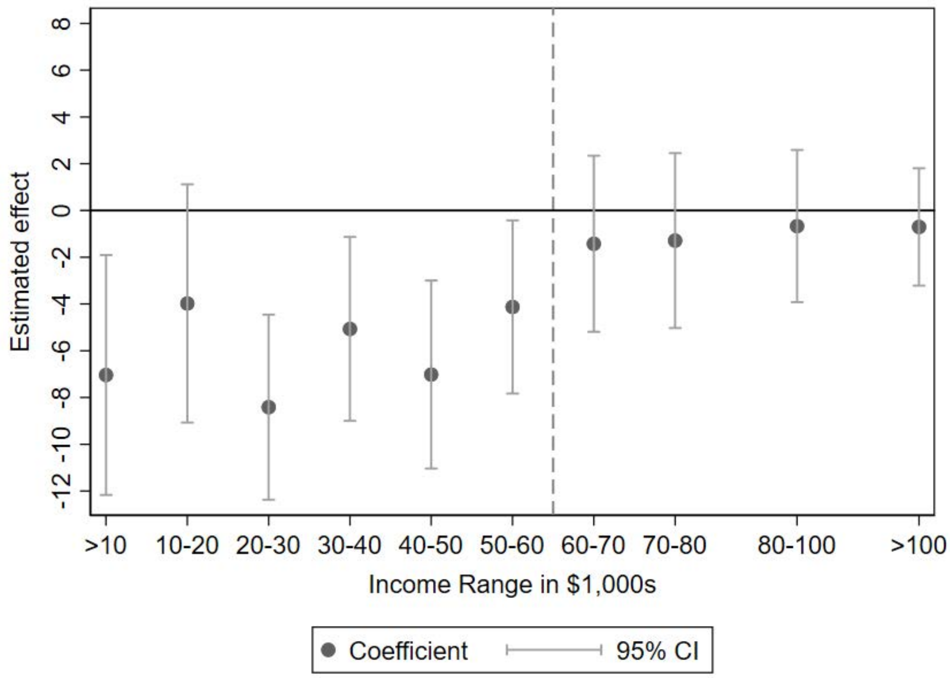
*, **, and *** indicate statistical significance at the ten, five, and one percent levels, respectively.

Table 8: The Effect of SNAP Timing on SAT-Taking

	All Students	Low-Income School	High SNAP Zip	Low-Income Zip
Ever Took SAT				
SNAP Scarce % Main 4 Exams	-0.0236	-0.0396	-0.0142	-0.0195
	(0.0224)	(0.0389)	(0.0244)	(0.0246)
Observations	1149469	288,596	431,878	592,828
Controls	Yes	Yes	Yes	Yes
State-by-DOM Fixed Effects	Yes	Yes	Yes	Yes
Cohort Fixed Effects	Yes	Yes	Yes	Yes
School Fixed Effects	Yes	Yes	Yes	Yes

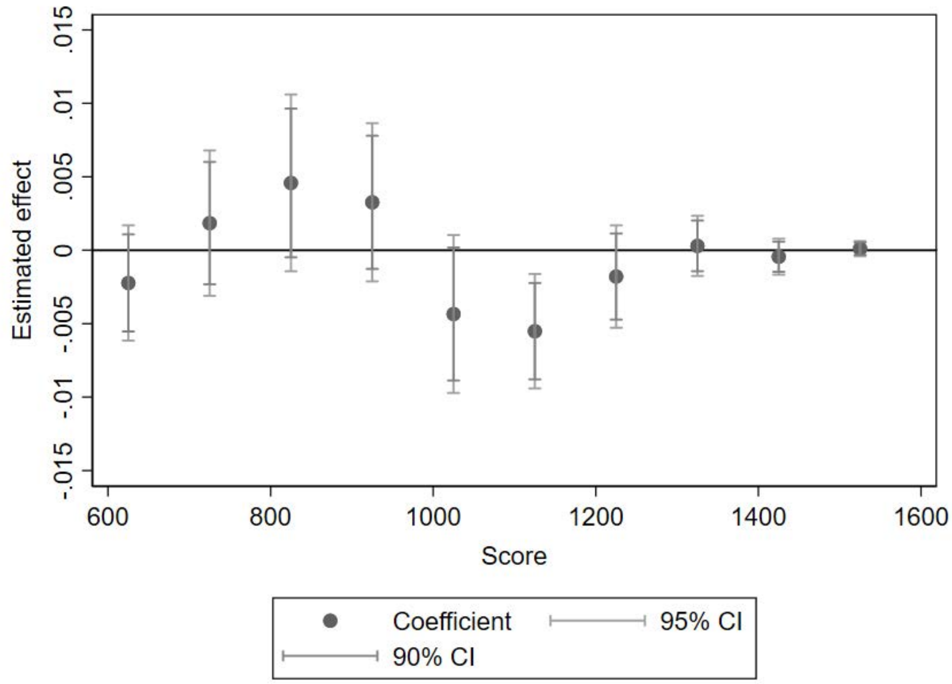
Notes: Estimates are based on data from The College Board on PSAT and SAT scores from 2009–2014 cohorts. Zip code-level data on SNAP participation and median family income are from the 2012 American Community Survey. The sample includes only students that took the PSAT. Controls include indicator variables for race, ethnicity, and gender. "Low-Income Schools" includes schools with a majority of students reporting a household income lower than $60,000. "High SNAP Usage Zip Codes" includes zip codes with over 15 percent of households participating in SNAP. "Low-Income Zip Codes" include zip codes with median incomes below $60,000. Standard errors are clustered on the state-by-disbursement day-of-month-by-cohort level.
*, **, and *** indicate statistical significance at the ten, five, and one percent levels, respectively.

Figure 1: Effects of SNAP Timing on SAT Score by Family Income



Notes: Data on SAT scores and family incomes are from The College Board. The vertical line, drawn at $60,000, denotes an approximate household income cutoff for SNAP eligibility. Coefficients and their respective 95% confidence intervals are generated from a regression estimated using OLS, as specified in Equation (2), interacting whether a student is "SNAP scarce," i.e. within 15–31 days of potential SNAP receipt based on their last name, with household income bins. Standard errors are clustered at the state-by-disbursement day-of-month-by-cohort level.

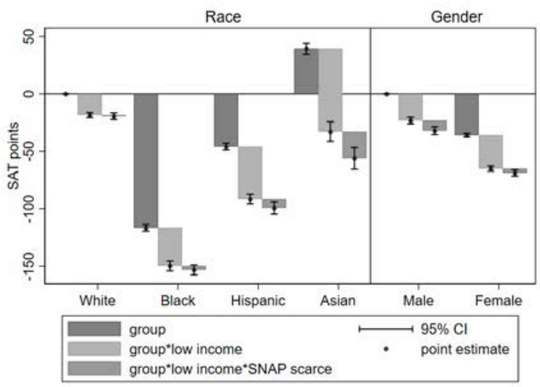
Figure 2: Effects of SNAP Timing on SAT Score Ranges for Low-Income Students



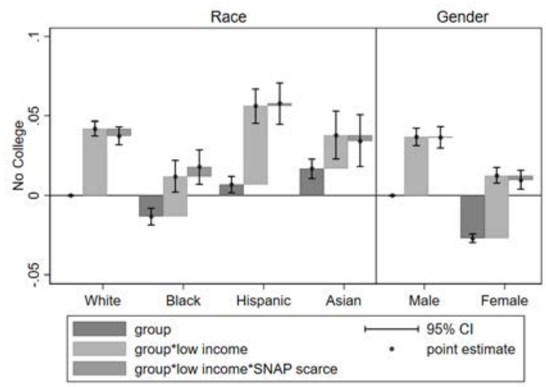
Notes: Data on SAT scores are from The College Board. Coefficients and their respective 90% and 95% confidence intervals are generated from 10 separate regressions estimated for low-income students using OLS, as specified in Equation (1), using an indicator that a student's score falls within a 100 point range as the outcome variable. The main variable of interest is whether a student is "SNAP scarce," i.e. within 15–31 days of potential SNAP receipt, based on their last name.

Figure 3: Effects of SNAP Timing by Subgroups

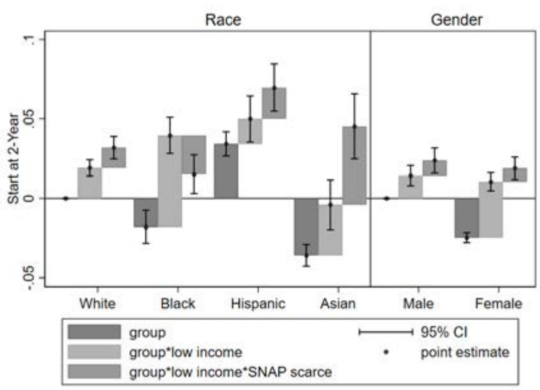
(a) SAT Score



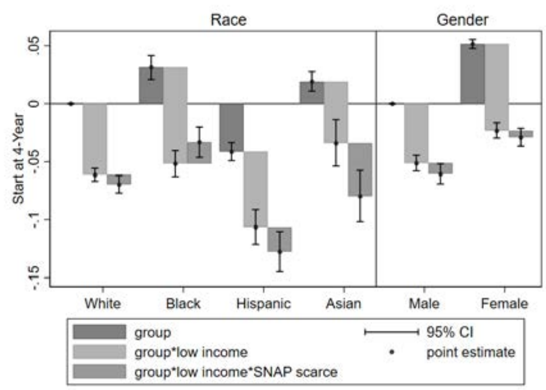
(b) No College



(c) Start 2 Year



(d) Start 4 Year



Notes: Estimates are based on data from The College Board on SAT scores and National Student Clearinghouse data on college attendance from 2009–2014 cohorts. We estimate 2 regressions (per outcome) that include interactions of race/gender with the variable of interest ($low-income*SNAPscarce$) as well as the "low-income" indicator. For each subgroup, we report the coefficient for said group (e.g. "female"), the coefficient for low-income individuals in that group (e.g. "female*low-income") and the treatment effect for that group (e.g. "female*low-income*SNAP scarce"). Bars are used to indicate the cumulative effect of the three coefficients per group so that the point estimate markers represent the combined effects of each variable as they accumulate. The rightmost point estimate for each group presents the total impact of being a member of that group, being low-income and experiencing scarcity combined relative to a white (or male) student who is high-income and not in the "SNAP scarce" range.

Appendix

For Online Publication

Table A1: State Issuance Schedules, by State

State	Letter Groups	Issuance Days	Require SAT?	Require ACT?	Require PSAT?
Arizona	A-B, C-D, E-F, G-H, I-J, K-L, M-N, O-P	1-13	No	No	No
	Q-R, S-T, U-V, W-X, Y-Z	1-13			
DC	A-B, C, D-F, G-H, I-K, L-M, N-Q, R-S, T-V, W-Z	1-10	Yes (as of 2014)	No	No
Indiana	A-B, C-D, E-G, H-I, J-L, M-N, O-R, S, T-V, W-Z	1-10	No	No	No
Iowa	A-B, C-D, E-G, H-I, J-L, M-O, P-R, S, T-V, W-Z	1-10	No	No	No
Kansas	A-B, C-D, E-G, H-J, K-L, M, N-R, S, T-V, W-Z	1-10	No	No	No
Maryland	A-B, C-D, E-G, H-I, J-L, M-O, P-R, S, T-V, W-Z	6-15	No	No	No
Utah	A-G, H-O, P-Z	5, 11, 15	No	Yes	No
West Virginia	B & X-Z, C & F, H & N & V, I & M & O & U,	1-9	No	No	No
	Q & S & A & W, J-K & P, D-E & R, G & L & T				

Notes: Data on SNAP issuance schedules is from the USDA. Data on ACT and SAT requirements is from Education Commission of the States. See `https://www.ecs.org/state-information-request-use-of-act-sat-and-psat-for-high-school-testing-as-required-by-essa/` for more information.

Table A2: Effects of SNAP Timing on Math and Verbal SAT Scores

	SAT Math			SAT Verbal		
Scarcity Indicator						
$\geq$ 15 days since SNAP * Income $<$ 60k	-4.6913***	-2.7722***	-2.3038***	-6.1212***	-4.2227***	-3.4572***
	(0.9867)	(0.8051)	(0.6426)	(1.1130)	(0.9070)	(0.7065)
$\geq$ 15 days since SNAP	-1.8300**	-1.3638*	-0.8203	-0.4815	-0.0960	0.2506
	(0.8380)	(0.6962)	(0.6023)	(0.7722)	(0.6693)	(0.5790)
Income $<$ 60k	-32.8900***	-21.1358***	-13.3045***	-31.1066***	-21.6874***	-13.3471***
	(0.8354)	(0.6656)	(0.5350)	(1.0094)	(0.7884)	(0.6239)
Black		-75.4233***	-62.5138***		-66.1329***	-56.5637***
		(0.9000)	(0.5770)		(0.7466)	(0.5996)
Hispanic		-30.4508***	-29.2666***		-31.2397***	-30.0227***
		(0.6982)	(0.6158)		(0.7788)	(0.6150)
Asian		40.1073***	27.8270***		-4.8284***	-14.9030***
		(1.8252)	(1.3465)		(1.2651)	(0.9559)
Native		-27.4003***	-22.9394***		-28.1512***	-22.2755***
		(1.8188)	(1.7477)		(2.0661)	(1.9211)
Male		33.4130***	32.8011***		4.7383***	4.1577***
		(0.4063)	(0.3975)		(0.4710)	(0.4532)
Days Since SNAP						
Days since SNAP * Income $<$ 60k	-0.1518***	-0.0881**	-0.0822***	-0.2031***	-0.1429***	-0.1250***
	(0.0431)	(0.0361)	(0.0296)	(0.0487)	(0.0401)	(0.0319)
Days since SNAP	-0.0518*	-0.0357	-0.0092	-0.0033	0.0130	0.0343
	(0.0302)	(0.0268)	(0.0232)	(0.0288)	(0.0258)	(0.0223)
Income $<$ 60k	-33.2248***	-21.3549***	-13.3387***	-31.4584***	-21.8790***	-13.3693***
	(0.9580)	(0.7688)	(0.6221)	(1.1333)	(0.8863)	(0.7022)
Black		-75.4619***	-62.5276***		-66.1808***	-56.5823***
		(0.9012)	(0.5775)		(0.7470)	(0.6002)
Hispanic		-30.4566***	-29.2711***		-31.2456***	-30.0286***
		(0.6967)	(0.6156)		(0.7774)	(0.6148)
Asian		40.0918***	27.8167***		-4.8542***	-14.9216***
		(1.8256)	(1.3465)		(1.2643)	(0.9557)
Native		-27.3974***	-22.9386***		-28.1513***	-22.2784***
		(1.8176)	(1.7471)		(2.0644)	(1.9203)
Male		33.4119***	32.7985***		4.7376***	4.1550***
		(0.4063)	(0.3976)		(0.4710)	(0.4534)
Observations	420,881	420,881	420,881	420,881	420,881	420,881
State-by-DOM Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Test Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	No	Yes	No	No	Yes
School Fixed Effects	No	Yes	Yes	No	Yes	Yes

Notes: Estimates are based on data from The College Board on SAT scores from 2009–2014 cohorts. We estimate Equation (2) with controls including indicator variables for race, ethnicity, and gender. Standard errors are clustered on the state-by-disbursement day-of-month-by-cohort level.

*, **, and *** indicate statistical significance at the ten, five, and one percent levels, respectively.

Table A3: Summary Statistics By Income Level

	All Students		Low Income	Not Low Income	
	Mean	St.Dev.	Mean	Mean	Difference
Student Characteristics					
SAT Score	994.6	192.4	929.9	1034.3	104.4***
SAT Math	499.9	105.4	466.1	520.7	54.6***
SAT Verbal	494.7	102.8	463.8	513.6	49.9***
Took >1 SAT	0.47	0.50	0.36	0.53	0.17***
Black	0.15	0.36	0.23	0.10	-0.13***
Hispanic	0.089	0.29	0.14	0.056	-0.088***
Asian	0.051	0.22	0.057	0.048	-0.0094***
Male	0.47	0.50	0.43	0.50	0.072***
College Outcomes					
No College	0.13	0.33	0.18	0.098	-0.079***
Attend 2 Yr College	0.21	0.41	0.25	0.18	-0.072***
Attend 4 Yr College	0.66	0.47	0.57	0.72	0.15***
College Characteristics					
Barrons Top 4	0.58	0.49	0.47	0.65	0.18***
Flagship	0.15	0.36	0.11	0.17	0.061***
College 6 Yr. Grad Rate	57.2	18.6	51.6	59.8	8.27***
College Avg. SAT	1090.6	123.3	1055.0	1107.6	52.6***
Observations	420,881		160,089	260,792	

Notes: Data span 2009–2014 cohorts and include the following states: Arizona, District of Columbia, Indiana, Iowa, Kansas, Maryland, Utah, and West Virginia. Data on SAT scores are from The College Board. Data on college attendance are from the National Student Clearinghouse. Data on college characteristics are from IPEDS and are only reported for students who attend college, so the number of observations reported is not accurate for those measures in this table. Students are considered low-income if they report that their family income is below $60,000 on the SAT survey.

Table A4: Alternative Specifications: Effects of SNAP Timing on SAT Scores and College Outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
SAT Score							
$\geq$ 15 days since SNAP * Income $<$ 60k	-5.7611***	-6.7948***	-5.2406***	-6.4389***	-4.9208***	-5.7611***	-5.7611**
	(1.2327)	(1.3813)	(1.2427)	(1.3897)	(1.1813)	(1.6897)	(2.1072)
No College							
$\geq$ 15 days since SNAP * Income $<$ 60k	-0.0017	0.0002	0.0007	0.0030	-0.0024	-0.0017	-0.0017
	(0.0025)	(0.0025)	(0.0027)	(0.0027)	(0.0025)	(0.0029)	(0.0020)
Start 2-Year							
$\geq$ 15 days since SNAP * Income $<$ 60k	0.0089***	0.0112***	0.0045	0.0069**	0.0073**	0.0089**	0.0089**
	(0.0031)	(0.0033)	(0.0031)	(0.0033)	(0.0030)	(0.0034)	(0.0038)
Start 4-Year							
$\geq$ 15 days since SNAP * Income $<$ 60k	-0.0072**	-0.0114***	-0.0053	-0.0100***	-0.0049	-0.0072*	-0.0072**
	(0.0033)	(0.0035)	(0.0034)	(0.0035)	(0.0033)	(0.0041)	(0.0029)
College Graduation Rate							
$\geq$ 15 days since SNAP * Income $<$ 60k	-0.3527***	-0.4237***	-0.2058	-0.2823**	-0.2736**	-0.3527**	-0.3527***
	(0.1161)	(0.1249)	(0.1281)	(0.1401)	(0.1131)	(0.1357)	(0.0878)
College Average SAT							
$\geq$ 15 days since SNAP * Income $<$ 60k	-2.8144***	-3.1083***	-1.3324*	-1.5726*	-2.3410***	-2.8144***	-2.8144**
	(0.7088)	(0.7739)	(0.7907)	(0.8830)	(0.6762)	(1.0438)	(0.9763)
Selective							
$\geq$ 15 days since SNAP * Income $<$ 60k	-0.0093***	-0.0120***	-0.0071**	-0.0101***	-0.0067*	-0.0093**	-0.0093***
	(0.0035)	(0.0037)	(0.0035)	(0.0038)	(0.0035)	(0.0039)	(0.0018)
Flagship							
$\geq$ 15 days since SNAP * Income $<$ 60k	-0.0051**	-0.0053**	-0.0033	-0.0034	-0.0036*	-0.0051**	-0.0051***
	(0.0022)	(0.0022)	(0.0022)	(0.0023)	(0.0021)	(0.0025)	(0.0009)
Observations	420,881	420,537	388,422	388,076	420,881	420,881	420,881
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-by-DOM Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
School Fixed Effects	Yes	No	Yes	No	Yes	Yes	Yes
Zip Fixed Effects	No	Yes	No	Yes	No	No	No
Test Fixed Effects	Yes	Yes	No	No	Yes	Yes	Yes
Opportunity Fixed Effects	No	No	Yes	Yes	No	No	No
Income Bin Controls	No	No	No	No	Yes	No	No
Cluster	SDC	SDC	SDC	SDC	SDC	SC	S

Notes: Estimates are based on data from The College Board on SAT scores and National Student Clearinghouse data on college attendance from 2009–2014. We estimate Equation (2) with controls including indicator variables for race, ethnicity, and gender. Income bin controls include indicator variables for household income bins as reported on the SAT survey by students. Standard errors are clustered on either the state-by-disbursement day-by-cohort level (SDC), state-by-cohort (SC) or state (S) level as indicated.

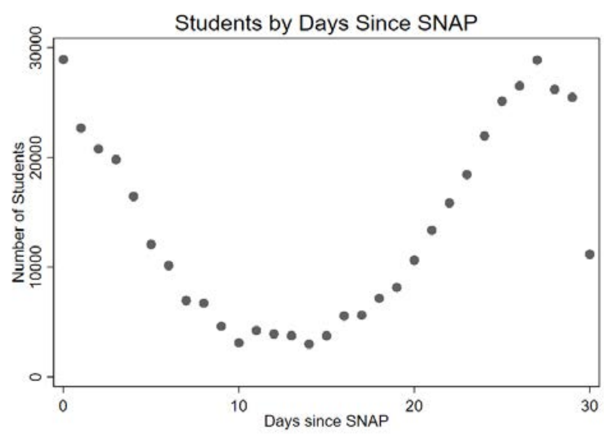
*, **, and *** indicate statistical significance at the ten, five, and one percent levels, respectively.

Table A5: Effects of SNAP Timing on SAT Scores and College Attendance, by Demographic Subgroups

	SAT Score	No College	Start 2-Year	Start 4-Year
Interacting Race with Treatment				
Low Inc.*Scarce*White	-1.0190	-0.0045	0.0128***	-0.0082**
	(1.4444)	(0.0029)	(0.0036)	(0.0038)
Low Inc.*Scarce*Black	-3.4598	0.0058	-0.0244***	0.0186***
	(2.1327)	(0.0055)	(0.0062)	(0.0067)
Low Inc.*Scarce*Hispanic	-7.8358***	0.0016	0.0197***	-0.0213**
	(2.7475)	(0.0066)	(0.0076)	(0.0088)
Low Inc.*Scarce*Asian	-23.3729***	-0.0035	0.0494***	-0.0458***
	(4.8490)	(0.0083)	(0.0104)	(0.0113)
Low Inc.*Scarce*Native				
Observations	404,420	404,420	404,420	404,420
Interacting Gender with Treatment				
Low Inc.*Scarce*Male	-8.6613***	-0.0003	0.0095**	-0.0092**
	(1.7294)	(0.0035)	(0.0041)	(0.0044)
Low Inc.*Scarce*Female	-3.6186***	-0.0028	0.0085**	-0.0057
	(1.3619)	(0.0030)	(0.0036)	(0.0040)
Observations	420,881	420,881	420,881	420,881
Controls	Yes	Yes	Yes	Yes
State-by-DOM Fixed Effects	Yes	Yes	Yes	Yes
Cohort Fixed Effects	Yes	Yes	Yes	Yes
Test Fixed Effects	Yes	Yes	Yes	Yes
School Fixed Effects	Yes	Yes	Yes	Yes

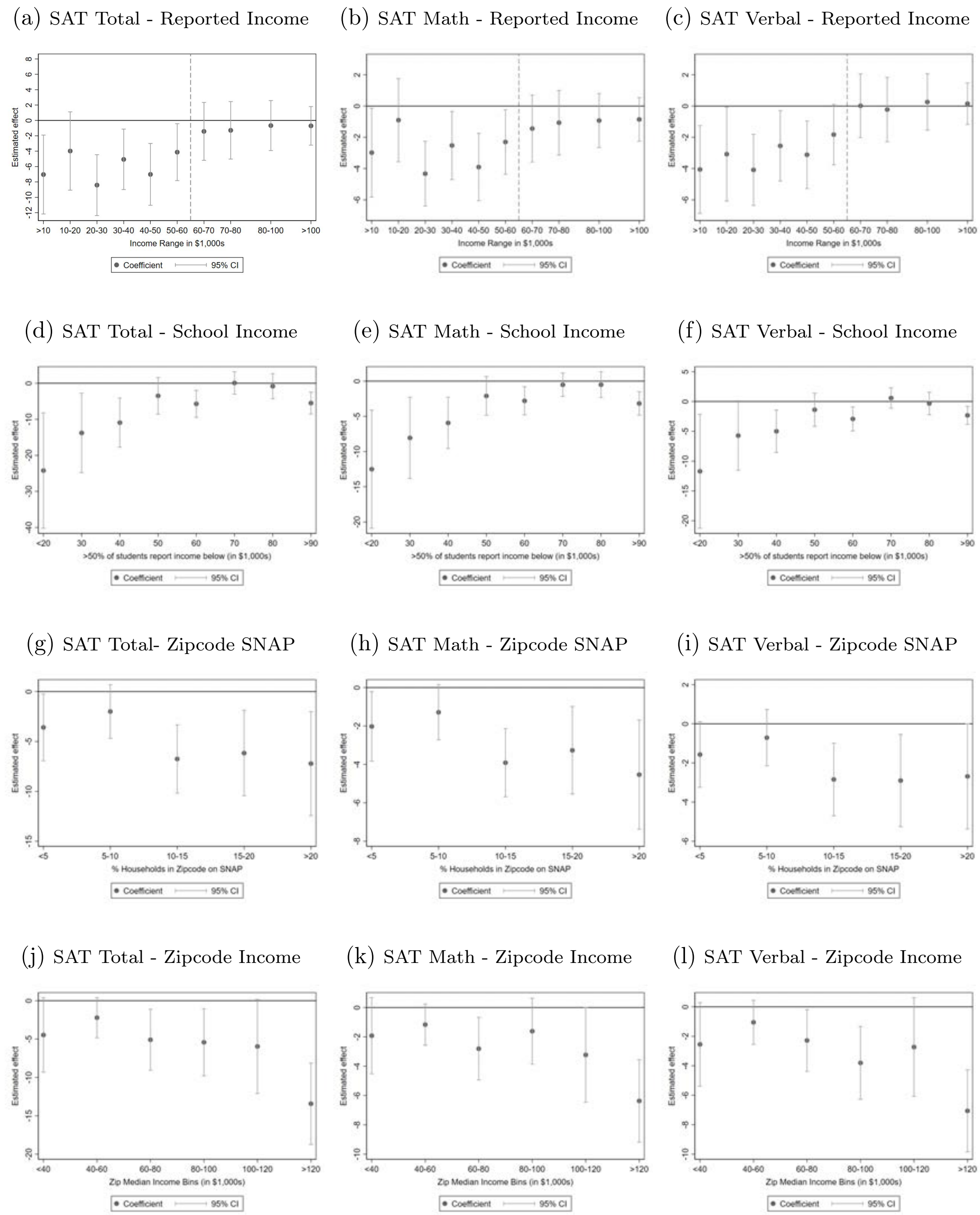
Notes: Estimates are based on data from The College Board on SAT scores and National Student Clearinghouse data on college attendance from 2009–2014 cohorts. We estimate an extension of Equation (2) that includes interactions of race/gender with the variable of interest ($low - income * SNAPscarce$) as well as the "low-income" indicator. For each subgroup, we report the coefficient for the treatment effect for that group (e.g. "female*low-income*SNAP scarce"). We estimate 2 regressions per outcome: one for race and one for gender. In the race regressions, we only include students who indicated that they are white, black, Hispanic, or Asian. Standard errors are clustered on the state-by-disbursement day-of-month-by-cohort level.
*, **, and *** indicate statistical significance at the ten, five, and one percent levels, respectively.

Figure A1: Number of Students by Days Since SAT



Notes: Figures are based on data from The College Board on SAT scores from 2009–2014 cohorts. We calculate the "Days Since SNAP" for all students taking into account their test date and state schedule. The figure plots the raw number of students for each number of days since possible disbursement.

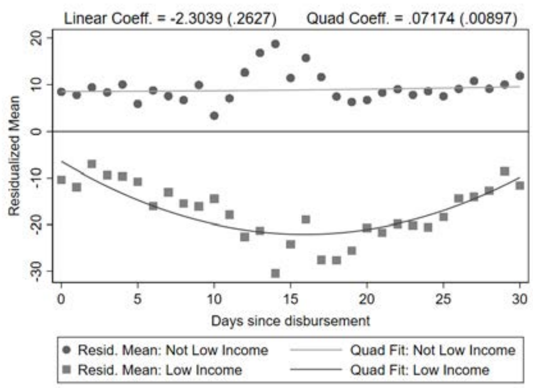
Figure A2: Effects of SNAP Timing on SAT Scores, by Various Poverty Measures



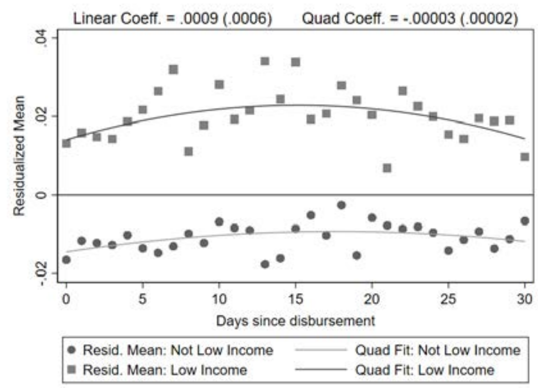
Notes: Data on SAT scores are from The College Board, and Zipcode attributes are from the American Community Survey. Coefficients and 95% confidence intervals are generated by estimating Equation (2), interacting whether a student is “SNAP scarce," with income measure bins. The top row corresponds to reported income. Each bin in the second row indicates that at least half of the students report an income below a given threshold, but less than half indicate income below a previous threshold. The third row pertains to SNAP usage by families in the student’s home zip code, and the last row is by median family income. Standard errors are clustered at the state-by-disbursement day-of-month-by-cohort level.

Figure A3: Effects of SNAP Timing by Days Since Disbursement

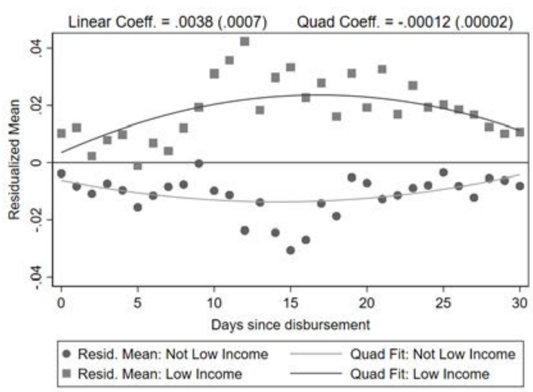
(a) SAT Score



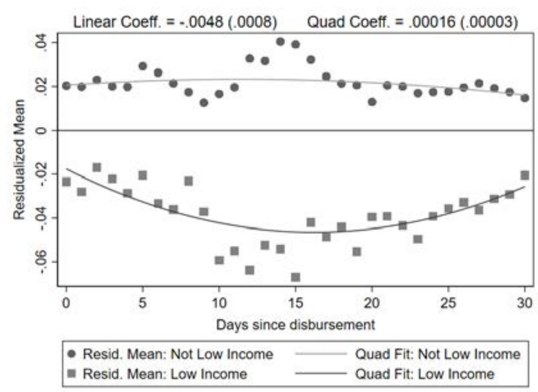
(b) No College



(c) Start 2 Year



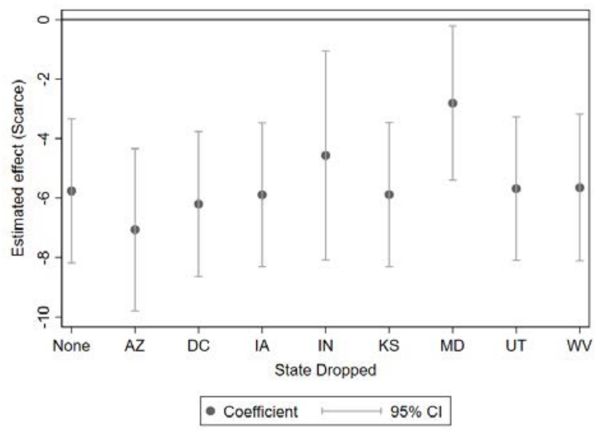
(d) Start 4 Year



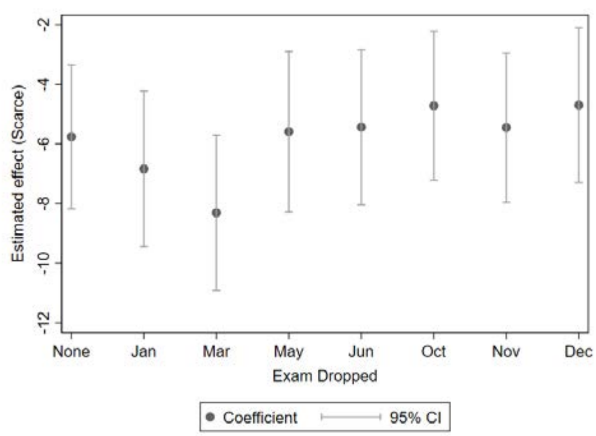
Notes: Figures are based on data from The College Board on SAT scores and National Student Clearinghouse data on college attendance from 2009–2014 cohorts. Each figure plots day-level means of residuals for days over the SNAP benefit month (after differencing out state-by-day-of-month, cohort, test, and school fixed effects and race and gender effects) with quadratic fits of each of the outcomes listed. Means for low-income students are represented by squares, while means for other students are represented by circles. We present both the linear coefficient and quadratic coefficient and their corresponding standard errors in parenthesis from a quadratic analogue of Equation 2.

Figure A4: Effects of SNAP Timing on SAT Scores, Dropping Each State and Exam

(a) Dropping Each State



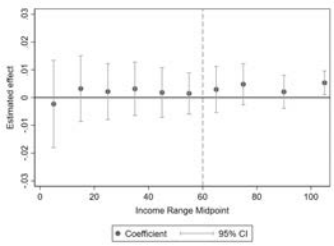
(b) Dropping Each Exam



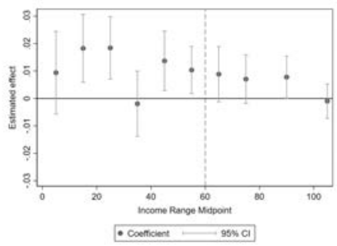
Notes: Figures are based on data from The College Board on SAT scores from 2009–2014 cohorts. Each figure displays the main results where we estimate Equation (2) with controls including indicator variables for race, ethnicity, and gender. The variable of interest is $SNAP_{icst} * lowincome_{icst}$. In Panel (a), we drop each state, and in Panel (b), we drop each exam. The outcome variable is composite SAT score. Standard errors are clustered on the state-by-disbursement day-of-month-by-cohort level.

Figure A5: Effects of SNAP Timing on College Attendance, by Various Poverty Measures

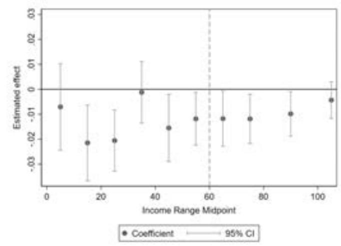
(a) No College - Reported Income



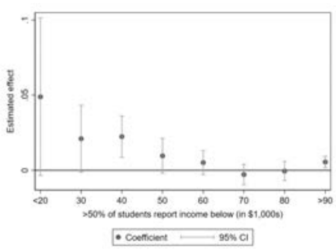
(b) Start 2 Yr - Reported Income



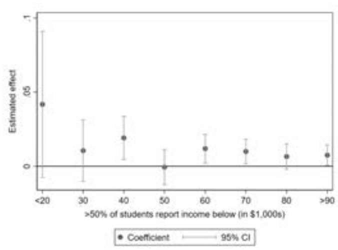
(c) Start 4 Yr - Reported Income



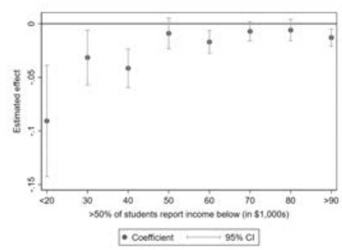
(d) No College - School Income



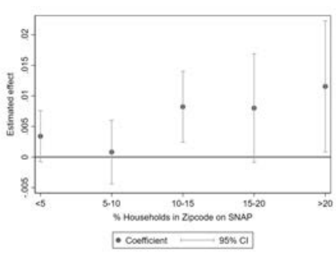
(e) Start 2 Yr - School Income



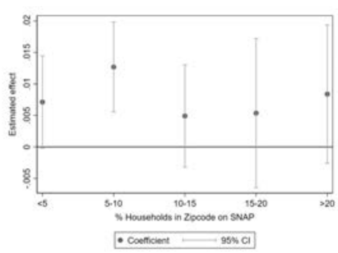
(f) Start 4 Yr - School Income



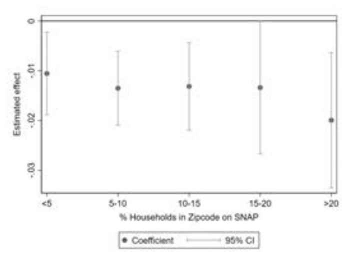
(g) No College - Zipcode SNAP



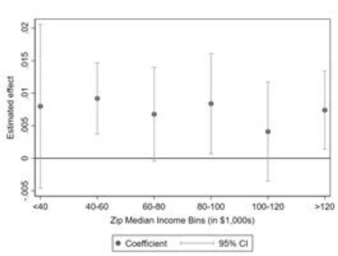
(h) Start 2 Yr - Zipcode SNAP



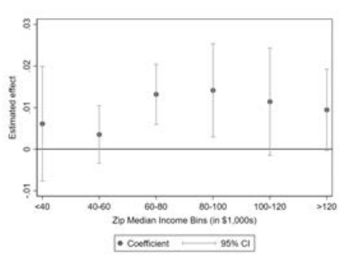
(i) Start 4 Yr - Zipcode SNAP



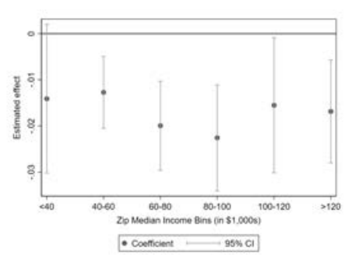
(j) No College - Zipcode Income



(k) Start 2 Yr - Zipcode Income



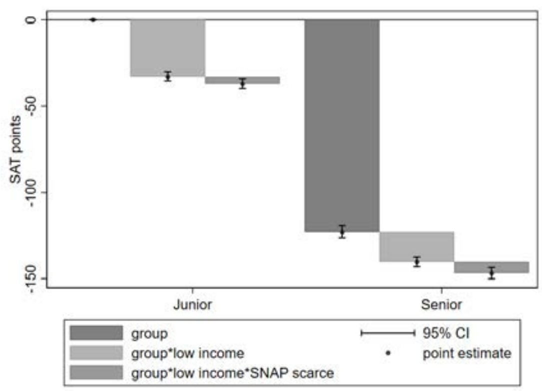
(l) Start 4 Yr - Zipcode Income



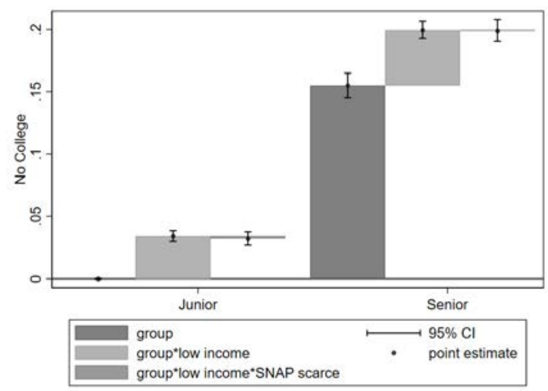
Notes: Data on SAT scores are from The College Board, and Zipcode attributes are from the American Community Survey. Coefficients and 95% confidence intervals are generated by estimating Equation (2), interacting whether a student is "SNAP scarce," with income measure bins. The top row corresponds to reported income. Each bin in the second row indicates that at least half of the students report an income below a given threshold, but less than half indicate income below a previous threshold. The third row pertains to SNAP usage by families in the student's home zip code, and the last row is by median family income. Standard errors are clustered at the state-by-disbursement day-of-month-by-cohort level.

Figure A6: Effects of SNAP Timing by High School Seniority

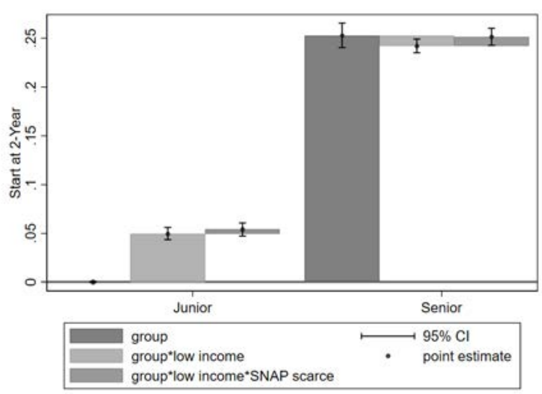
(a) SAT Score



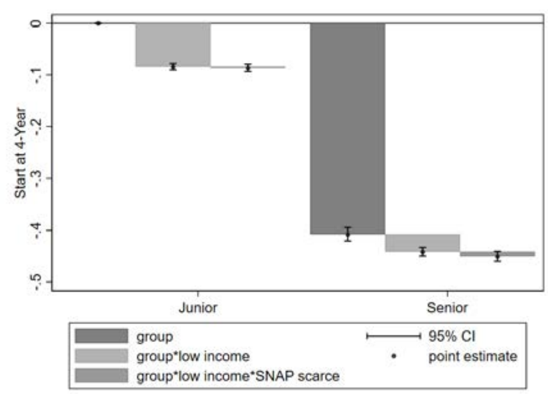
(b) No College



(c) Start 2 Year



(d) Start 4 Year



Notes: Estimates are based on data from The College Board on SAT scores and National Student Clearinghouse data on college attendance from 2009–2014 cohorts. We estimate an extension of Equation (2) that includes interactions of indicators for junior and senior students with the variable of interest ($low - income * SNAPscarce$) as well as the "low-income" indicator. For each subgroup, we report the coefficient for the treatment effect for that group ("group*low-income*SNAP scarce"). Standard errors are clustered on the state-by-disbursement day-of-month-by-cohort level.