Updating Human Capital Decisions: Evidence from SAT Score Shocks and College Applications*

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Abstract

We estimate whether students update the colleges to which they consider applying in response to large, unanticipated information shocks generated by the release of SAT scores– a primary factor in admission decisions. Exploiting population data on the timing of college selection and a policy that induces students to choose colleges prior to taking exam, we find that students update their portfolios in terms of selectivity, tuition, and sector. However, the magnitude of updating is too modest to significantly reduce unexplained variation across students, suggesting that non-academic factors are the dominant determinants of college match.

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1 Introduction

A large literature considers the role of non-academic determinants of college choice, such as tuition rates and parental resources. Updating human capital decisions to reflect new information about academic ability provides an important alternative to such explanations. Thus recent studies have examined how the revelation of college grades affect students' dropout decisions and choice of major (Zafar, 2011; Arcidiacono, Hotz, and Kang, 2012; Stange, 2012; Stinebrickner and Stinebrickner, 2012 and 2013; Wiswall and Zafar, 2015; and Arcidiacono et al. 2016). This study provides a direct analogue at another crucial time for human capital investment: when high school students select colleges to which they may apply. Specifically, we examine whether students update the portfolio of colleges to which they send their SAT scores in response to large, unanticipated positive and negative information shocks generated by the release of scores. Using new population data on the timing of students' selection of colleges for their portfolios, we exploit a design that contrasts the colleges students selected before they take the SAT with those selected after their scores are released. College entrance exams are among the most important factors in determining college admission and are perhaps the single most important new information students receive during the college selection process. If students do not update their portfolios in response to their scores, it indicates that college selection is largely predetermined by non-academic factors and preexisting beliefs. Our estimates provide new causal evidence about how human capital preferences are formed and why college mismatch occurs. This information is of fundamental interest owing to the potentially high returns to college quality.[1]

The primary challenge in estimating whether students update is the need to observe their college choices before and after new academic information is revealed. Unfortunately, a student has only one realized application portfolio and, in many cases, receives only one entrance exam score. To overcome this, we exploit a College Board policy that induces students to select a limited number of colleges to receive their SAT scores at the time that they register for the exam.[2] Subsequently, students receive their scores and decide whether and where to send additional reports. Using a new national data set that includes the exact date when each college was selected by the student, we are able to estimate the effect of SAT information shocks on the composition of college portfolios. Conditional on sending more reports, an unanticipated positive (negative) shock causes a student to select a portfolio that has higher (lower) selectivity, tuition, graduation rates, fraction of private colleges, and geographic dispersion. However, the estimated effects are quite modest: a one standard deviation score shock generates a 0.05 standard deviation shift in portfolio selectivity, which is one-tenth the magnitude of cross-sectional estimates. These results suggest that non-academic factors are the dominant determinants of college choice.

Several factors make this environment a nearly ideal context for identifying the extent to

[1] For estimates of the returns to college quality, see, for example, Behrman, Rosenzweig, and Taubman (1996), Black and Smith (2006), Hoekstra (2009), and Cohodes and Goodman (2014).

[2] See Pallais (2015) for analysis showing that students tend to use the free score reports that are available prior to taking the exam. Three-quarters of SAT takers in our data use at least one of their free reports.

which students update the colleges they select. First, many students experience large SAT score shocks that are difficult to anticipate – the standard deviation of within-student differences between first and second SAT scores is 70.3 points, or 0.35 standard deviations. Second, we measure updating using the high-stakes selection of colleges to receive scores rather than with subjective survey responses that are common in the updating literature. Third, the data used for analysis include students' PSAT scores and, in many cases, two or more SAT attempts. Multiple exams allow us to measure what information is new to the student and to test whether or not students anticipate their scores. Fourth, students make their pre-exam college choices shortly before taking the SAT, limiting the possibility that updating stems from time-varying factors that are correlated with exam performance.[3] Finally, the analysis is based on national administrative data that produce precise estimates and allow us to consider heterogeneous effects across socio-economic characteristics such as household income and race.

Identification is based on a difference-in-differences style design that estimates the extent to which colleges selected before and after students learn their scores reflect this new information. We present an empirical model analogous to those used in the employer learning literature that reveals several important considerations for the interpretation of the reduced-form results.[4] The model confirms that students should place greater importance on SAT scores as they are released and reduce their reliance on measures of ability that were previously used to anticipate scores. We show that estimates of updating will be biased to the extent that students anticipate their scores or employ time-varying strategies that are correlated with ability, and we show how to correct for each of these issues.

There are two primary reasons to believe that SAT score shocks may alter the colleges students select to receive reports. First, entrance exam scores and high school grades are typically the most important factors used by colleges when making admission decisions. This is evident from the widespread and often mechanical use of admission indices that are a function of GPA and exam score by public universities and university systems.[5] In addition, many universities require students to have a minimum SAT score in order to be considered for admission.[6] Second, students may update their beliefs about their likelihood of being successful at more selective colleges given new

[3]A natural concern is that changes in the colleges selected and exam performance over time are caused by a concurrent time-varying factor such as performance in high school. This concern is alleviated by the fact that students select their pre-exam portfolios not when they take the PSAT, but shortly before taking the SAT.

[4]The model is most closely related to those presented in Farber and Gibbons (1996), Altonji and Pierret (2001), and Lange (2007). The updating that occurs when students' scores are released shares similarities with the updating by employers when they observe the performance of employees (Arcidiacono, Bayer, and Hizmo, 2010; Rockoff et al., 2012; Kahn and Lange 2014). Student updating plays a significant role in theoretical models of college choice (Manski, 1989; Altonji, 1993; Altonji, Blom, and Meghir, 2012).

[5]For example, admission indices are used by Alabama State, Iowa State, Utah State, the University of Memphis, the University of Southern Florida, the University of Colorado System, and the California State University System. Authors' estimates for eight state universities indicate that the SAT and high school GPA are the dominant determinants of college admission, with a one standard deviation increase in SAT score increasing the probability of admission by more than 10 percentage points (after controlling for a rich set of covariates including high school attended, race, gender, and performance on AP exams).

[6]For example, minimum SAT score requirements are used by the University of Mississippi, the University of Florida, Kansas State University, and the University System of Georgia.

objective information about their ability relative to a national pool of college-bound students.

Our estimates reveal, however, that after scoring 100 points higher on the SAT than anticipated, a student will select colleges whose matriculating students scored about 5 points higher on the exam. To put this in perspective, consider two students who anticipate getting the same SAT score but before taking the exam choose colleges with average scores of 1100 and 1200, respectively. After their scores are released, the gap in college selectivity closes by only 5 points if the less ambitious student scores 100 points higher on the exam. The magnitude of updating is smaller when the cumulative portfolio is considered, because students select about half the colleges before taking exam. Thus a one standard deviation SAT score shock results in an approximately 0.10 standard deviation shift in the selectivity of newly added colleges and a 0.05 standard deviation shift in the selectivity of the cumulative portfolio. There is a similar pattern of effects for other college characteristics, including tuition levels and sector. These modest magnitudes indicate that inertia due to factors such as parental knowledge and financial resources result in new information closing a small fraction of the portfolio gap evident across students. Cross-sectional estimates indicate that a one standard deviation difference in SAT score is associated with a 0.4 standard deviation difference in portfolio selectivity after controlling for a rich set of covariates. The disparity between our causal estimates and the cross-sectional correlation implies that much of the apparent match between student ability and college quality is due to unobserved factors rather than sorting because of academic qualifications.[7] Further, many students do not send reports to additional colleges after taking the SAT, generating even more inertia in portfolio choice. Thus we present a lower bound response in which non-senders are assumed to not update their portfolios.

Students who take the exam two or more times experience multiple information shocks. We find that the composition of colleges selected after the first exam more closely reflects the first score and likewise for colleges selected after the release of the second score. Importantly, the results indicate that students do not incorporate information from the second score into their choices when only the first score is known, supporting the validity of the empirical design. Those who receive positive shocks appear to alter their portfolios more than those who receive negative shocks. This is consistent with evidence that changes in the portfolio are driven by students sending their scores more aggressively to "reach" (more selective) colleges with little change in the "safety" (less selective) colleges. Interestingly, heterogeneity analysis by race and household income does not indicate that the average effects obscure larger responses from potentially sensitive subgroups. To abstract from the choice to take the exam multiple times, we replicate the design using a merged sample of one- and two-time takers, and find very similar estimates.

A number of studies in the literature have found that human capital decisions are sensitive to perceived returns and expectations (Attanasio and Kaufmann, 2009; Jensen, 2010; Jacob and Linkow, 2011; Abramitzky and Lavy, 2014), performance labels (Papay, Murnane, and Willett,

[7] A number of non-academic factors may be responsible for the high degree of inertia in college choice. For example, some students may have strong geographic preferences, such as attending college close to home because it is familiar to them or is less expensive because they are eligible for in-state tuition. Others may have allegiance to particular college brands because they have parents or siblings who attended them.

2016), and parental perceptions of children's ability (Dizon-Ross, 2014). Nonetheless, significant mismatch between student ability and college quality has been well documented (Arcidiacono, 2005; Arcidiacono, Khan, and Vigdor, 2011; Hoxby and Avery, 2012; Smith, Pender, and Howell, 2013; Arcidiacono and Lovenheim, 2016; Dillon and Smith, 2016). This study provides causal estimates of the disconnect between academic ability and the college selection process. The results are consistent with evidence that college choices are shaped by non-academic factors such as counseling services (Avery and Kane 2004; Carrell and Sacerdote, 2016; Oreopoulos and Ford, 2016), information about the cost of college (Bettinger et al., 2012; Hoxby and Turner, 2014), and ease of access to entrance exams (Klasik, 2013; Hurwitz et al., 2014; Bulman, 2015; Goodman, 2016). Thus the estimates in this paper reveal the role of entrance exams in shaping college portfolios, shed light on how students update their human capital choices, and add causal evidence to our understanding of college mismatch.

The paper is organized as follows. Section 2 describes the policy and new administrative data used to conduct the analysis. Section 3 introduces an empirical framework of student updating and identifies several testable implications. Section 4 presents the primary specifications and results. Section 5 discusses the implications of the findings.

2 SAT Scores and College Score Reports

This paper examines whether students update the portfolio of colleges to which they send their SAT scores in response to new information about the strength of their applications and college readiness. Panel data provide an opportunity to factor out unobserved, time-invariant individual and household characteristics and beliefs that influence college choices.[8] This paper uses administrative data from the College Board that include each entrance exam score and the exact timing of when students send score reports to colleges. Thus our panel consists of colleges selected during multiple information periods: before the exam; after scores are released; and, for two-time takers, after scores for the second exam are released. This section details the content of the individual-level administrative data, the construction of the sample for analysis, and the magnitude and predictability of within-student variation in exam performance.

2.1 Administrative Data

The SAT is a college entrance exam administered by the College Board that is taken by high school students across the United States, typically in their junior or senior year. The exam consists of math and critical reading sections scored between 200 and 800, so students can receive a combined score between 400 and 1600.[9] The distribution of combined scores is presented in Figure 1. Each

[8] Estimating the importance of academic characteristics on student choices is inherently problematic in the cross-section because many student and household characteristics are difficult to measure (e.g., parental expectations, familiarity with the application process, geographic preferences, student motivation, financial resources, high school quality, and peer effects).

[9] A writing section was introduced in 2005 but is not taken by all students or used by all colleges in the admissions process.

section was normalized in 1995 to have a mean score of 500 and a standard deviation of 110. Students are permitted to take the SAT more than one time. This analysis focuses on years prior to 2009 during which all of a student's scores are reported to a college. In later years, Score Choice policies allowed students to pick and choose which scores are sent, which significantly complicates the empirical design necessary to measure updating. Along with student scores on each SAT attempt, the data contain scores for the Preliminary SAT / National Merit Scholarship Qualifying Test (PSAT), which is a lower-stakes version of the SAT taken in one's sophomore or junior year of high school. The College Board also administers a questionnaire upon exam registration that asks students to provide their high school GPA, race, parental income, high school attended, and home zip code.

The analysis in this paper examines the colleges to which students send their SAT scores via the College Board. Each report sent to a four-year college is merged with college characteristics from the National Center for Education Statistics Integrated Postsecondary Education Data System. The data also include the exact date that students request each report. When registering for the SAT, students have the option to send their scores to four colleges for no additional cost. They must select the colleges within nine days of taking the exam, so a high fraction of takers elect to send reports before the exam. After this period, scores may be sent for a fee of approximately 11 dollars each. Students from lower-income households are eligible to send additional reports for free. During the period of analysis, reports sent to colleges include every score earned by the student, though colleges do not automatically receive a new report if a student retakes the exam. Thus a student may send a report more than one time to the same college, which is particularly common among those who improve their scores. For students who took the SAT once, we divide score reports into those requested before taking the exam and those requested after the scores are released.[10] For students who take the SAT twice, we consider reports requested before the first exam, after the first exam score is released but before the second exam is taken (including reports that are free with the second registration), and after the second exam score is released. We calculate the average characteristics of the colleges in each of these periods, including the SAT scores of matriculating students, in-state tuition, graduation rate, fraction private, and distance from the student's home. The distribution of portfolio quality in the pre-exam period is presented in Figure 1.

Because there is no national administrative database of college applications, a number of studies have used score reports as a proxy for applications when studying the effects of affirmative action (Long, 2004; Card and Krueger, 2005), tuition levels (McDuff, 2007), guaranteed admission programs (Andrews, Ranchhod, and Sathy, 2010), score report fees (Pallais, 2015), and application patterns (Bound, Hershbein, and Long, 2009). In many contexts, the fact that students can send score reports to colleges to which they do not apply creates a wedge between the desired outcome (applications) and the observed outcome (score reports). However, score reports are advantageous for examining how students update their beliefs over time. While most applications are completed

[10]Score Sends requests are delayed until new scores are available, so the analysis is based on the request date rather than the fulfillment date. About 3 percent of students make requests immediately after the exam is taken but before the scores are released. These requests are excluded because they may reflect partial treatment.

after students take the SAT, score reports reveal students' choices before and after the exam. Further, completed applications are endogenous to the updating we wish to estimate. For example, a student may send a score report to a selective college prior to taking the SAT and not apply after receiving a lower-than-expected score. That is, the updating we estimate is likely to be one of the factors that drives a wedge between score reports and applications.

Nonetheless, the evidence suggests that there is a strong (though not one-to-one) relationship between score reports and applications. Because more than 80 percent of traditional four-year colleges recommend or require entrance exam scores to be considered for admission, score reports largely define the set of four-year colleges to which a student could apply. Consistent with this, Card and Krueger (2005) find a "very high" correlation between application and score report totals for universities and Smith (2016) finds that high-ability, low-income students report applying to more than 60 percent of the colleges that receive their scores. Pallais (2015) finds a somewhat weaker relationship when estimating the responsiveness of students to additional free reports.

2.2 Population for Analysis

The analysis is based on the population of students who took the PSAT and SAT between 2007 and 2009 and who sent at least one score report before taking the SAT.[11] The PSAT is taken by more than 75 percent of SAT takers and provides students with a measure of how they might perform on the SAT. Approximately 75 percent of SAT takers send at least one free score report to a college prior to taking exam, and nearly two-thirds of these students use all four of their free reports. The reports allow us to observe the types of colleges students consider before receiving their scores. Analysis of revised portfolio composition is conditional on students sending score reports after taking the SAT.

Table 1 presents summary statistics for the population of PSAT takers who took the SAT one or two times and for the subset of these students who sent score reports before and after the exam (who constitute the sample for analysis). Among one-time takers who send reports after the exam, 49 percent are male, 14 percent are black, and 13 percent are Hispanic. Mean PSAT and SAT scores are 1085 and 1136, respectively. Two-time takers who send reports are quite similar, with 46 percent male, 11 percent black, and 12 percent Hispanic, and average scores of 1086 on the PSAT and 1114 on the first SAT. Relative to the population of takers, these students have similar demographic characteristics but have higher average performance on the PSAT and SAT.[12] Thus we consider the determinants of retaking the exam and sending additional score reports explicitly.

Table 2 presents the correlates of retaking the SAT. Larger score shocks, approximated by the difference between the SAT and PSAT scores, are only weakly correlated with taking the exam twice. For example, having an SAT score that is 100 points lower than one's PSAT is associated

[11] The choice of cohorts is determined by the availability of data that include the date when score reports are sent.

[12] Our analysis is restricted to those who took the PSAT, because this provides a baseline measure of expected performance. SAT takers who did not take the PSAT have similar demographic characteristics (51 percent are male, 11 percent are black, and 13 percent are Hispanic) but have lower performance on the SAT, with an average score of 958 points.

with an increase in the retake rate of 2 percentage points.[13] By comparison, students from the highest income category are 9 percentage points more likely to take the exam than those in the lowest income category, and one GPA point is associated with an 11 percentage point higher rate of retaking. Thus higher-income and higher-performing students are over-represented in the sample of two-time takers. To ensure that splitting the sample does not bias the estimates, we replicate the design for a merged sample of one- and two-time takers.

The analysis is necessarily restricted to students who send score reports before and after taking the SAT. Columns (3) and (4) of Table 2 reveal that students from higher-income households are more likely to send additional score reports after receiving their scores.[14] In contrast, the estimates do not reveal that students who receive the largest information shocks are more likely to send additional reports. For example, a 100 point shock is associated with a less than 1 percentage point increase in the probability of sending additional reports. Thus the magnitude of updating a student is likely to have done does not seem to be a significant determinant of whether the student is included in the analysis.[15] Nonetheless, the primary results of the paper should be interpreted in light of the fact that students from higher-income households and with higher GPAs are over-represented. Further, those who send more reports may be those who are more sensitive to new information. Thus we implement a bounding exercise in Section 4.5 in which students who do not send additional reports after receiving their scores are included in the sample under the assumption that they did not update.

2.3 Within-Student Variation in Scores

There is significant within-student variation in scores earned on college entrance exams. This variation is important for two reasons. First, unpredictable variation in scores generates the information shocks necessary to identify updating. Second, the magnitude of the variation determines the importance of updating in practice.

The top graph in Figure 2 presents the distribution of the differences between students' first SAT scores and their PSAT scores. The mean is close to 0 and the standard deviation of the difference is 85.6 points. Thus within-student variation is nearly one-half of the 190 point standard deviation across students. To examine the extent to which other factors may help to explain this variation, we generate a predicted SAT score using a rich set of observables in addition to the PSAT, including a complete set of fixed effects for pre-exam portfolio selectivity, high school GPA, household income, gender, and race. The standard deviation of the difference between each student's actual and predicted SAT score is 80.5 points.[16] Thus the PSAT score appears to be the

[13] Vigdor and Clotfelter (2003) examine retaking behavior among applicants to three selective universities.

[14] Students from households with income exceeding 100,000 dollars are 5 percentage points more likely to send additional reports than students from households with income less than 50,000 dollars. A one point increase in GPA is correlated with an 8 percentage point higher probability of sending additional reports.

[15] How much students update their beliefs depends on the interaction of two factors: the size of the information shock |SAT-PSAT| (which is observable), and sensitivity to new information (which is unobservable). The finding that the size of the information shock is not strongly correlated with sending additional reports suggests that students who update the most may not be more likely to send additional reports.

[16] While the PSAT has an R-squared of 0.86 for predicting SAT scores, the R-squared for all other covariates

most important predictor of a student's SAT score for the researcher and perhaps for the student as well.

Within-student variation in scores is also evident when students take the SAT multiple times. The bottom graph in Figure 2 presents the distribution of the differences between students' first and second scores. The standard deviation of the difference is 70.3 points. This variation is especially interesting considering that the exams are, by design, equally difficult and cover the same body of knowledge. Note that while students perform slightly better on average the second time they take the exam (the mean improvement is about 30 points), this increase is small relative to the magnitude of the variation in scores. As a result, nearly 40 percent of students earn a lower score when they take the exam a second time. This is notable because repeat takers have additional time for test preparation and experience taking the exam, and they may have chosen to retake in part because they believe that they had an unexpectedly poor performance the first time. Students taking the exam a second time and earning a lower score is consistent with there being significant and unpredictable noise in performance. We predict each student's second score using all the observables listed above in addition to the first SAT score. The resulting standard deviation of the difference is 63.6 points.[17] That is, even with two measures of exam performance in hand, the PSAT and the first SAT, realized performance varies considerably and is difficult to predict. In Section 4, we supplement this descriptive evidence with an empirical test of whether students can anticipate their scores, exploiting the fact that anticipation will reveal itself as the incorporation of future scores into current portfolio choice.

3 Empirical Framework

We develop an empirical model that highlights several important considerations for interpreting the reduced form estimates. Intuitively, updating should result in positive coefficients on scores as they are released (i.e., students give weight to information as it becomes available) and negative coefficients on factors such as PSAT scores (i.e., students rely less on other measures of ability). The model also reveals methods for detecting and correcting two sources of bias in the estimates. First, if students partially anticipate their scores using factors that are unobserved by the researcher, then the estimates of updating will be attenuated. Intuitively, the magnitude of the information shock for the student is smaller than what is observable in the data. Second, students may employ strategies such as sending scores to safety colleges before the exam and reach colleges after (or vice versa). If these strategies are correlated with ability, then the estimates will be biased. For example, if high ability students select colleges more aggressively after taking the exam, then the estimate of updating will be biased upward (which is the case in practice). We present a method

(including GPA and demographics) is only 0.43. Thus the addition of these variables to the predictive model only increases the predictive power to 0.87.

[17]The addition of demographic covariates to the PSAT and first SAT scores only increases the R-squared of the model from 0.88 to 0.89. Without the PSAT and first SAT, other covariates explain 38 percent of the variation in the second SAT score. As with one-time takers, prior exams appear to be the dominant predictor of subsequent performance.

to account for time-varying college selection strategies, and show that the effect of the second score after only the first score is released is a measure of net bias and can be used to recover causal effects.

3.1 Student Updating

The empirical model is analogous to those in the employer learning literature (Farber and Gibbons, 1996; Altonji and Pierret, 2001; Lange, 2007), but with students updating their portfolios in response to receiving new information from the SAT. We present the model for students who take the exam twice, which accounts for one-time takers as a special case.[18] Students form beliefs about optimal portfolios which can be summarized by a single continuous measure of quality y.[19] The portfolio is a function of three components: s are characteristics observable to the student and the researcher (e.g. PSAT scores); q are characteristics observable only to the student (e.g., personal essays); and z is the true SAT score that a student would receive in the absence of measurement error.[20] We assume the distribution of (s, q, z) is jointly normal with non-negative correlations across vectors. This assumption has been made previously in the literature (e.g., Lange, 2007), makes the model tractable, and there are several opportunities in the empirical analysis to examine if it is reasonable.[21] The optimal portfolio for a student i is assumed to be linear in these elements:

$$y_i = \delta q_i + r s_i + z_i \tag{1}$$

Since y_i has no natural scale, we normalize it so that the marginal effect of the true SAT score is equal to 1. Students select colleges to receive reports in $t = 0$ without knowing either SAT score; receive their first score (z_1) in $t = 1$ and choose additional colleges; and receive their second score (z_2) in $t = 2$ and choose colleges with knowledge of both scores. These scores are imperfect signals of z: $z_t = z + \epsilon_t$, where ϵ_t is a normally distributed measurement error term with mean zero and variance σ_ϵ^2, and $E[\epsilon_j \epsilon_k] = 0, \forall j \neq k$.

It follows from joint normality that students' expectations of their scores prior to knowing the results of either exam can be written as $z = E[z|s, q] + \nu = \gamma_1 q + \gamma_2 s + \nu$, where ν is a mean zero random variable with variance σ_ν^2. In this expression, γ_1 and γ_2 reflect the extent to which

[18]The framework can be extended naturally to students who take the SAT three or more times, but in practice a modest fraction of students take the exam more than twice during this period.

[19]We abstract from the method by which a student determines the optimal portfolio and only assume that there is a monotonic relationship between portfolio quality and student characteristics. For theoretical treatments of the portfolio choice problem see Epple, Romano, and Sieg (2006), Chade, Lewis, and Smith (2011), and Fu (2014).

[20]A fourth factor that can affect the portfolio are time-invariant characteristics unobservable to the student and the researcher (e.g., confidential letters of recommendation), often designated as η in the employer learning literature. In practice, these factors do not add intuition or alter the results of the model and thus are omitted for brevity.

The model differentiates between a *true* SAT score and the score a student earns, which allows the full set of scores to matter when individuals take the exam multiple times. As our analysis focuses on years prior to Score Choice, colleges observe and may use the full set of scores for admissions decisions. For students who take the exam only once, imposing that the true score is equal to the earned score has no consequences for the results.

[21]If the normality assumption is violated, then the expectations become linear projections and the signs of the predictions still hold.

students predict their SAT scores using unobservable and observable characteristics, respectively. At no point does a student observe the true score z, only the imperfect signals z_1 and z_2. After each score is announced, students update their beliefs and rely less on q and s to predict their true scores:

$$\begin{aligned} E[z|s, q, z_1] &= (1 - \pi_1)(\gamma_1 q + \gamma_2 s) + \pi_1 z_1 \\ E[z|s, q, z_1, z_2] &= (1 - 2\pi_2)(\gamma_1 q + \gamma_2 s) + \pi_2 z_1 + \pi_2 z_2 \end{aligned} \tag{2}$$

The extent to which students update their beliefs depends on how accurate they believe their priors to be relative to actual exam scores. Specifically, the exams will receive weight $\pi_t = \sigma_\nu^2/(\sigma_\epsilon^2 + t\sigma_\nu^2)$, which follows from Bayesian updating with a normally distributed prior and t normally distributed signals. Note that if students believe revealed scores to be very informative of z (or only care about the admissions implications of realized scores), then π_1 is close to 1, and if the test score is relatively uninformative, π_1 is close to 0. Similar intuition applies for π_2. Substituting the expressions from (2) into (1), we can write the portfolios a student selects in each period as follows.

$$\begin{aligned} y_0 &= [\delta + \gamma_1]\, q + [r + \gamma_2]\, s \\ y_1 &= [\delta + \gamma_1(1 - \pi_1)]\, q + [r + \gamma_2(1 - \pi_1)]\, s + \pi_1 z_1 \\ y_2 &= [\delta + \gamma_1(1 - 2\pi_2)]\, q + [r + \gamma_2(1 - 2\pi_2)]\, s + \pi_2 z_1 + \pi_2 z_2 \end{aligned} \tag{3}$$

The weight students place on unobservable characteristics q and observable characteristics s prior to learning exam scores is the sum of their direct effects on portfolio choice (δ and r) and their role in predicting unobserved SAT scores (γ_1 and γ_2). Students rely less on these characteristics after the release of the first score z_1 (evident from the $1-\pi_1$ term), and further reduce this reliance after the release of the second score (evident from the $1 - 2\pi_2$ term). The importance of each realized score is a function of the perceived accuracy of the exam.

3.2 Coefficient Estimates and Bias

This section presents the composition of the reduced form coefficients, potential sources of bias, and methods for correcting bias. In practice, we observe s and the two test scores, z_1 and z_2, but not unobservables q. Because (s, q, z) are jointly normal, the conditional expectation of q given s and z and the linear projection are equivalent:

$$q = E[q|s, z] + u = \gamma_3 s + \gamma_4 z + u \tag{4}$$

In this expression, γ_3 and γ_4 reflect the extent to which students observable characteristics and true SAT score are predictive of their unobservable characteristics. As we do not observe z, but instead z_1 and z_2, the researcher's expectation is

$$E[q|s, z_1, z_2] = [\gamma_3 + \gamma_4(1 - 2\phi_2)]\, s + \gamma_4\phi_2 z_1 + \gamma_4\phi_2 z_2 \tag{5}$$

where ϕ_2 is the standard coefficient from Bayesian updating with two i.i.d. normal signals, and reflects that more weight is placed on s due to the noisiness of z_1 and z_2 as predictors of z.

A difference-in-difference design that interacts all observables with an indicator for each time period will reveal how the coefficients on the test scores change as they are revealed to the student. We can define the following regressions of y on s, z_1, and z_2 in each period:

$$\begin{aligned} E^*[E[y|s,q]|s,z_1,z_2] &\equiv a_0 s + b_0 z_1 + c_0 z_2 \\ E^*[E[y|s,q,z_1]|s,z_1,z_2] &\equiv a_1 s + b_1 z_1 + c_1 z_2 \\ E^*[E[y|s,q,z_1,z_2]|s,z_1,z_2] &\equiv a_2 s + b_2 z_1 + c_2 z_2 \end{aligned} \tag{6}$$

We can determine the coefficients by substituting (5) into (3):

$$\begin{aligned} a_0 &= r + \delta[\gamma_3 + \gamma_4(1-2\phi_2)] + [\gamma_2 + \gamma_1\gamma_3 + \gamma_1\gamma_4(1-2\phi_2)] \\ b_0 &= \gamma_4\phi_2(\delta + \gamma_1) \\ c_0 &= \gamma_4\phi_2(\delta + \gamma_1) \end{aligned} \tag{7}$$

Though the student does not observe z_1 and z_2 prior to taking the exam, the scores will have positive coefficients because they are correlated with the omitted variables q. This effect has two components. The first, δ, is time invariant and reflects that q has a causal effect on y. The second is a time-varying "anticipation" effect γ_1 which captures that students use q to predict z before the test scores arrive. The magnitudes are scaled up or down by the correlation between unobservables q and true scores z (γ_4) and the accuracy of realized scores as predictors of z (ϕ_2). Note that if realized scores are i.i.d. draws from the distribution of the true latent score, then $b_0 = c_0$, which provides a natural test of the validity of this assumption (i.e., the first and second SAT scores should have the same coefficients prior to either score being released).

After the first score is revealed, substituting (5) into (3) reveals that the coefficients change as follows:

$$\begin{aligned} a_1 - a_0 &= -\pi_1\left[\gamma_2 + \gamma_1\gamma_3 + \gamma_1\gamma_4(1-2\phi_2)\right] \\ b_1 - b_0 &= \pi_1(1 - \gamma_1\gamma_4\phi_2) \\ c_1 - c_0 &= -\pi_1\gamma_1\gamma_4\phi_2 \end{aligned} \tag{8}$$

As expected, students increase their reliance on the revealed scores and reduce their reliance on other measures of ability. However, the difference-in-difference coefficient $b_1 - b_0$ on z_1 is biased downward. It reflects both the causal estimate of updating, π_1, and a decrease in the reliance by the student on q to predict z ($\gamma_1\gamma_4\phi_2$ is the anticipation term). The more accurately students can predict their scores using factors that we cannot observe, the more we will underestimate their response to new information. Fortunately, the magnitude of the bias is captured by the coefficient on the not yet revealed second score z_2. Thus the difference $(b_1 - b_0) - (c_1 - c_0)$ yields the causal effect of updating.

Substituting (5) into (3) reveals the estimates after both exams are revealed can be expressed as follows:

$$\begin{aligned} a_2 - a_0 &= -2\pi_2 \left[\gamma_2 + \gamma_1\gamma_3 + \gamma_1\gamma_4(1 - 2\phi_2)\right] \\ b_2 - b_0 &= \pi_2(1 - 2\gamma_1\gamma_4\phi_2) \\ c_2 - c_0 &= \pi_2(1 - 2\gamma_1\gamma_4\phi_2) \end{aligned} \tag{9}$$

With all scores available to students, they further reduce their reliance on observable characteristics and now place positive weight on the second exam score. As in the pre-exam period, the coefficients on the first and second SAT scores are equal if realized test scores are i.i.d. There is, however, no longer a natural correction for bias during this period.

We note that it is likely that students employ portfolio selection strategies that vary over time for reasons other than updating. For example, students may send scores to low-risk "safety" colleges before taking the exam and defer decisions about "reach" colleges until after learning their scores. These strategies will be innocuous if the changes over time are uncorrelated with the determinants of the optimal portfolio, as level changes are captured by time period fixed effects. However, higher-ability students might have larger or smaller average gaps between their "safety" and "reach" colleges than lower-ability students for reasons unrelated to updating.[22] Time-varying strategies can be incorporated into the model by allowing the scale of y to differ across periods. Specifically, we allow students to select portfolios of quality y after the exam and portfolios of quality $\Omega_0 y$ before the exam. A value of Ω_0 that is less than one indicates that higher-ability students choose more selective colleges after the exam relative to the pre-exam period than do lower-ability students (and vice-versa for Ω_0 greater than one). Failure to adjust for this scaling will generate a mechanical bias in the estimates. For instance, if $\Omega_0 < 1$, the coefficient on the SAT in the post-exam period will reflect both updating and bias caused by higher-ability students applying more aggressively after the exam for reasons unrelated to score shocks.[23]

To correct bias caused by time-varying strategies, we estimate the scaling factors explicitly and use them to adjust the portfolio scales in each period. Consider a regression of y_t on observable information about ability s. As originally shown by Farber and Gibbons (1996), this estimate will simply be $E^*[\Omega_t E[y|s]|s] = \Omega_t E^*[y|s]$ where the equality follows from the law of iterated projections.[24] We estimate this using a series of regressions,

$$y_t = d_t s + \epsilon_t \tag{10}$$

[22] For example, lower-ability students might select colleges with average selectivity of 1000 before the SAT and 1100 after, while higher-ability students might select colleges with selectivity of 1200 before and 1320 after. The larger change in portfolio selectivity for higher-ability students could be caused by factors unrelated to SAT score shocks.

[23] Specifically, for one-time takers, the estimate will be $b_1 - \Omega_0 b_0$, which is larger than $b_1 - b_0$.

[24] Note that because of the normality assumptions, the linear projection and the conditional expectation are the same thing, so the law of iterated expectations also applies.

If the coefficient vector on s changes across time periods, it can only be attributed to changes in strategy. The estimate of Ω_t is then $\hat{\Omega}_t = \frac{d_t}{d_T}$, where we normalize to period 1 scale for one-time takers and period 2 scale for two-time takers.

4 Estimates of Student Updating

College entrance exams are required by the vast majority of four-year colleges and are a primary factor in admission decisions. Thus the revelation of scores may be the single largest academic information shock that students experience with respect to shaping college choice. We employ a difference-in-differences style design to estimate if, and to what extent, students update the portfolio of colleges to which they send score reports in response to the revelation of their performance. The primary outcome of interest is college selectivity as measured by the average SAT scores of matriculating students. Additional outcomes presented include tuition levels, graduation rates, college sector, and geographic proximity.[25] We present outcomes for new colleges added to the portfolio in each period and the resulting change in the cumulative portfolio.[26]

As detailed in Section 3, portfolio updating will generate positive coefficients on scores as they are released and negative coefficients on academic measures previously used to predict scores. Two-time takers provide an explicit test of, and correction for, the extent to which the estimates are biased by score anticipation and time-varying strategies that are correlated with ability. Because students select into sending score reports after the exam, we implement a bounding exercise in which those who do not send additional reports are added to the analysis and assumed to not update their portfolios. Appendix A presents estimates from a cross-sectional regression for comparison. Note that these naive estimates are suggestive of updating, as the second SAT score appears to play a dominant role for score reports sent after it is released while the importance of the first score and the PSAT score are diminished.

4.1 Primary Specifications

In the case of students who take the exam one time, we estimate the following specification,

$$y_{it} = \beta_0 + \beta_1 s_i + \beta_2 z_{1i} + \beta_3 \mathbb{1}_{t=1} + \beta_4 s_i \mathbb{1}_{t=1} + \beta_5 z_{1i} \mathbb{1}_{t=1} + \epsilon_{it} \tag{11}$$

where, for simplicity, we can think of s_i as students' PSAT scores (though we also include high school GPA, household income, gender, race, and geographic location), z_1 are SAT scores, and

[25] Black and Smith (2006) detail the potential pitfalls of using a single measure of college quality, so we present a range of outcomes. Likewise, the use of ordinal variables such as test scores as an outcome has shortcomings (Bond and Lang, 2013 and 2014), so we verify that our results are robust to multiple polynomial transformations of our quality measure, including both highly left-skewed and highly-right skewed transformations.

[26] Students who initially believe they are high type, may reassess downward after receiving negative score shocks. They may respond to this by selecting additional colleges that are of the appropriate selectivity given their new beliefs. Alternatively, they may overcompensate and choose even less selective schools in order to balance their prior mistakes.

$\mathbb{1}_{t=1}$ is an indicator for the score report being sent after the scores are released. The outcomes y_{it} are the average characteristics of the colleges selected before or after the scores are released, with one observation per student per period.[27] The specification allows the PSAT and SAT to differ in their relative importance. An alternative specification measures the score shock as the difference between the SAT and PSAT, which generates a coefficient that is the average of the increased weight students place on newly revealed SAT scores and the decreased weight placed on PSAT scores.

Students who take the SAT more than one time provide especially compelling evidence of the pattern and magnitude of updating. Observing the responses to multiple shocks necessarily increases the credibility of estimates because the probability that some unobserved, time-varying confounder would coincide with the treatment on multiple occasions is quite low. For students who take the SAT twice, the specification is,

$$\begin{aligned} y_{it} &= \beta_0 + \beta_1 s_i + \beta_2 z_{1i} + \beta_3 z_{2i} + \beta_4 \mathbb{1}_{t=1} + \beta_5 \mathbb{1}_{t=2} \\ &\quad + \beta_6 s_i \mathbb{1}_{t=1} + \beta_7 z_{1i} \mathbb{1}_{t=1} + \beta_8 z_{2i} \mathbb{1}_{t=1} + \beta_9 s_i \mathbb{1}_{t=2} + \beta_{10} z_{1i} \mathbb{1}_{t=2} + \beta_{11} z_{2i} \mathbb{1}_{t=2} + \epsilon_{it} \end{aligned} \tag{12}$$

where z_{1i} and z_{2i} are the first and second SAT scores. The coefficients β_7 and β_{11} represent the change in the coefficient on the first and second SAT scores after each is released, and the coefficients β_6 and β_9 represent the corresponding reduction in importance of the PSAT.[28]

Identification assumes that students are not able to anticipate their scores – i.e., that score shocks are exogenous. Anticipation of scores will generate downward bias, as the shock experienced by students will be smaller than is measured in the data. The distribution of PSAT and SAT scores presented in Section 2 suggests that scores are difficult to predict owing to significant within-student variation that is not correlated with observables. A second source of bias may occur if, for example, higher-ability students have the same "safety" schools but better "reach" schools than lower-ability students. In Section 3.2, we showed how to correct for this using time-variance in the correlation between portfolios and measures of ability that are always observable to the student. The estimates of Ω_t are presented in Appendix B and indicate that higher-ability students tend to be somewhat more aggressive with the colleges they select post-exam than lower-ability students, which will generate positive bias.

Two-time takers allow us to formally test whether the estimates of updating are biased upward or downward by score anticipation and time-varying strategies. Specifically, the coefficient β_8 on the second SAT score when only the first score is known is a measure of net bias. As shown in Section 3, the difference $\beta_7 - \beta_8$ is π_1, the unbiased estimate of updating in response to the SAT. Note that the design is not sensitive to time-varying factors such as performance in high school, participation in test preparation classes, or changes in motivation. This is because students choose

[27] The coefficients β_1 and β_2 correspond to a_0 and b_0 in the empirical model. The coefficient β_4 represents $a_1 - a_0$, the change in the coefficient on the PSAT after the SAT score is released, and β_5 represents $b_1 - b_0$, the change in the coefficient on the SAT.

[28] Specifically, the coefficient β_7 corresponds to $b_1 - b_0$ in the empirical model, the change in the coefficient on the first SAT in period 1, and β_{11} is $c_2 - c_0$, the change in the coefficient on the second SAT in period 2.

their pre-exam college portfolios shortly before taking the SAT, whereas the post-exam portfolios are selected after scores are released.

4.2 One-Time Takers: Updating

The estimates in Table 3 reveal that students update their college portfolios in response to new information. Students' adjust their college selections to reflect their SAT scores after they are released and concurrently reduce their reliance on PSAT scores.[29] In the pre-exam period, the coefficient on the PSAT reveals that a 100 point higher score is correlated with an 11 point increase in the selectivity of the colleges to which students send their scores. A similar positive correlation exists for the SAT. In column (1), which includes a rich set of student characteristics, the point estimates indicate that a 100 point increase in SAT score causes a 7 point increase in the selectivity of colleges relative to the pre-exam period. This estimate is essentially unchanged when we include high school fixed effects in column (2) and zip code fixed effects in column (3); in both cases interacting the fixed effects with a period indicator to account for changes in portfolio composition that are common to a school or community. Column (4) presents the preferred, strategy-adjusted specification. The resulting estimates are slightly smaller than those from the unadjusted specification, with a 5.3 point change in portfolio selectivity per 100 point SAT score shock. This implies that the unadjusted estimates are biased slightly upwards, which is consistent with the finding that higher-ability students send score reports to more selective colleges after receiving their scores. The adjusted estimates reveal that a one standard deviation increase in SAT score leads to a 0.10 standard deviation increase in college selectivity for newly selected colleges.

The selectivity of the cumulative portfolio is important for understanding the extent to which score shocks are reflected in the colleges in a student's choice set. The estimates in columns (5) and (6) indicate that students update in response to new information, but the overall changes are much smaller because the colleges they selected before the exam do not change. A 100 point positive shock to SAT score leads to an increase in the selectivity of colleges of about 3 SAT points. That is, a one standard deviation shift in score changes the selectivity of the cumulative portfolio by 0.05 standard deviations. The high level of inertia over time challenges the assumption that academic factors are a primary determinant of college portfolios. The fact that students select a large fraction of colleges for their portfolios before taking the exam due to the availability of free reports further reduces the alignment between portfolios and academic ability.

The causal estimates of updating are one-tenth of the magnitude found in a cross-sectional analysis as presented in Appendix A. Specifically, after controlling for a rich set of covariates, a 100 point difference in SAT score is correlated with a 22 point difference in portfolio selectivity, or 0.4 standard deviations. Thus the degree of mismatch between student ability and college quality

[29] The specification controls for a rich set of student characteristics measured prior to the exam and their interaction with the post exam period, including fixed effects for race, gender, GPA, income, and geographic location. Appendix C presents a specification that includes a continuous measure of GPA interacted with each period. The resulting estimates of updating are nearly identical to those in the preferred specification and reveal that students rely less on their GPA after the SAT score is known.

observed in cross-sectional data, which is high already, may understate the disconnect between student ability and college preferences. This is surprising in light of the fact that, even if students know that scores are an imprecise measure of ability, the SAT plays a primary role in admission decisions and thus provides a strategic incentive for students to respond.

An alternative specification regresses portfolio quality before and after the scores are released on the gap between a student's SAT and PSAT scores. The results presented in Appendix C reveal that a 100 point positive shock increases portfolio quality by 5 points, which is nearly identical to the primary specification. It is worth noting that when selecting a college, going to the best school may be less desirable than going to a college at the appropriate level of selectivity.[30] Thus we estimate if students who experience larger score shocks, measured in terms of the absolute value of the gap, are more likely to send reports to appropriate "target" schools. As shown in Appendix C, there is little evidence that this occurs to a significant degree.

4.3 Two-Time Takers: Updating

The results for two-time takers presented in Table 4 provide especially compelling evidence that students update their college portfolios in response to SAT scores. Newly selected colleges in the period after the first score is released reflect that score. The unadjusted estimate of the response to the first SAT score is about 5 points per 100, while the magnitude of response to the second SAT score is about 8 points per 100. The small positive coefficient on the yet-to-be-released second score in columns (1)-(3) is the net bias generated by time-varying strategies and score anticipation. After adjusting for strategies in column (4), the estimates of updating are 4 and 6 points for the first and second exams, respectively. The remaining bias is close to 0, as revealed by the yet-to-be-released second score, indicating that students do not accurately anticipate their scores and that the coefficient on the first score can be interpreted causally.[31] As predicted by the model, students rely less on the PSAT after the first score is known, and further reduce their reliance on that test after the second score is known.[32] Note that the effect of the first SAT score on colleges selected after the second score is revealed (measured relative to the baseline period) is small in magnitude and disappears after accounting for student strategies. That is, students rely most heavily on new information when adjusting their portfolios.

The estimated effects of updating for the cumulative portfolio in columns (5) and (6) reveal that the first SAT, and not the second, affects the portfolio when only the first score has been released. A 100 point shock from the first SAT score causes students to adjust their portfolio by

[30] For example, Loury and Gorman (1995) find that students with low SAT scores have lower probabilities of graduating when attending colleges with relatively higher median SAT scores. Arcidiacono et al. (2014) find that minority college completion rates actually increased after an affirmative action ban, which caused a shifting of minorities into less selective schools. Arcidiacono, Aucejo, and Hotz (2016) find that students with low academic preparation have higher returns to pursuing STEM fields at less selective schools than at more selective schools. For a comprehensive recent review, see Arcidiacono and Lovenheim (2016).

[31] Subtracting the bias from the coefficient on the first SAT produces the unbiased causal estimate of updating. With this adjustment, a 100 point positive SAT score shock on the first exam is estimated to cause a 4.5 point increase in college portfolio selectivity.

[32] Similar discounting is observed for a continuous measure of GPA as shown in Appendix C.

about 2 points. Note that the estimated bias is only 0.1 points, as indicated by the coefficient on the second score. After both exams are known to the student, the first and second scores have identical effects on the cumulative portfolio. The estimates for two-time takers are very similar to those for one-time takers in sign and magnitude. To abstract from selection into retaking the exam, we merge one- and two-time takers and replicate the primary design. The results indicate that a 100 point test score shock causes a 5.5 point change in the average score of matriculating students at the colleges in the portfolio. This is consistent with estimates generated separately for each group. A specification that regresses portfolio quality before and after each score is released on the gap between the score and a student's PSAT reveals similar estimates. Specifically, as shown in Appendix C the first and second scores generate increases in the selectivity of newly selected colleges of 3 and 6 points, respectively, and increases in the selectivity of the cumulative portfolio of 3 and 2 points.

Taken as a whole, the estimates reveal that students modestly update their college selections in response to large information shocks about the strength of their applications. The causal estimates of updating are a small fraction of the relationship observed in the cross-section. For example, among two-time takers, each 100 points on the second SAT is correlated with an 18 point difference in portfolio selectivity, which is five times the causal estimate for newly selected colleges and ten times the estimate for the change in the cumulative portfolio.

Two results for two-time takers provide additional validation of the empirical design. First, if SAT scores are essentially random draws relative to a student's expectations, then they should be given equal weight before either score is known.[33] The estimated coefficients are 0.111 and 0.119 in period 0 and a formal test fails to reject that they are equal. Second, after both scores are known, each exam should be given equal additional weight for the cumulative portfolio. The coefficients for this period are very similar, with values of 0.015 and 0.014, and are not statistically different.

4.4 Alternative Measures of Portfolio Quality

Table 5 presents estimates of updating for a rich set of college portfolio characteristics. The results follow a similar pattern to those for portfolio selectivity and reveal several interesting insights about how students update.

The least selective college chosen after a score is released does not appear to be very sensitive to the score shock, while the most selective college is. A positive 100 point score shock increases the selectivity of the best college chosen by 12 points for one-time takers and 13 points for two-time takers, while the corresponding increases for the least selective college chosen are less than 2 points. These results suggest that students may send their scores to a set of "safety" schools regardless of their SAT performance and choose "reach" schools on the basis of their probability of admission. Higher scores generate modest increases in the fraction of private colleges to which students send

[33] Students pick colleges to receive their scores shortly before taking the SAT for the first time. If students have some time-specific insight about their performances on the exam at that time, then these colleges will be more closely correlated with the first exam scores than with the second exam scores.

their scores. Specifically, a 100 point positive score shock increases the number of private schools selected by about 1 percentage point for both one- and two-time takers. Likewise, the expected graduation rate of college selected is about 1 percentage point higher. These results imply that a one standard deviation shock in performance on the SAT results in a shift in the fraction of private colleges of 0.05 standard deviations and in the graduation rate of 0.10 standard deviations.[34]

Students who receive positive information shocks may be more likely to consider colleges that require greater investment because of their higher tuition levels or because they are located farther from home. This could occur if, for example, students realize that their higher scores are more likely to result in admission to selective colleges or if they (and their parents) are more willing to invest in human capital when the probability of success seems greater. The results reveal that a 100 point positive score shock increases the mean in-state tuition of colleges selected by 400 dollars, or 0.10 standard deviations per one standard deviation score shock. The average distance of selected colleges increases by 10 miles, or 0.04 standard deviations.

The estimates for each characteristic of the portfolio systematically reflect decreased importance placed on the PSAT after each SAT score is released. Of particular note for two-time takers is that, relative to the baseline period, the coefficients on the not-yet-released second SAT scores are generally not large or statistically significant, even without adjusting for strategies. This result supports the assumption that the estimates are not significantly biased by score anticipation and time-varying strategies that are correlated with ability. Time-varying strategy-adjusted estimates for each outcome are presented in Appendix B, and closely mirror the unadjusted estimates in both sign and magnitude. As with the selectivity estimates, colleges selected after the second score is revealed primarily incorporate this new information and not the first score, even though both scores are known and the estimates are relative to the pre-exam period.

Taken as whole, updating as measured by a range of college characteristics provides clear causal evidence that students incorporate new information about their probability of admission and likelihood of success into their portfolio choices. Students who receive positive information shocks send score reports to more "reach" colleges and to colleges that are more likely to be private, have higher graduation rates, charge higher tuition, and are farther from home. However, as with portfolio selectivity, the updating is an order of magnitude smaller than the size of the shock, suggesting high levels of inertia in college choice, and thus contributing causal evidence to our understanding of the mismatch between student ability and college quality.

4.5 Extensive Margin Selection

Because reports must be sent after the exam in order to measure updating, the results are local to students who send more than the four free reports. While this is not a threat to the internal validity of the design, it does affect the interpretation of the estimates. Specifically, students in the sample used for analysis may have different socio-economic characteristics and may be more or less sensitive

[34] The pattern of effects is nearly identical when considering related outcomes such as six year graduation rate, Barron's selectivity ratings, and a college selectivity index based on factor analysis.

to new information than the population of all SAT takers. As discussed in Section 2, sending additional score reports appears to be primarily a function of household income and performance in high school, and is only marginally sensitive to the magnitude of the score shock. Nonetheless, it is important to consider the implications for the estimates if those who send additional reports are those who are most sensitive to score shocks. Thus we estimate the lower bound of student response by assuming that all students who do not send additional reports did not update their beliefs. In practice, this is done by replacing missing post-exam portfolios with pre-exam portfolios. The resulting estimates are presented in column (7) of Table 5. The estimates are mechanically smaller than the primary estimates and exhibit the same pattern of updating.

A specific subpopulation that may be especially prone to selecting out of sending additional reports are students who also take the ACT. These students may be less likely to use their SAT scores for admission and thus to reveal their entire portfolios. Thus we replicate the design while restricting attention to states where the SAT is the most commonly taken entrance exam. The results for this restricted sample are presented in Appendix C. The estimates are nearly identical to those for the full sample, with the adjusted estimates indicating that a 100 point score shock increases the selectivity of colleges selected by 6 points for one- and two-time takers. Thus it does not appear that the estimates are significantly biased by selection in ACT-dominant states.

4.6 Heterogeneity in Updating

Student responses to SAT scores may vary with gender, race, household resources, or the direction of the information shock. That is, modest average effects could obscure larger effects for subgroups that are especially sensitive to information about their admission probabilities. For example, students from higher- or lower-income households may respond differently to score shocks. Students whose parents are unfamiliar with the college application process may respond less to an information shock if they choose a fixed set of local colleges for geographic or financial reasons. Conversely, students from low-income households may be more responsive to their scores if they rely on having multiple offers of admission in order to negotiate for greater financial aid, do not wish to spend money on low-probability applications, or the SAT substitutes for other forms of college counseling. The results in Table 6 indicate that students of all income ranges update in a way that is statistically significant but modest in magnitude. A specification with interacted effects indicates that, while students from lower-income households update slightly more, the difference is not statistically significant.[35] Likewise, male students have slightly larger coefficients than female students but the differences are not large in magnitude or statistically significant.

Interestingly, the results indicate that students who receive positive shocks are more responsive than students who receive negative shocks. This is consistent with the finding that the change in portfolio quality is primarily driven by the most selective colleges added to the portfolio. Students may select safer schools regardless of their performance on the SAT, but only those who

[35] Estimates by race reveal that each group updates in response to new information and with no systematic and statistically significant differences in magnitude across groups.

receive unexpected positive news choose to add more selective colleges to their portfolios. This is consistent with students being averse to selecting colleges to which they think they might not be admitted. Among two-time takers, all subgroups exhibit a consistent pattern, with portfolios reflecting the first and second SAT as each is released. Newly released first scores are highly significant and yet-to-be-released second SAT scores are not. These results support the hypothesis that no subgroup of students systematically anticipates future scores.

5 Conclusion

The estimates in this paper reveal the role of entrance exams in shaping college portfolios, shed light on how students update their human capital choices, and provide causal evidence for the inertia underlying student-college mismatch. We find consistent evidence that students adjust the colleges to which they send their SAT score reports in response to new information about the strength of their applications. Positive information shocks generated by SAT scores cause students to choose more selective colleges that charge higher tuition, have higher graduation rates, and are located farther from home. However, the magnitude of the response is much too small to close the unexplained gaps between students who appear to have similar academic qualifications. These results suggest that it is difficult to change students' college choices even after providing them with new, highly relevant information about their probability of admission and likelihood of success. The results contribute causal, revealed preference based evidence to a growing literature that attempts to understand how students update their human capital choices and why college mismatch occurs.

A point of significant policy interest is identifying ways to close the gap in outcomes between students from higher and lower-income households. College entrance exams, which are taken by nearly all students considering a four-year college, provide students with standardized feedback about their likelihood of admission and potential for success in college. This study suggests that the SAT can play a role in bringing college portfolios into alignment with academic performance. However, there is a significant amount of inertia in portfolio choice that must be overcome. The predetermined nature of college choice could be due to non-academic factors such as poor counseling, geographic preference, price sensitivity, and loyalty to colleges attended by relatives and friends. Alternatively, students may not be skilled at translating SAT performance into college admission predictions. The magnitude of student updating is likely to vary with both the timeliness and the salience of new information about college choice. These findings may help to improve the way in which students, parents, and school counselors receive and respond to critical information in the application process.

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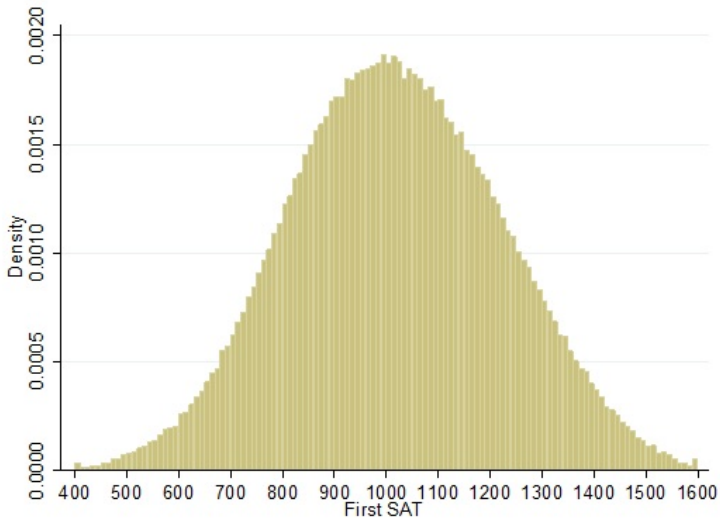
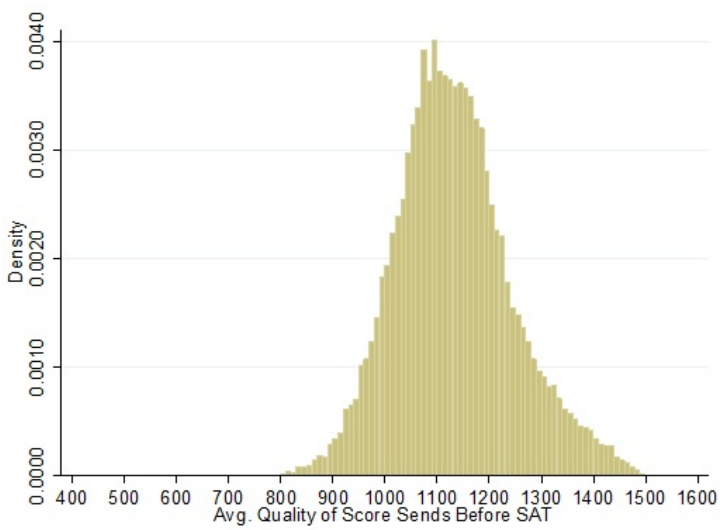
Figure 1: Distribution of SAT Scores and Portfolio Quality

A. Distribution of First SAT Scores



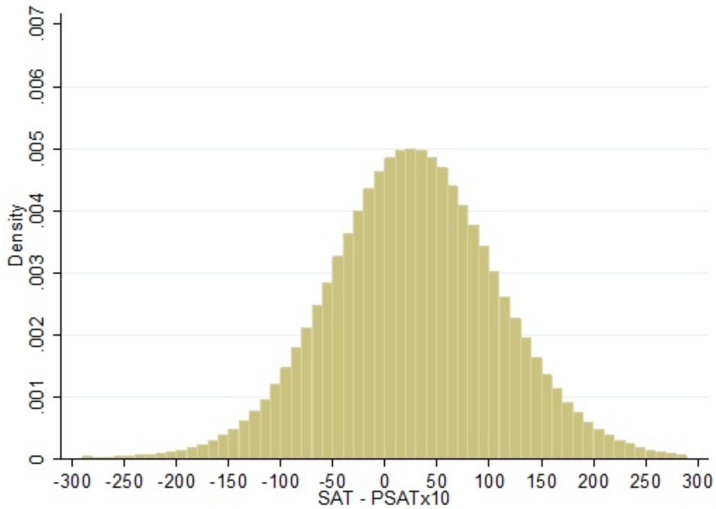
B. Distribution of Pre-Exam College Portfolios



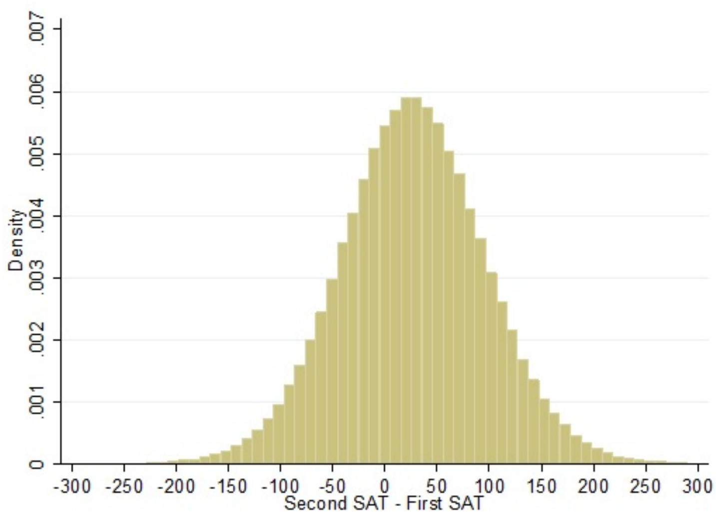
Note: The top figure presents the score distribution of students' first SAT scores. The score is measured in multiples of 10 points. The standard deviation of the distribution is 200 points. The bottom figure presents the distribution of the average SAT scores of matriculates of colleges in each students' score report portfolio (one measure of portfolio quality). The standard deviation of the distribution is 110 points.

Figure 2: Within-Student Variation in Scores: PSAT, First SAT, and Second SAT

A. First SAT - PSAT



B. Second SAT - First SAT



Note: The top figure presents the difference between a student's SAT and PSAT scores. The PSAT score has been multiplied by 10 to be on the same scale as the SAT. The standard deviation of the difference is 85.6 points. The bottom figure presents the difference between a student's second SAT and first SAT scores. The standard deviation of the difference is 70.3 points.

Table 1: Summary Statistics

	Observations (1)	Mean (2)	Std. Dev. (3)
Sample of One-Time Takers			
Male	129,039	0.490	0.500
White	129,039	0.608	0.488
Black	129,039	0.136	0.343
Hispanic	129,039	0.133	0.340
Other Race	129,039	0.123	0.328
PSAT Score	129,039	1084.8	218.7
SAT Score	129,039	1135.5	220.0
Sample of Two-Time Takers			
Male	111,520	0.463	0.499
White	111,520	0.605	0.489
Black	111,520	0.113	0.317
Hispanic	111,520	0.116	0.320
Other Race	111,520	0.166	0.372
PSAT Score	111,520	1085.6	190.9
First SAT Score	111,520	1113.7	185.5
Second SAT Score	111,520	1146.4	190.9
Population of One-Time Takers			
Male	627,190	0.470	0.499
White	627,190	0.588	0.492
Black	627,190	0.161	0.368
Hispanic	627,190	0.158	0.365
Other Race	627,190	0.093	0.290
PSAT score	627,190	972.0	208.6
SAT Score	627,190	1009.3	213.5
Population of Two-Time Takers			
Male	534,399	0.452	0.498
White	534,399	0.604	0.489
Black	534,399	0.138	0.345
Hispanic	534,399	0.128	0.334
Other Race	534,399	0.131	0.337
PSAT Score	534,399	1010.8	192.1
First SAT Score	534,399	1038.0	190.6
Second SAT Score	534,399	1064.4	196.6

Note: This table presents summary statistics for the population of students who took the PSAT and took the SAT one or two times, and separately for students who sent score reports to colleges before and after receiving their exam scores. All students included in this table took the PSAT as either a sophomore or a junior in high school. The cohorts included in the analysis graduated from high school between 2007 and 2009. The PSAT score has been multiplied by 10 to be on a comparable scale to the SAT score – a transformation that is used throughout the analysis.

Table 2: Retaking the SAT and Sending Score Reports

	Retook SAT		Sent Post-Exam Reports	
	(1)	(2)	(3)	(4)
| SAT - PSAT |	-0.0004***	0.0002***	0.0000	-0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
| SAT - PSAT | *Positive		-0.0007***		0.0003***
		(0.0000)		(0.0000)
PSAT Score	-0.0001***	-0.0002***	0.0003***	0.0003***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
High School GPA	0.1058***	0.1144***	0.0788***	0.0764***
	(0.0009)	(0.0009)	(0.0009)	(0.0009)
Male	-0.0215***	-0.0164***	-0.0165***	-0.0179***
	(0.0009)	(0.0009)	(0.0009)	(0.0009)
Asian	0.0881***	0.0852***	0.0341***	0.0349***
	(0.0019)	(0.0019)	(0.0020)	(0.0020)
Black	-0.0031*	-0.0114***	0.0597***	0.0620***
	(0.0017)	(0.0017)	(0.0017)	(0.0017)
Hispanic	-0.0163***	-0.0214***	-0.0012	0.0003
	(0.0017)	(0.0017)	(0.0017)	(0.0017)
Parental Income 50-100k	0.0570***	0.0585***	0.0331***	0.0327***
	(0.0013)	(0.0013)	(0.0013)	(0.0013)
Parental Income 100k+	0.0904***	0.0923***	0.0499***	0.0494***
	(0.0015)	(0.0015)	(0.0015)	(0.0015)
Observations	1,157,855	1,157,855	1,157,855	1,157,855
R-squared	0.066	0.070	0.073	0.073

Note: This table examines the determinants of whether students retake the SAT and whether they send additional score reports. Columns (1) and (2) examine the extent to which student characteristics, household characteristics, and the magnitude of the score shock are correlated with retaking the exam. Columns (3) and (4) examine the extent to which these factors are correlated with sending additional score reports after taking the exam. The specifications includes the number and quality of reports sent before taking the SAT as additional control variables. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table 3: One-Time Takers: Portfolio Updating in Response to an SAT Score Shock

Average SAT of Matriculates						
	New Colleges Added to Portfolio				Cumulative Portfolio	
				Adjusted		Adjusted
	(1)	(2)	(3)	(4)	(5)	(6)
PSAT Score	0.113***	0.111***	0.116***	0.132***	0.116***	0.123***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)
SAT Score	0.141***	0.136***	0.141***	0.160***	0.141***	0.149***
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)
After SAT * PSAT Score	-0.022***	-0.031***	-0.029***	-0.045***	-0.012***	-0.018***
	(0.004)	(0.005)	(0.005)	0.005	(0.005)	(0.004)
After SAT * SAT Score	0.072***	0.070***	0.071***	0.053***	0.029***	0.021***
	(0.004)	(0.005)	(0.005)	0.006	(0.005)	(0.005)
Student Controls (x Post)	X	X	X	X	X	X
High School FEs (x Post)		X				
Zip Code FEs (x Post)			X	X	X	X
Observations	258,036	258,036	258,036	258,036	258,036	258,036
R-squared	0.360	0.339	0.359	0.358	0.397	0.394

Note: This table presents the estimated effect of newly released SAT scores on a student's choice of college portfolio for alternative specifications. Columns (1)-(4) present the change in the average SAT of matriculating students at colleges selected before and after a student's score is released. Columns (5) and (6) present the change in the cumulative portfolio as a result. The estimates in columns (4) and (6) have been adjusted to account for strategies that are correlated with student aptitude. Student controls include fixed effects for high school grade point average, race, gender, and household income. Each specification includes the interaction of the controls with an indicator for the post exam period. Note that only students who send score reports both before and after taking the SAT are included in the analysis. Standard errors are clustered at the zip code level. Bootstrapped errors are used in columns (4) and (6) to account for the fact that the adjusted outcomes incorporate the estimates of Ω_t. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table 4: Two-Time Takers: Portfolio Updating in Response to SAT Score Shocks

Average SAT of Matriculates	New Colleges Added to Portfolio				Cumulative Portfolio	
				Adjusted		Adjusted
	(1)	(2)	(3)	(4)	(5)	(6)
PSAT Score	0.075***	0.072***	0.077***	0.090***	0.077***	0.084***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
SAT 1 Score	0.103***	0.099***	0.102***	0.119***	0.102***	0.111***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.005)	(0.006)
SAT 2 Score	0.110***	0.109***	0.127***	0.104***	0.109***	0.119***
	(0.004)	(0.004)	(0.004)	(0.006)	(0.004)	(0.005)
After SAT 1 * PSAT Score	-0.016***	-0.018***	-0.019***	-0.030***	-0.010*	-0.016***
	(0.003)	(0.005)	(0.006)	(0.006)	(0.005)	(0.005)
After SAT 1 * SAT 1 Score	0.048***	0.055***	0.053***	0.041***	0.026***	0.021***
	(0.004)	(0.006)	(0.006)	(0.007)	(0.006)	(0.007)
After SAT 1 * SAT 2 Score	0.011***	0.011*	0.011*	-0.004	0.007	-0.001
	(0.004)	(0.006)	(0.006)	(0.007)	(0.006)	(0.007)
After SAT 2 * PSAT Score	-0.035***	-0.035***	-0.038***	-0.051***	-0.017***	-0.023***
	(0.005)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)
After SAT 2 * SAT 1 Score	0.019***	0.016**	0.017**	0.000	0.024***	0.015**
	(0.006)	(0.007)	(0.007)	(0.008)	(0.006)	(0.007)
After SAT 2 * SAT 2 Score	0.079***	0.078***	0.079***	0.062***	0.024***	0.014**
	(0.005)	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)
Student Controls (x Post)	X	X	X	X	X	X
High School FEs (x Post)		X				
Zip Code FEs (x Post)			X	X	X	X
Observations	334,506	334,506	334,506	334,506	334,506	334,506
R-squared	0.388	0.377	0.389	0.387	0.442	0.437

Note: This table presents the estimated effect of newly released SAT scores on a student's choice of college portfolio for alternative specifications. Columns (1)-(4) present the change in the average SAT of matriculating students at colleges selected before and after students' first and second SAT scores are released. Columns (5) and (6) present the change in the cumulative portfolio as a result. The estimates in columns (4) and (6) have been adjusted to account for strategies that are correlated with student aptitude. Student controls include fixed effects for high school grade point average, race, gender, and household income. Each specification includes the interaction of the controls with indicators for each post exam period. Note that only students who send score reports both before and after taking the SAT are included in the analysis. Standard errors are clustered at the zip code level. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table 5: Alternate Measures of Portfolio Quality

	Min SAT (1)	Max SAT (2)	Percent Private (3)	In-State Tuition (4)	4-Year Grad Rate (5)	Average Distance (6)	Lower Bound (7)
One-Time Takers							
PSAT Score	0.097***	0.126***	0.021***	7.471***	0.015***	0.244***	0.086***
	(0.004)	(0.004)	(0.001)	(0.298)	(0.001)	(0.016)	(0.001)
SAT Score	0.127***	0.147***	0.020***	7.475***	0.020***	0.200***	0.086***
	(0.004)	(0.004)	(0.001)	(0.304)	(0.001)	(0.016)	(0.001)
After SAT * PSAT Score	-0.044***	-0.017***	-0.012***	-2.993***	-0.005***	-0.087***	-0.002
	(0.006)	(0.006)	(0.002)	(0.444)	(0.001)	(0.023)	(0.002)
After SAT * SAT Score	0.011*	0.118***	0.011***	4.093***	0.010***	0.115***	0.014***
	(0.006)	(0.007)	(0.002)	(0.459)	(0.001)	(0.023)	(0.002)
R-squared	0.212	0.322	0.081	0.171	0.291	0.045	0.223
Two-Time Takers							
PSAT Score	0.070***	0.082***	0.017***	5.483***	0.010***	0.147***	0.067***
	(0.005)	(0.005)	(0.001)	(0.362)	(0.001)	(0.018)	(0.002)
SAT 1 Score	0.089***	0.102***	0.020***	6.735***	0.015***	0.159***	0.084***
	(0.006)	(0.006)	(0.002)	(0.425)	(0.001)	(0.021)	(0.002)
SAT 2 Score	0.109***	0.100***	0.010***	4.819***	0.015***	0.146***	0.087***
	(0.005)	(0.005)	(0.002)	(0.411)	(0.001)	(0.020)	(0.002)
After SAT 1 * PSAT Score	-0.017**	-0.021***	-0.004*	-1.164**	-0.003***	-0.032	-0.008***
	(0.007)	(0.007)	(0.002)	(0.506)	(0.001)	(0.025)	(0.002)
After SAT 1 * SAT 1 Score	0.042***	0.057***	0.007***	2.937***	0.007***	0.102***	0.025***
	(0.008)	(0.008)	(0.002)	(0.600)	(0.001)	(0.029)	(0.003)
After SAT 1 * SAT 2 Score	0.011	0.010	0.003	0.977*	0.001	0.020	0.007**
	(0.008)	(0.007)	(0.002)	(0.576)	(0.001)	(0.027)	(0.003)
After SAT 2 * PSAT Score	-0.059***	-0.022***	-0.009***	-2.858***	-0.006***	-0.057**	-0.013***
	(0.007)	(0.007)	(0.002)	(0.553)	(0.001)	(0.026)	(0.002)
After SAT 2 * SAT 1 Score	0.024***	0.017*	-0.001	0.449	0.003**	0.082***	0.019***
	(0.008)	(0.009)	(0.003)	(0.645)	(0.001)	(0.030)	(0.003)
After SAT 2 * SAT 2 Score	0.015**	0.131***	0.010***	4.036***	0.011***	0.066**	0.028***
	(0.008)	(0.008)	(0.003)	(0.622)	(0.001)	(0.030)	(0.003)
R-squared	0.241	0.336	0.095	0.182	0.315	0.045	0.389

Note: This table presents the estimated effect of newly released SAT scores on a student's choice of college portfolio for alternative measures of quality. The top and bottom panels present the effects for one- and two-time takers, respectively. The outcome in columns (1) and (2) correspond to the lowest and highest average SAT score of matriculating students among colleges in the portfolio. Column (3) is the fraction of colleges in the portfolio that are private not-for-profit. Columns (4) and (5) consider the average in-state tuition and graduation rates for colleges in the portfolio. Column (6) presents that average distance from each student's home zip code to the colleges to which they send reports. Column (7) assumes that students who do not send score reports after the exam do not update. Student controls include fixed effects for high school grade point average, race, gender, and household income. Each control is interacted with indicators for the post exam periods. Standard errors are clustered at the zip code level. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table 6: Updating by Gender, Household Income, and the Type of Shock

	Gender		Household Income			Type of Shock	
	Male	Female	0-50k	50-100k	>100k	Positive	Negative
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
One-Time Takers							
PSAT Score	0.125***	0.112***	0.117***	0.101***	0.128***	0.109***	0.126***
	(0.005)	(0.005)	(0.009)	(0.008)	(0.007)	(0.006)	(0.010)
SAT Score	0.134***	0.147***	0.103***	0.146***	0.159***	0.166***	0.100***
	(0.005)	(0.005)	(0.009)	(0.008)	(0.007)	(0.006)	(0.010)
After SAT * PSAT Score	-0.039***	-0.024***	-0.038***	-0.027**	-0.025**	-0.032***	-0.012
	(0.008)	(0.008)	(0.013)	(0.012)	(0.010)	(0.009)	(0.014)
After SAT * SAT Score	0.081***	0.064***	0.084***	0.067***	0.068***	0.083***	0.037**
	(0.008)	(0.008)	(0.013)	(0.012)	(0.011)	(0.009)	(0.015)
R-squared	0.387	0.332	0.276	0.334	0.3736	0.385	0.289
Two-Time Takers							
PSAT Score	0.087***	0.068***	0.065***	0.067***	0.076***	0.062***	0.124***
	(0.006)	(0.006)	(0.012)	(0.009)	(0.007)	(0.010)	(0.012)
First SAT Score	0.099***	0.101***	0.093***	0.096***	0.106***	0.117***	0.063***
	(0.007)	(0.007)	(0.014)	(0.011)	(0.008)	(0.010)	(0.012)
Second SAT Score	0.099***	0.120***	0.094***	0.117***	0.121***	0.126***	0.077***
	(0.007)	(0.007)	(0.013)	(0.010)	(0.008)	(0.009)	(0.012)
After SAT 1 * PSAT Score	-0.016**	-0.022***	-0.008	-0.011	-0.010	-0.027**	-0.022
	(0.008)	(0.008)	(0.017)	(0.012)	(0.010)	(0.013)	(0.017)
After SAT 1 * SAT 1 Score	0.059***	0.046***	0.034*	0.043***	0.058***	0.078***	0.045***
	(0.009)	(0.009)	(0.019)	(0.015)	(0.012)	(0.014)	(0.016)
After SAT 1 * SAT 2 Score	0.002	0.018**	0.019	0.016	-0.002	-0.003	0.018
	(0.009)	(0.009)	(0.018)	(0.014)	(0.011)	(0.013)	(0.017)
After SAT 2 * PSAT Score	-0.050***	-0.027***	-0.041**	-0.028**	-0.038***	-0.048***	-0.044**
	(0.009)	(0.009)	(0.018)	(0.014)	(0.011)	(0.014)	(0.018)
After SAT 2 * SAT 1 Score	0.015	0.018*	0.011	0.013	0.013	0.023	0.038**
	(0.010)	(0.010)	(0.021)	(0.016)	(0.013)	(0.016)	(0.017)
After SAT 2 * SAT 2 Score	0.092***	0.066***	0.092***	0.077***	0.075***	0.083***	0.065***
	(0.010)	(0.010)	(0.020)	(0.016)	(0.013)	(0.014)	(0.018)
R-squared	0.415	0.369	0.332	0.365	0.440	0.402	0.348

Note: This table presents the estimated effect of newly released SAT scores on choice of college portfolio for various population subgroups. The top and bottom panels present the effects for one- and two-time takers, respectively. Each column presents the change in the average SAT of matriculating students at colleges selected before and after a student's score is released. The results are differentiated by gender (male, female), household income (less than 50,000 dollars, between 50,000 and 100,000 dollars, and more than 100,000 dollars), and by type of shock (positive or negative). Each specification includes zip code fixed effects interacted with an indicator for the post exam periods. Note that only students who send score reports both before and after taking the SAT are included in the analysis. Note that some students' characteristics are missing from College Board data and thus the subgroup totals do not sum to number of students in the population. Standard errors are clustered at the zip code by period level. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Appendix

A Cross-Sectional Estimates

Table A1 presents the cross-sectional relationship of portfolio selectivity with academic and non-academic factors. The resulting coefficients provide baseline context for the causal estimates discussed in Section 4. We regress college portfolio selectivity (as measured by the average SAT score of matriculating students) on a student's PSAT score, SAT score, high school GPA, high school attended, and demographic characteristics including gender, race, and household income. For one-time takers, a 100 point difference in SAT score is correlated with a 20 point difference in selectivity. Thus a one standard deviation higher exam score is correlated with an approximately 0.4 standard deviation increase in portfolio selectivity. Among two-time takers, each 100 points on the second SAT is correlated with an 18 point difference in portfolio selectivity.

High school GPA and socio-economic factors are also strongly correlated with the college portfolios students select. A one point change in GPA is correlated with a difference of 30 to 50 points in portfolio selectivity and the difference in portfolio selectivity for students from households with income between 50,000 and 100,000 dollars relative to those with more than 100,000 dollars is about 7 points. The fact that demographic characteristics are strongly correlated with college choices suggests that non-academic factors play an important role in creating mismatch between student ability and college selectivity.

Table A1: Cross-Sectional Correlates of Portfolio Quality

	One-Time Taker	Two-Time Taker	
	Colleges Chosen After SAT	Colleges Chosen After First SAT	Colleges Chosen After Second SAT
	(1)	(2)	(3)
SAT 1 Score	0.217***	0.194***	0.119***
	(0.004)	(0.002)	(0.004)
SAT 2 Score			0.184***
			(0.004)
PSAT Score	0.090***	0.095***	0.043***
	(0.004)	(0.002)	(0.003)
High School GPA	50.052***	40.738***	50.400***
	(0.623)	(0.302)	(0.558)
Male	3.949***	8.293***	0.410
	(0.598)	(0.280)	(0.492)
Asian	32.117***	30.919***	26.533***
	(1.174)	(0.554)	(0.844)
Black	10.700***	12.917***	18.361***
	(1.131)	(0.527)	(0.990)
Hispanic	21.029***	24.790***	24.104***
	(1.079)	(0.539)	(0.931)
Parental Income 50-100k	-3.467***	-4.315***	-5.989***
	(0.877)	(0.407)	(0.772)
Parental Income 100k+	4.205***	4.368***	1.525**
	(0.880)	(0.434)	(0.746)
Observations	128,680	372,232	172,720
R-squared	0.370	0.372	0.387

Note: This table presents the cross-sectional estimates of PSAT and SAT scores on the quality of the colleges to which students send score reports. Column (1) examines colleges selected after the SAT for one-time takers. Column (2) examines colleges selected after the first SAT for students who take the exam twice. Column (3) examines colleges selected after the second SAT for students who take the exam twice. Note that only students who send score reports both before and after taking the SAT are included in the analysis. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

B Strategy-Adjusted Estimates

This appendix presents revised estimates after accounting for time-varying strategies that are correlated with student ability. These adjustments are important if higher-ability students systematically send score reports to more selective colleges after receiving their scores.

B.1 Estimating Strategy

As introduced in Section 3, we can estimate time-varying strategies that are correlated with ability by estimating $y_t = d_t s + \epsilon_t$ for the outcome of interest y_t on a measure of ability s that is known to the student in every period. The estimate of time-varying strategy relative to the last period T is $\hat{\Omega}_t = \frac{d_t}{d_T}$. This captures how portfolio characteristics vary across periods as a function of a measure of student ability.

Table B2 presents estimates of Ω_t using the PSAT as the measure of ability known to the student in every period. Values less than 1 indicate that the outcome is systematically larger in the post exam period for students with higher measures of ability (i.e. the $d_0 < d_1$ for one-time takers and $d_0 < d_2$ or $d_1 < d_2$ for two-time takers). This appears to be the case for 7 of the 9 outcomes, suggesting that higher-ability students are generally more aggressive with their post-exam portfolio than are lower-ability students.

B.2 Adjusted Estimates for Alternative Outcomes

The resulting strategy adjusted estimates are included for the primary measure of college quality, SAT of matriculating students, in Tables 3 and 4 of the text. We present the equivalent estimates for alternative outcomes in Table B3. These estimates indicate clear evidence of updating in response to new information. For one-time takers, post-exam portfolios significantly discount the information in the PSAT while placing greater weight on the newly released SAT scores. Likewise, for two-time takers, students only place additional weight on the first and second scores after they are released. Importantly, there is no evidence that the second score is incorporated significantly when only the first score is known. Thus there is strong evidence that students do not anticipate future scores and the estimates are not biased after adjustment. This evidence is strengthened by the timing of students' portfolio selection. Specifically, colleges selected after the first exam are frequently chosen shortly before taking the SAT for a second time as one of the student's four free reports. Thus, if time-varying covariates are generating bias, reports sent after the first exam should be more correlated with the second score than with the first score.

Table B2: Estimates of Strategy Adjustment: Omega

	New SAT (1)	Cum SAT (2)	Min SAT (3)	Max SAT (4)	Perc Priv (5)	In-State Tuition (6)	Grad Rate (7)	Avg Dist (8)	Lower Bound (9)
One-Time Takers									
Omega (t=0)	0.883	0.949	1.206	0.751	1.063	0.967	0.898	0.971	0.941
	(0.010)	0.010	(0.020)	(0.009)	(0.031)	(0.018)	(0.012)	(0.028)	(0.007)
Two-Time Takers									
Omega (t=0)	0.861	0.919	1.135	0.712	1.061	0.948	0.866	0.853	0.891
	(0.010)	(0.009)	(0.019)	(0.009)	(0.026)	(0.016)	(0.011)	(0.025)	(0.005)
Omega (t=1)	0.972	0.980	1.258	0.810	1.180	1.073	0.978	1.000	0.966
	(0.010)	(0.009)	(0.019)	(0.010)	(0.029)	(0.018)	(0.011)	(0.027)	(0.005)

Note: This table presents the estimates of time-varying strategy Ω_t. The top and bottom panels present the adjustments used for one- and two-time takers, respectively. Estimates are based on changes in the outcome variable between periods as a function of performance on the PSAT.

Table B3: Alternate Measures of Portfolio Quality: Strategy Adjusted

	Min SAT (1)	Max SAT (2)	Percent Private (3)	In-State Tuition (4)	4-Year Grad Rate (5)	Avg Dist (6)	Lower Bound (7)
One-Time Takers							
PSAT Score	0.081***	0.169***	0.020***	7.733***	0.017***	0.257***	0.086***
	(0.003)	(0.005)	(0.001)	(0.280)	(0.001)	0.017	(0.001)
SAT Score	0.106***	0.195***	0.019***	7.726***	0.023***	0.205***	0.086***
	(0.004)	(0.006)	(0.001)	(0.343)	(0.001)	0.017	(0.001)
After SAT * PSAT Score	-0.027***	-0.061***	-0.011***	-3.346***	-0.007***	-0.101***	-0.002
	(0.005)	(0.006)	(0.002)	(0.405)	(0.001)	0.022	(0.002)
After SAT * SAT Score	0.032***	0.071***	0.012***	3.924***	0.008***	0.118***	0.0143***
	(0.006)	(0.007)	(0.002)	(0.475)	(0.001)	0.026	(0.002)
Observations	258,036	258,036	258,036	257,919	256,947	257,026	257,026
Two-Time Takers							
PSAT Score	0.061***	0.115***	0.016***	5.779***	0.012***	0.175***	0.076***
	(0.004)	(0.006)	(0.001)	(0.350)	(0.001)	(0.021)	(0.015)
SAT 1 Score	0.078***	0.145***	0.019***	7.166***	0.017***	0.183***	0.094***
	(0.005)	(0.008)	(0.002)	(0.433)	(0.001)	(0.026)	(0.002)
SAT 2 Score	0.096***	0.139***	0.010***	5.035***	0.017***	0.170***	0.098***
	(0.005)	(0.008)	(0.001)	(0.411)	(0.001)	(0.024)	(0.002)
After SAT 1 * PSAT Score	-0.019***	-0.039***	-0.005	-1.736	-0.004	-0.061**	-0.015***
	(0.005)	(0.009)	(0.002)	(0.446)	(0.001)	(0.029)	(0.002)
After SAT 1 * SAT 1 Score	0.026***	0.052***	0.004**	1.755***	0.006***	0.076***	0.020***
	(0.007)	(0.011)	(0.002)	(0.569)	(0.001)	(0.031)	(0.003)
After SAT 1 * SAT 2 Score	-0.002	-0.003	0.002	0.392	-0.001	-0.000	-0.002
	(0.007)	(0.010)	(0.002)	(0.536)	(0.001)	(0.031)	(0.003)
After SAT 2 * PSAT Score	-0.051***	-0.055***	-0.009***	-3.169***	-0.007***	-0.082***	-0.021***
	(0.006)	(0.008)	(0.002)	(0.518)	(0.001)	(0.028)	(0.002)
After SAT 2 * SAT 1 Score	0.034***	-0.026**	0.000	0.010	0.000	0.055	0.008***
	(0.007)	(0.011)	(0.003)	(0.691)	(0.001)	(0.035)	(0.003)
After SAT 2 * SAT 2 Score	0.029***	0.092***	0.010***	3.848***	0.009***	0.045	0.017***
	(0.008)	(0.010)	(0.002)	(0.644)	(0.001)	(0.035)	(0.003)
Observations	334,506	334,506	334,506	334,378	333,687	332,883	332,883

Note: This table presents the estimated effects of newly released SAT scores on a student's choice of college portfolio after adjusting for score report strategies. The outcomes are adjusted as detailed in Section 3 prior to estimation. The top and bottom panels present the effects for one- and two-time takers, respectively. The outcome in columns (1) and (2) correspond to the lowest and highest average SAT score of matriculating students among colleges in the portfolio. Column (3) is the fraction of colleges in the portfolio that are private not-for-profit. Columns (4) and (5) consider the average in-state tuition and graduation rates for colleges in the portfolio. Column (6) presents that average distance from each student's home zip code to the colleges to which they send reports. Column (7) assumes that students who do not send score reports after the exam do not update. Student controls include fixed effects for high school grade point average, race, gender, and household income. Each control is interacted with indicators for the post exam periods. Bootstrapped standard errors are used to account for the fact that the outcomes incorporate the estimates of Ω_t.

C Alternative Specifications and Samples

C.1 A Specification Based on the Gap Between SAT and PSAT Scores

An alternative specification to the one presented in Section 4 interacts the difference between a student's SAT and PSAT scores, (SAT-PSAT), with an indicator for each information period. This specification will produce identical estimates to the primary specification under two conditions. First, the extent to which students discount the PSAT after the SAT is revealed would need to match the extent to which they increase the importance of the SAT. That is, this design treats one point lower on the PSAT as equivalent to one point higher on the SAT, so the resulting estimate is the average of the weight students place on each of these exams. In practice, the amount that students discount the PSAT tends to be somewhat smaller in magnitude than the weight given to the newly revealed SAT score. Second, the estimates will not be equal if students employ time-varying strategies. Specifically, this specification does not suffer from a scaling effect because ability is differenced out by subtracting the PSAT score from the SAT score.

The estimates for this specification are presented in Table C4. They reveal that a 100 point score shock causes students to update the selectivity of the colleges they select by about 5 points for one-time takers and 3 points and 6 points after the first and second scores are released for two-time takers. These magnitudes are nearly identical to those in the preferred, adjusted specifications presented in Tables 3 and 4 of the paper.

C.2 SAT Dominant States

Students who take the ACT in addition to the SAT may choose not to send their SAT scores to colleges if they perform better on the ACT. This issue adds a dimension of complexity in terms of selection that is not easy to model or desirable for estimation. To determine whether it affects the estimates presented in Section 4, we replicate the design while restricting attention to states in which the SAT is the most commonly taken exam. This approach is likely to significantly reduce the fraction of students who have taken the ACT in the sample.

The estimates for SAT dominant states are presented in Table C5 and are nearly identical to those for the sample of all states. Specifically, the preferred, adjusted estimate of updating for one-time takers is a 5.8 point increase in selectivity for a 100 point score shock, relative to 5.3 points for the full sample. For two-time takers, the estimates of updating are 4.1 points after the first exam and 6.5 points after the second exam, which is comparable to 4.1 and 6.2 points for the full sample. Thus the fact that some students take both the ACT and the SAT does not appear to significantly confound the empirical design.

C.3 Target Colleges

When selecting a college, sometimes going to the best school can be less important than going to the "right" school. In our main analysis, we show that students' college portfolios, as measured by the schools they designate to receive their SAT scores, become more closely correlated with their SAT scores once the scores are known. However this may not necessarily mean that students are making "better" choices. Perhaps students systematically overshoot relative to their ideal college choice once this information is revealed.[36]

This appendix estimates the quality of the matching between students and their portfolio choices in response to new information. Intuitively, once students learn their SAT scores, they may be more likely to send reports to colleges with which they are better matched, and the biggest change may be for those who receive the largest SAT score "shock". This will occur if a student's beliefs about which schools are a good match become both more correct and more precise.[37] Table C6 examines the fraction of colleges in a student's portfolio for which the median incoming student has an SAT score within 5 percent of the student's score (i.e., a target college). About 25 percent of colleges fall into this range. However, there is no evidence that students who experience the largest shocks ultimately send reports to a higher fraction of target colleges after learning their SAT scores. This result holds for several alternative definitions of target colleges as defined by the bandwidth around a student's actual SAT score.

C.4 Continuous GPA

The primary specification in Section 4 presents the decrease in weight that students place on their PSAT scores after their SAT scores are revealed. The specification controls for students' high school GPAs using fixed effects for each possible reported value (e.g., 3.0, 3.3,...) interacted with an indicator for each period. In this appendix we convert the GPA to a continuous value and examine if there is evidence that students rely on it less after SAT scores are revealed. Students may reduce their reliance on their high school GPAs if they use them to predict their SAT scores.

The results presented in Table C7 are adjusted for time-varying strategies and the unit of measurement for the GPA is hundredths of a GPA point (similar scale used for SAT points). The estimates of updating are nearly identical to the primary specification. After scores are released, students appear to place less weight on their GPAs, as each of the signs is negative and two are statistically significant. Thus, students appear to predict SAT scores using their GPAs, though not to the degree that they do using their PSAT scores. This finding is consistent with PSAT scores being more predictive of SAT scores than are GPAs.

[36]To be clear, if students systematically overshoot after they receive their scores, they might not necessarily be misusing their information. Portfolio choices made after learning one's SAT score must also take into account the choices made before one has this information. It may be optimal for students to select some colleges above their ability level given that the potential benefits of attending a higher-quality institution might offset the disadvantages of being an underprepared student in that institution.

[37]This can be shown formally through an extension of our model and is available upon request.

Table C4: Score Gap Specification

Average SAT of Matriculates	New Colleges Added to Portfolio (1)	(2)	(3)	Cumulative Portfolio (4)
One-Time Takers				
(SAT 1 - PSAT)	0.0115***	0.0092***	0.0110***	0.0110***
	(0.0036)	(0.0034)	(0.0036)	(0.0036)
After SAT 1 * (SAT 1 - PSAT)	0.0489***	0.0497***	0.0499***	0.0201***
	(0.0038)	(0.0052)	(0.0054)	(0.0048)
Observations	258,036	258,036	258,036	258,036
R-squared	0.247	0.237	0.241	0.267
Two-Time Takers				
(SAT 1 - PSAT)	-0.0297***	-0.0229***	-0.0307***	-0.0225***
	(0.0043)	(0.0034)	(0.0035)	(0.0030)
(SAT 2 - PSAT)	0.0319***	0.0360***	0.0350***	0.0127***
	(0.0029)	(0.0049)	(0.0050)	(0.0046)
After SAT 1 * (SAT 1 - PSAT)	0.0298***	0.0245***	0.0298***	0.0274***
	(0.0043)	(0.0031)	(0.0033)	(0.0031)
After SAT 2 * (SAT 2 - PSAT)	0.0588***	0.0575***	0.0590***	0.0201***
	(0.0040)	(0.0051)	(0.0053)	(0.0044)
Observations	334,506	334,506	334,506	334,506
R-squared	0.257	0.257	0.250	0.287
Student Controls (x Post)	X	X	X	X
High School FEs (x Post)		X		
Zip Code FEs (x Post)			X	X

Note: This table presents the estimated effect of the gap between students' SAT and PSAT scores on their choice of college portfolios before and after the SAT scores are released. The top and bottom panels present the effects for one- and two-time takers, respectively. Columns (1)-(4) present the change in the average SAT of matriculating students at colleges selected before and after scores are released. Columns (5) and (6) present the change in the cumulative portfolio as a result. Student controls include fixed effects for high school grade point average, race, gender, and household income. Each control is interacted with indicators for the post exam periods. Standard errors are clustered at the zip code level. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table C5: SAT Dominant States

Average SAT of Matriculates	New Colleges Added to Portfolio				Cumulative Portfolio	
				Adjusted		Adjusted
	(1)	(2)	(3)	(4)	(5)	(6)
One-Time Takers						
PSAT Score	0.114***	0.110***	0.116***	0.132***	0.116***	0.122***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.036)
SAT Score	0.138***	0.134***	0.139***	0.157***	0.139***	0.146***
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
After SAT * PSAT Score	-0.031***	-0.036***	-0.034***	-0.050***	-0.013***	-0.019***
	(0.004)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)
After SAT * SAT Score	0.078***	0.075***	0.077***	0.058***	0.030***	0.0224***
	(0.004)	(0.006)	(0.006)	(0.007)	(0.005)	(0.006)
Observations	206,026	206,026	206,026	206,026	206,026	206,026
Two-Time Takers						
PSAT Score	0.076***	0.070***	0.077***	0.090***	0.077***	0.084***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
SAT 1 Score	0.104***	0.101***	0.103***	0.119***	0.103***	0.112***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.005)	(0.006)
SAT 2 Score	0.106***	0.102***	0.105***	0.123***	0.105***	0.115***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.005)	(0.006)
After SAT 1 * PSAT Score	-0.016***	-0.018***	-0.019***	-0.029***	-0.010*	-0.015***
	(0.003)	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)
After SAT 1 * SAT 1 Score	0.048***	0.054***	0.052***	0.041***	0.025***	0.019***
	(0.004)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)
After SAT 1 * SAT 2 Score	0.009**	0.009	0.010	-0.005	0.007	-0.001
	(0.004)	(0.006)	(0.007)	(0.008)	(0.006)	(0.007)
After SAT 2 * PSAT Score	-0.039***	-0.035***	-0.040***	-0.051***	-0.017***	-0.023***
	(0.005)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)
After SAT 2 * SAT 1 Score	0.015**	0.013*	0.013*	-0.003	0.023***	0.015**
	(0.006)	(0.008)	(0.008)	(0.008)	(0.006)	(0.007)
After SAT 2 * SAT 2 Score	0.082***	0.081***	0.083***	0.065***	0.024***	0.014*
	(0.006)	(0.007)	(0.007)	(0.009)	(0.006)	(0.007)
Observations	284,871	284,871	284,871	284,871	284,871	284,871
Student Controls (x Post)	X	X	X	X	X	X
High School FEs (x Post)		X				
Zip Code FEs (x Post)			X	X	X	X

Note:
This table presents the estimated effect of newly released SAT scores on a student's choice of college portfolio for alternative specifications. Attention is restricted to students attending high school in states where the SAT is the most commonly taken entrance exam. The top and bottom panels present the effects for one- and two-time takers, respectively. Columns (1)-(4) present the change in the average SAT of matriculating students at colleges selected before and after a student's score is released. Columns (5) and (6) present the change in the cumulative portfolio as a result. The estimates in columns (4) and (6) have been adjusted to account for strategies that are correlated with student aptitude. Student controls include fixed effects for high school grade point average, race, gender, and household income. Each specification includes the interaction of the controls with an indicator for the post exam period. Note that only students who send score reports both before and after taking the SAT are included in the analysis. Standard errors are clustered at the zip code level. Bootstrapped errors are used in columns (4) and (6) to account for the fact that the adjusted outcomes incorporate the estimates of Ω_t. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table C6: Target Colleges: One- and Two-Time Takers

Average SAT of Matriculates	One-Time Takers (1)	Two-Time Takers (2)
| SAT 1 - PSAT |	0.0099***	-0.0035**
	(0.0014)	(0.0014)
| SAT 2 - PSAT |		0.0144***
		(0.0011)
After SAT 1 * | SAT 1 - PSAT |	-0.0031	0.0005
	(0.0021)	(0.0021)
After SAT 1 * | SAT 2 - PSAT |		-0.0002
		(0.0021)
Student Controls (x Post)	X	X
Zip Code FEs (x Post)	X	X
Observations	258,424	334,677
R-squared	0.070	0.085

Note: This table presents the estimated effect of newly released SAT scores on a student's choice of college portfolio for alternative specifications. Columns (1)-(4) present the change in the average SAT of matriculating students at colleges selected before and after students' first and second SAT scores are released. Columns (5) and (6) present the change in the cumulative portfolio as a result. The estimates in columns (4) and (6) have been adjusted to account for strategies that are correlated with student aptitude. Student controls include high school grade point average, race, and household income. Bootstrapped errors are used in columns (4) and (6) to account for the fact that the adjusted outcomes incorporate the estimates of Ω_t. Each specification includes the interaction of the controls with an indicator for the post periods. Note that only students who send score reports both before and after taking the SAT are included in the analysis. Standard errors are clustered at the zip code level. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table C7: Portfolio Updating with Continuous GPA

Average SAT of Matriculates	One-Time Takers		Two-Time Takers	
	New Colleges	Cumulative Portfolio	New Colleges	Cumulative Portfolio
	(1)	(2)	(3)	(4)
GPA	0.543***	0.502***	0.555***	0.519***
	(0.009)	(0.008)	(0.012)	(0.011)
PSAT Score	0.136***	0.125***	0.091***	0.085***
	(0.004)	(0.003)	(0.004)	(0.004)
SAT 1 Score	0.164***	0.152***	0.119***	0.111***
	(0.004)	(0.004)	(0.006)	(0.006)
SAT 2 Score			0.129***	0.120***
			(0.005)	(0.005)
After SAT 1 * GPA	-0.043***	-0.012	-0.016	-0.004
	(0.012)	(0.011)	(0.015)	(0.014)
After SAT 1 * PSAT Score	-0.046***	-0.019***	-0.030***	-0.016***
	(0.005)	(0.004)	(0.005)	(0.005)
After SAT 1 * SAT 1 Score	0.053***	0.022***	0.042***	0.021***
	(0.006)	(0.005)	(0.008)	(0.007)
After SAT 1 * SAT 2 Score			-0.005	-0.001
			(0.007)	(0.007)
After SAT 2 * GPA			-0.042***	-0.008
			(0.015)	(0.012)
After SAT 2 * PSAT Score			-0.051***	-0.024***
			(0.005)	(0.004)
After SAT 2 * SAT 1 Score			-0.001	0.015**
			(0.008)	(0.007)
After SAT 2 * SAT 2 Score			0.063***	0.014**
			(0.008)	(0.006)
Student Controls (x Post)	X	X	X	X
Zip Code FEs (x Post)	X	X	X	X
Observations	257,360	257,360	334,038	334,038

Note: This table presents the estimated effect of newly released SAT scores on a student's choice of college portfolio for one- and two-time SAT takers. The PSAT and GPA are interacted with indicators for each post exam period. Columns (1) and (3) present the change in the average SAT of matriculating students at colleges selected before and after students' first and second SAT scores are released. Columns (2) and (4) present the change in the cumulative portfolio as a result. All specifications are adjusted for application strategies. Additional student controls include fixed effects for race, gender, and household income. Each specification includes the interaction of the controls with an indicator for the post exam period. Note that only students who send score reports both before and after taking the SAT are included in the analysis. Standard errors are clustered at the zip code level. Bootstrapped errors are used to account for the fact that the adjusted outcomes incorporate the estimates of Ω_t. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.