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

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Abstract

We estimate whether students update their college application portfolios in response to large, unanticipated information shocks generated by the release of SAT scores – a primary component of admissions decisions. Exploiting new population data on the timing of college selection and a policy that induces students to choose colleges prior to taking exam, we find that the release of scores causes students to 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 may be the dominant determinants of college choice.

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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 aptitude 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. 2015). This paper provides a direct analogue at another crucial time for human capital investment – when students decide where to apply to college. Specifically, we examine if students update their college application portfolios in response to large, unanticipated positive and negative information shocks generated by the release of SAT scores. Using new population data on the timing of when students select colleges for their portfolios, we exploit a design that contrasts colleges selected before and after SAT scores are released. College admission exams are among the most important determinants of admissions and represent perhaps the single most important source of new information students receive during the college selection process. If portfolios are not updated in response to the release of scores, it indicates that college choices are essentially predetermined by non-academic factors and preexisting beliefs. Measuring the extent of inertia is important for understanding how expectations are formed and because of the potentially high returns to college quality.[1]

The primary challenge to estimating student responses to academic information is the need to observe college choices before and after new information is revealed. This is perhaps one reason why the literature has focused on dropout and major choices in response to the intermittent release of grades during college. Unfortunately, a student has only one college application portfolio and, in many cases, receives only one college entrance exam score. To overcome this we exploit a College Board policy that induces students to identify a limited number of colleges to receive their scores for free at the time that they register for the exam.[2] Subsequently, students receive their score and choose if 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 score reports, an unanticipated positive (negative) shock in SAT score causes a student to select a portfolio of colleges that has higher (lower) selectivity, tuition, graduation rates, and fraction of private colleges. However, the estimated effects are quite modest in magnitude in absolute terms and relative to cross-sectional differences. In fact, the change in a student's overall college portfolio in response to an SAT score shock is one-tenth the size of cross-sectional estimates. This is surprising in light of the importance of the SAT for college admissions, and suggests that socioeconomic differences in college application behavior stem predominantly from non-academic factors and is

[1]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 available prior to taking the exam. Three-quarters of SAT takers in our data use at least one of their free reports and about two-thirds of these students use all four.

not meaningfully reduced with objective information about one's likelihood of admission to selective colleges.

Several factors make this environment a nearly ideal context for identifying the extent to which students update their college portfolios. First, many students experience large SAT score shocks that are difficult to anticipate. Specifically, the standard deviation of within-student differences between first and second SAT scores is 70.3 points, or 0.35 standard deviations. Score variation of this magnitude is sufficient to significantly alter students' probability of admission to colleges.[3] Our empirical design allows us to test whether students accurately anticipate their SAT scores, and we find no evidence that they do. Second, unlike studies that rely on surveys of students' subjective beliefs, we are able to observe beliefs through the high stakes decision of selecting colleges to receive scores. Third, the data used for analysis include students' PSAT scores and, in many cases, multiple SAT attempts. This allows us to estimate what information contained in a newly released score is new to the student. Fourth, students make their pre-exam college choices shortly before taking the SAT, limiting the potential that updating stems from time-varying factors that are correlated with exam performance.[4] Finally, the analysis is based on national administrative data that produces precise estimates and allows us to consider heterogeneous effects across important socio-economic characteristics such as income and race.

Identification is based on a difference-in-difference style design that estimates the extent to which college portfolios selected before and after students observe their scores reflect this new information. We present an empirical model analogous to those in the employer learning literature that reveals several important considerations for the interpretation of the reduced form results.[5] The model confirms that students will place greater importance on SAT scores after they are released and will reduce their reliance on measures of aptitude that were previously used to anticipate SAT scores. We highlight that estimates of updating may be downward biased to the extent that students accurately anticipate their scores using unobservable information. Importantly, we show how the magnitude of attenuation can be estimated explicitly.

The estimates show that after a student learns that she scored 100 points higher on the SAT than anticipated, she will begin applying to colleges whose matriculates scored about 5 points higher on the exam. This is equivalent to a 1 standard deviation change in a student's score generating an approximately 0.10 standard deviation shift in the selectivity of newly selected colleges.[6] To put

[3] 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 an average of 17 percentage points.

[4] A natural concern is that changes in portfolio composition and exam performance over time are caused by a concurrent time-varying factor such as performance in high school. This is alleviated by the fact that students select their pre-exam portfolios shortly before taking the SAT, so the pre-exam portfolio should already reflect time-varying factors concurrent with SAT performance.

[5] The model is most closely related to those in Farber and Gibbons (1996), Altonji and Pierret (2001), and Lange (2007). The updating that occurs as students' scores are released shares similarities to the updating by employers as 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).

[6] Figure 1 presents the distribution of SAT scores, which have a standard deviation of 200 points, and college

this in perspective, consider two students who anticipate getting the same SAT score but apply to colleges with average scores of 1100 and 1200, respectively. The gap in selectivity for college selected after scores are released only closes by 5 points if the less ambitious student scores 100 points higher on the exam. The magnitude of updating is smaller when considering the overall composition of the portfolio, as about half of colleges are selected prior to the exam. That is, a one standard deviation SAT score shock results in an approximately 0.05 standard deviation shift in the selectivity of a student's overall portfolio. In contrast, 100 points on the SAT is correlated with an approximately 20 point, or 0.4 standard deviation, difference in portfolio selectivity in a cross-sectional regression that conditions on a rich set of covariates. The 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. There is a similar pattern of effects in terms of sign and magnitude for a wide range of college characteristics. For example, a positive score shock increases the fraction of private colleges selected in the post exam period by 1 percentage point and the average annual tuition by 400 dollars.

The estimates for students who take the exam two times may be even more convincing, as there are multiple within-student treatments. The composition of colleges selected after the release of the first score more closely reflect that score and likewise for colleges selected after the release of the second score.[7] Importantly, the results indicate that students do not incorporate information from the second score when only the first score has been released, 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 applying more aggressively to "reach" colleges with little change in the least selective "safety" colleges. Interestingly, heterogeneity analysis does not indicate that the average effects obscure larger responses from sensitive subgroups. Updating is similar in magnitude for students from high and low income households, for males and females, and for students of different races.

The literature has frequently found that students alter human capital investment in response to perceived returns and expectations (Attanasio and Kaufmann, 2009; Jensen, 2010; Jacob and Linkow, 2011; Abramitzky and Lavy, 2014). Papay, Murnane, and Willett (2016) find updating based on the labels assigned to No Child Left Behind test scores, while Dizon-Ross (2014) finds that parental perceptions of child aptitude affect human capital investment. Conversely, Card and Krueger (2005) find no effect of eliminating affirmative action on the portfolios of minority students despite reducing the likelihood of admission. The finding that SAT scores play a modest role in shaping college choice is consistent with results in the literature that college choices are partially a function of non-academic factors such as the availability of college counseling services (Avery and

portfolios, which have a standard deviation of 110 points.

[7] To abstract from selection into taking the SAT one or two times, the identification design is replicated using a merged sample of one and two-time takers. The resulting estimates closely mirror those found when considering the two groups separately. On the extensive margin, students who experience a score shock with a magnitude of 100 points are less than one percentage point more likely to send reports to additional colleges. So students who update the most do not appear to be over or under represented in the analysis.

Kane 2004; Carrell and Sacerdote, 2012; Oreopoulos and Ford, 2016), information about the cost of college (Bettinger et al., 2012; Hoxby and Turner, 2014), ease of access to entrance exams (Klasik, 2013; Hurwitz et al., 2014; Goodman, 2014; Bulman, 2015), and mismatch between students and colleges (Hoxby and Avery, 2012; Smith, Pender, and Howell, 2013; Dillon and Smith, 2016).

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 if students update their college portfolios in response to new information about the strength of their applications and college readiness. Panel data provides an opportunity to factor out unobserved, time-invariant individual and household characteristics and beliefs that influence college choices.[8] There are, however, two fundamental challenges for employing a panel data approach in this and related contexts. First, in the typical progression, students only choose one college application portfolio, which is not conducive to observing changes over time. Second, a panel data approach requires new information that is not anticipated by students and is observed by the researcher. While students may receive large positive and negative shocks when their SAT score is released, this is of little use if the researcher cannot account for students' prior expectations.

This paper exploits a unique policy and a rich new dataset from the College Board to estimate the effect of information shocks generated by SAT scores on college choices. We exploit administrative data that include the exact timing of when students send score reports to colleges and a College Board pricing policy that induces students to select some colleges to receive their SAT score before they take the exam. While a student has only one college application portfolio, they construct this portfolio by selecting colleges before and after they take the SAT. Our panel therefore consists of information periods: the portfolio selected before taking the exam, and the portfolio selected after scores have been released. Nearly half of students take the exam a second time. This generates a third information period in which students may update in response to the second SAT. Multi-time takers also provide a natural test of the extent to which students anticipate scores, as we can measure if they appear to respond to future scores that have not been released.

[8] Estimating the importance of aptitude is inherently problematic in cross-sectional data. The choice of where to apply is a function of many student and household characteristics. Some of these characteristics are both observable and measurable (household income, parental education, student grade point average, and geographic location), but may not be included in a single data source. Many other characteristics are difficult to measure or are unlikely to be included in any data source (e.g. parental expectations, parental familiarity with the college application process, student motivation, resources of extended family, high school quality, peer effects). If any of these characteristics is correlated with both the measure of student aptitude and college choice, then the estimated effects in a cross-sectional analysis will be biased.

2.1 SAT and Score Report 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 years. The exam is comprised of math and critical reading sections scored between 200 and 800, so students can receive a combined score between 400 and 1600.[9] Each section was normalized to have a mean score of 500 and a standard deviation of 110 in 1995. Students are permitted to take the SAT more than one time. This analysis focuses on years prior to 2009 during which each of a student's scores is reported to a college. In later years, Score Choice policies allowed students to pick and choose scores to be sent to colleges, which significantly complicates the empirical design needed 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 includes information on high school GPA, race, parental income, high school attended, and home zip code.

Our analysis relies on observing student Score Sends, which are official SAT reports that students have sent to colleges for consideration in the admissions process. A score report includes each of a student's SAT scores. The reports provide a measure of student interest in colleges and previous studies have argued that they are a reasonable proxy for applications (Card and Krueger, 2005; Pallais, 2015). Score Sends are especially advantageous for measuring updating in this setting as they reveal intended application portfolios, regardless of whether students complete these applications after scores are released. For example, a student who chooses to send her score to an elite college prior to taking the SAT may not apply after receiving a lower than expected score. This updating would be obscured if only completed applications were observed. The score report data identify the college to which the report is directed. 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 (NCES IPEDS).[10] 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. This must be done within nine days of taking the exam, so a high fraction of takers send reports prior to the exam. After the ten day period (or for additional reports prior to the ten day expiration), 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.[11] A student may send a report more than one time to the same college, which is particularly common

[9] A writing section was introduced in 2005 but not all students take this section and not all colleges use it in the admissions process.

[10] Some colleges, typically two-year colleges or specialty colleges (e.g. religious or arts) do not report all of the measures of selectivity used in this analysis.

[11] Score Choice was adopted in the spring of 2009, whereby students could choose which SAT scores to send if there were multiple administrations.

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.[12] We calculate the average characteristics of the colleges in each of these two periods, including the SAT scores of matriculating students, in-state tuition, graduation rate, and fraction private. We note that reports may be selected during three periods for students who took the exam twice: those selected prior to the first exam; those selected after the first score is released but before the second exam is taken, including reports that are free with the second registration; and those selected after the second exam scores are released. We calculate the average characteristics of the colleges in each of the three periods.

2.2 Population for Analysis

The analysis is based on the population of students who took the SAT between 2007 and 2009 and who sent at least one score report prior to taking the SAT.[13] The PSAT is taken by more than 75 percent of SAT takers and provides students with a measure of how they may perform. Approximately 75 percent of SAT takers send at least one free score report to a college prior to taking the 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 a student is considering prior to receiving their score. Analysis of revised portfolio composition is conditional on students sending score reports after taking the SAT. We explicitly estimate the determinants of sending additional reports and discuss the implications for interpreting the estimates.

Table 1 presents summary statistics for demographic characteristics and test scores in the sample. Over 627,000 students took the SAT once and 534,000 took it twice. Approximately 46 percent are males and 59 percent are white. Mean PSAT scores are about 100, which is approximately equivalent to a 1000 on the SAT. Students who took the SAT once have an average score of 1009, while students who took it twice average a 1038 and 1064 for the first and second sittings. Approximately 21 percent of one-time takers sent scores after the exam and 32 percent of two-time takers did so after the second exam.

2.3 Within-Student Variation in Scores

There is significant within-student variation in scores earned on the PSAT and the first and second taking of the SAT. This variation is important for two reasons. First, unpredictable variation in scores generates the information shocks necessary for the identification of portfolio 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 each students' first SAT score and their PSAT score. The mean is close to 0 and the standard deviation of the

[12] Score Sends requests are delayed until new scores are available, so the analysis is based on the request date rather than the fulfillment date. Requests that come immediately after the exam is taken but before the scores are released are excluded. Such requests are relatively uncommon and are excluded due to the fact that they may reflect partial treatment (as the student has taken the exam but not seen his or her score).

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

difference is 85.6 points. Note that this within-student variation is nearly one-half the standard deviation of 190 points across students. A student who earns a 1000 on the PSAT has an approximately 30 percent chance of earning a score lower than a 900 or greater than 1100 on the SAT. 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 pre-exam portfolio selectivity, high school GPA, and demographic characteristics.[14] The bottom graph in Figure 2 presents the difference between each student's actual and predicted SAT score. The standard deviation of the difference is 80.5 points. That is, the rich set of characteristics provides essentially no additional explanatory power for predicting the SAT beyond the PSAT. The PSAT score is the most important predictor of a student's SAT score for the researcher (and perhaps the student as well) and that there is significant within-student variation in exam scores.

Within-student variation in scores is also evident when students take the SAT multiple times. The top graph in Figure 3 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 of the difference is 26 points), this increase is small relative to the variation in scores. Nearly 40 percent of students earn a lower score when they take the exam a second time. This is notable as repeat takers have additional time for test preparation, experience taking the exam, and may have chosen to retake in part because they believe that they had a bad draw the first time. This is consistent with there being significant and unpredictable noise in performance. We predict each student's second score use all observables listed above in addition to the first SAT score. The resulting differences are presented in the bottom graph in Figure 3. The standard deviation of the difference is 63.6 points. That is, even with two measures of prior SAT scores in hand, the PSAT and the first SAT, realized performance varies considerably from predicted performance.

We supplement this descriptive evidence that SAT scores are difficult to anticipate with explicit estimates of test score anticipation in Section 4. The analysis exploits the realization that if students anticipate their scores, then future scores will be incorporated into current portfolio choice. There is little evidence that this is the case, supporting the assumption that the score shocks observed by the researcher are highly correlated with the true score shocks experienced by students.

[14]Specifically, the predicted SAT score is estimated using a fixed effect for each possible PSAT score; an indicator for whether the student took the PSAT as a sophomore or junior; a cubic polynomial in the selectivity of pre-SAT portfolio (as measured by the average SAT score of matriculating students); fixed effects for high school grade point average; gender; fixed effects for race; fixed effects for parental income level; and a fixed effect for the year the exam was taken.

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 observable). The revelation of SAT scores should reduce students' reliance on other measures of aptitude, resulting in negative coefficients on factors such as PSAT scores and high school GPA. Less intuitively, the model shows that the reduced form estimates may understate the extent to which students incorporate SAT scores into their college portfolios. This occurs if students use information unobservable to the researcher to anticipate their scores. In the case of students who take the exam multiple times, the magnitude of this downward bias can be estimated explicitly. Specifically, when only the first SAT score has been released, the coefficient on the second SAT score reflects the bias term. The not-yet-released second SAT score provides a placebo test for the validity of the design. Additional predictions of the model serve to validate the identification design. For example, if SAT scores are essentially random draws relative to a true, latent score, then the first and second score should be equally predictive of portfolios prior to either being released.

3.1 Student Updating

The empirical model is analogous to 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 a student who takes the exam twice, which accounts for one time takers as a special case.[15] A student forms beliefs about her optimal college application portfolio which can be summarized by a single continuous measure of quality y.[16] The optimal portfolio is a function of four components: s is a set of characteristics observable to the student and the researcher (e.g. PSAT scores); q are characteristics observable to the student, but not the researcher (e.g. personal essays); z is the true SAT score that a student would receive in the absence of measurement error; and η are characteristics unobservable to the student and the researcher (e.g. confidential letters of recommendation).[17] Without loss of generality, we impose that η is uncorrelated with z.[18] The distribution of (s, q, z, η) is assumed to

[15]The framework can be applied to students who take the SAT three or more times. The predictions extend naturally, but in practice a modest fraction of students take the exam more than two times during this period.

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

[17]The model differentiates between a *true* SAT score and the score a student actually receives as this allows the full set of SAT scores to matter for the application decision for individuals who take the SAT multiple times. As our analysis focuses on years prior to score choice, students understand that colleges observe and may use the full set of SAT scores for admissions decisions. For students who take the exam only once, imposing that there is no measurement error and that the received score is equal to z would have no consequences for the results.

[18]In other words, z contains all the information about a student's desirability to colleges that he or she does not initially know but can learn from SAT performance, while η contains all of the information that students do not initially know and cannot learn from SAT performance.

be 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.[19] The optimal portfolio for student i is assumed to be linear in each of these elements,

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

which is normalized to be in units of optimal portfolio choice as it has no natural scale.

Students select colleges in $t = 0$ without knowing either SAT score, receive their first score in $t = 1$ and choose a new portfolio of colleges, and receive their second score in $t = 2$ and choose a portfolio with full knowledge of all scores. Beginning in $t = 0$, students form expectations about their unobserved factors z and η using observed factors s and q. It follows from joint normality that these expectations will be

$$\begin{aligned} z &= E[z|s,q] + \nu = \gamma_1 q + \gamma_2 s + \nu \\ \eta &= E[\eta|s,q] + e = \alpha_1 q + \alpha_2 s + e \end{aligned}$$

where e and ν are mean zero normal random variables with variances σ_e^2 and σ_ν^2, and $E[se] = E[s\nu] = E[q\nu] = 0$. The student then uses these beliefs to select an optimal period 0 application portfolio,

$$\begin{aligned} y_0 &= \Omega_0 E[y|s,q] \\ &= \Omega_0 \left[(\delta + \alpha_1 + \Lambda\gamma_1) q + (r + \alpha_2 + \Lambda\gamma_2) s \right] \end{aligned} \tag{2}$$

The weight the student places on her observable characteristics s and q is the sum of their direct effect on the choice of portfolio (δ and r), their role in inferring unobservable characteristics η that affect portfolio choice (α_1 and α_2), and their role in predicting the unobserved SAT score (γ_1 and γ_2) weighted by the importance of the SAT (Λ). Here Ω_0 is a scaling factor that allows for the possibility that application strategies may be correlated with aptitude. Estimation of Ω is discussed in Section 3.3.

Prior to choosing colleges in period 1, the student observes her score, z_1, which acts as a signal of the true SAT: $z_1 = z + \epsilon$ where ϵ is distributed normally with mean zero and variance σ_ϵ^2. Using this information, the student forms a new belief of z,

$$E[z|s,q,z_1] = \pi_1 z_1 + (1 - \pi_1)(\gamma_1 q + \gamma_2 s) \tag{3}$$

where $\pi_t = \sigma_\nu^2 / (\sigma_\epsilon^2 + t\sigma_\nu^2)$, which follows from Bayesian updating with a normally distributed prior and t normally distributed signals. Using these beliefs, the student chooses her optimal portfolio

[19] If the normality assumption is violated, then all of the expectations become linear projections and the signs of the predictions still hold. The joint normality assumption is only necessary for calculating the extent of test score anticipation.

in period 1,

$$\begin{aligned} y_1 &= E[y|s,q,z_1] \quad (4) \\ &= [\delta + \alpha_1 + \Lambda(1-\pi_1)\gamma_1]\, q + [r + \alpha_2 + \Lambda(1-\pi_1)\gamma_2]\, s + \Lambda\pi_1 z_1 \end{aligned}$$

Relative to y_0, the introduction of z_1 causes the student to reduce her reliance on q and s for predicting z (evident from the $1-\pi_1$ term) and places weight on the score z_1. In period 2, the student observes her second SAT score, z_2, and uses all available information to form a belief about z.

$$E[z|s,q,z_1,z_2] = \pi_2 z_1 + \pi_2 z_2 + (1-2\pi_2)(\gamma_1 q + \gamma_2 s) \quad (5)$$

She then chooses her optimal application portfolio,

$$\begin{aligned} y_2 &= E[y|s,q,z_1,z_2] \quad (6) \\ &= [r + \alpha_2 + \Lambda\gamma_2(1-2\pi_2)]\, s + [\delta + \alpha_1 + \Lambda\gamma_1(1-2\pi_2)]\, q + \Lambda\pi_2 z_1 + \Lambda\pi_2 z_2 \end{aligned}$$

Note that the student further reduces her reliance on other factors.

3.2 Empirical Model

In practice, we observe s and the two test scores, z_1 and z_2. The expectation of q, which we do not observe, conditional on the observed test scores is $E[q|s,z_1,z_2] = [\gamma_3 + \gamma_4(1-2\phi_2)]\, s + \gamma_4\phi_2 z_1 + \gamma_4\phi_2 z_2$ where ϕ_2 is the standard coefficient from Bayesian updating with two i.i.d. normal signals. Regressing y_0 on s, z_1, and z_2 implies the linear projection,

$$E^*[\Omega_0 E[y|s,q]|s,z_1,z_2] \quad = \quad a_0 s + b_0 z_1 + c_0 z_2 \quad (7)$$

where,

$$\begin{aligned} a_0 &\equiv \Omega_0\left(r + \alpha_2 + [\delta + \alpha_1][\gamma_3 + \gamma_4(1-2\phi_2)] + \Lambda[\gamma_2 + \gamma_1\gamma_3 + \gamma_1\gamma_4(1-2\phi_2)]\right) \\ b_0 &\equiv \Omega_0\left[(\delta + \alpha_1)\gamma_4\phi_2 + \Lambda\gamma_1\gamma_4\phi_2\right] \\ c_0 &\equiv \Omega_0\left[(\delta + \alpha_1)\gamma_4\phi_2 + \Lambda\gamma_1\gamma_4\phi_2\right] \end{aligned}$$

The magnitude of the coefficients on z_1 and z_2 depend on the extent to which the scores are correlated with unobservables q that predict a student's score.[20] Note that the coefficients on the SAT scores are equal in the pre-exam period, so future scores are equally predictive of pre-exam portfolios. This follows if the scores are i.i.d. draws from the distribution of the true latent score. Estimating the same regression for y_1 yields,

$$E^*[\Omega_1 E[y|s,q,z_1]|s,z_1,z_2] \quad \equiv \quad a_1 s + b_1 z_1 + c_1 z_2 \quad (8)$$

[20] Specifically, δ is the direct weight a student places on q to determine the optimal portfolio, α_1 reflects the use of q to predict unobserved factors, and γ_1 measures the extent to which students use q to predict their true SAT score.

where,

$$\begin{aligned}
a_1 &\equiv \Omega_1 \left(r + \alpha_2 + [\delta + \alpha_1][\gamma_3 + \gamma_4(1 - 2\phi_2)] + \Lambda(1 - \pi_1)(\gamma_2 + \gamma_1\gamma_3 + \gamma_1\gamma_4(1 - 2\phi_2))\right) \\
b_1 &\equiv \Omega_1 \left[(\delta + \alpha_1)\gamma_4\phi_2 + \Lambda(1 - \pi_1)\gamma_1\gamma_4\phi_2 + \Lambda\pi_1\right] \\
c_1 &\equiv \Omega_1 \left[(\delta + \alpha_1)\gamma_4\phi_2 + \Lambda(1 - \pi_1)\gamma_1\gamma_4\phi_2\right]
\end{aligned}$$

Of note is that the difference between the coefficient on the first and second SAT score is $\Lambda\pi_1$. That is, the coefficient on the second SAT score, which has not been released, captures the attenuating effect of unobservables. The additional effect of the first SAT score, which the student knows, is the effect of new information. After estimating Ω_0 and Ω_1, we can compare the regression coefficients. The following expressions correspond to the reduced form coefficients in the primary specification.

$$\begin{aligned}
A_{10} = \frac{a_1}{\Omega_1} - \frac{a_0}{\Omega_0} &= -\pi_1\Lambda\left[\gamma_2 + \gamma_1\gamma_3 + \gamma_1\gamma_4(1 - 2\phi_2)\right] \\
B_{10} = \frac{b_1}{\Omega_1} - \frac{b_0}{\Omega_0} &= \pi_1\Lambda(1 - \gamma_1\gamma_4\phi_2) \\
C_{10} = \frac{c_1}{\Omega_1} - \frac{c_0}{\Omega_0} &= -\pi_1\Lambda\gamma_1\gamma_4\phi_2
\end{aligned}$$

If students optimally adjust their college portfolio in response to their SAT score, there will be an increase in the coefficient on z_1 and a decrease in the coefficient vector on s in period 1 relative to period 0. Released scores reduce the student's reliance on the PSAT and high school GPA. The model also highlights that the estimated effect of the SAT is biased downward to the extent that students accurately anticipate their future scores using unobservable factors as reflected in the $\gamma_1\gamma_4\phi_2$ term.[21] The coefficient on the second SAT score, C_{10}, measures the magnitude of this attenuation.[22] Thus the difference $B_{10} - C_{10}$ is the effect of a student observing her SAT score on portfolio choice after adjusting for anticipation.

Now consider the regression of y_2 on s, z_1, and z_2. The linear projection yields,

$$E^*[E[y|s, q, z_1, z_2]|s, z_1, z_2] \equiv a_2 s + b_2 z_1 + c_2 z_2 \tag{9}$$

where,

$$\begin{aligned}
a_2 &\equiv r + \alpha_2 + (\delta + \alpha_1)[\gamma_3 + \gamma_4(1 - 2\phi_2)] + \Lambda(1 - 2\pi_2)(\gamma_2 + \gamma_1\gamma_3 + \gamma_1\gamma_4(1 - 2\phi_2)) \\
b_2 &\equiv (\delta + \alpha_1)\gamma_4\phi_2 + \Lambda(1 - 2\pi_2)\gamma_1\gamma_4\phi_2 + \Lambda\pi_2 \\
c_2 &\equiv (\delta + \alpha_1)\gamma_4\phi_2 + \Lambda(1 - 2\pi_2)\gamma_1\gamma_4\phi_2 + \Lambda\pi_2
\end{aligned}$$

[21] Intuitively, the coefficient on the SAT scores is inflated in the baseline period due to the omitted variables q. After a score has been released, the student relies less on q to predict their true score z. If the student only cares about the first realized score, then the student no longer uses q to predict the score. As a result, the estimate of updating B_{10} is attenuated. In the model, γ_1 reflects the extent to which students can predict their true score z, while γ_4 captures the correlation between q and the true score.

[22] There will be a shifting away from future information z_2 to the extent that the student used unobservable information q to predict z and relies on this less after observing z_1.

Comparing these coefficients to the period 0 estimates,

$$\begin{aligned}
A_{20} = a_2 - \frac{a_0}{\Omega_0} &= -2\pi_2\Lambda\left[\gamma_2 + \gamma_1\gamma_3 + \gamma_1\gamma_4(1-2\phi_2)\right] \\
B_{20} = b_2 - \frac{b_0}{\Omega_0} &= \pi_2\Lambda(1-2\gamma_1\gamma_4\phi_2) \\
C_{20} = c_2 - \frac{c_0}{\Omega_0} &= \pi_2\Lambda(1-2\gamma_1\gamma_4\phi_2)
\end{aligned}$$

With all scores available to the student, the cumulative portfolio become a function of both z_1 and z_2. The more scores that have been released, the less other factors used to predict the scores matter. As in the pre-exam period, the coefficients on the first and second SAT scores are equal. This provides an additional testable implication of the model.

3.3 Time-Dependent Strategies

For convenience, we have assumed that we know Ω_t, the extent to which application strategies change throughout the application process across students of differing aptitude. There is a simple way to estimate each Ω_t. Consider a regression of y_t on s, the time-invariant information about ability that is available to both the student and researcher in all periods. 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.[23] If the coefficient vector on s changes in different time periods, it can only be attributed to changes in strategy. We estimate this using a series of regressions,

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

The estimate of Ω_t is then $\hat{\Omega}_t = \frac{d_t}{d_T}$, where T is the time period for which we wish to normalize the scale (period 1 for one-time takers and period 2 for two-time takers). In simple terms, regressing portfolio changes in each period on PSAT scores reveals the typical strategy of students of differing baseline aptitudes.

4 Estimates of Student Updating

Nearly every student considering attending a four-year college takes a college entrance exam and the SAT is a primary determinant of admissions at most colleges. Thus the revelation of scores may be the single largest academic information shock that students experience, especially with respect to shaping college choice. We employ a difference-in-differences style design to estimate if, and to what extent, students update their portfolios in response to observing their scores. As revealed by the model in Section 3, portfolio updating will generate positive coefficients on scores after 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 students anticipate

[23] 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.

future scores. The primary outcome of interest is college selectivity as measured by the average SAT scores of matriculates. Additional outcomes presented include tuition levels, graduation rates, private and public status, and selectivity ratings.[24] We present outcomes based on characteristics of new colleges added to the portfolio in each period and the average of all colleges in the portfolio (i.e. the cumulative portfolio).[25]

4.1 Cross-Sectional Differences

Table 2 presents the cross-sectional relationship of portfolio selectivity with academic and non-academic factors. The resulting coefficients provide baseline context for the causal estimates. We regress college portfolio selectivity (as measured by the average SAT score of matriculating students) on a student's PSAT score, SAT score, and observable characteristics including gender, race, household income, and high school attended. As noted, the resulting estimate will be biased by unobservables. 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 in exam score is correlated with an approximately 0.4 standard deviation difference 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 grade point average and socio-economic factors are also strongly correlated with the college portfolios students select. A one point change in grade point average, the difference between an A and B high school student, is correlated with a difference of 30 to 50 points in portfolio selectivity. After controlling for student scores and grades, the difference in portfolio selectivity for households with income between 50,000 and 100,000 dollars relative to those with more than 100,000 dollars is about 7 points.

4.2 One-Time Takers: Updating

In the case of students who take the exam one time, we use 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 a student's PSAT score (though we also include household income, high school grade point average, gender, race, and geographic location in the specification), z_1 is the student's SAT score, and $\mathbb{1}_{t=1}$ is an indicator for the report being sent after the score is

[24] Black and Smith (2006) detail the potential pitfalls of using a single measure of college quality. With this in mind, we present a range of outcomes and also consider a college quality index based on factor analysis. The use of ordinal variables, such as happiness and test scores, in the left-hand side of regressions has come under criticism by Bond and Lang (2013, 2014). Our results are robust to multiple polynomial transformations of our quality measure, including both highly left-skewed and highly-right skewed transformations. We will also analyze other quality measures and find similar results, providing additional evidence that our results are not due to arbitrary scaling.

[25] A student who initially believes she is a high type, may reassess downward after receiving a negative score shock. She may respond to this by applying to additional schools that are of the appropriate level given her new beliefs about her aptitude. Alternatively, she may overcompensate and apply to even less selective schools in order to balance her prior mistake, resulting in a portfolio average that she believes is appropriate.

released. The outcomes y_{it} are the average characteristics of the colleges selected before and after the score is known to the student, with one observation per student per period.[26]

If students update their portfolios to reflect SAT scores then $\beta_5 > 0$. The point estimates understate updating if students are able to predict their true scores using unobservables. In other words, if the deviation of SAT scores from PSAT scores are essentially random shocks, then the estimates will not be downward biased. The distribution of PSAT, first SAT, and second SAT scores presented in Section 2 was suggestive that scores are indeed quite noisy in the sense that they vary dramatically within student and are difficult to predict based on observables. Those who take the exam two times provide an opportunity to explicitly estimate the extent to which students anticipate future scores.

Columns (1)-(3) of Table 3 present the results for new colleges added to the portfolio. The estimates are consistent with updating in response to new information, as students adjust their portfolios to reflect their SAT scores after they are released (i.e. colleges selected after the release are more closely aligned with the new scores than those selected prior). In column (1), which includes a rich set of student characteristics, the point estimates indicate that a 100 point increase in SAT score leads to a 7 point increase in the selectivity of application portfolios. This point estimate is roughly unchanged when we include zip code fixed effects in column (2) and high school 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. Thus a one standard deviation increase in SAT score leads to a 0.12 standard deviation in college selectivity for newly selected colleges.[27]

In column (5) we estimate the effect of student updating in terms of the cumulative selectivity of the portfolio. The change in the cumulative portfolio is perhaps most important for understanding the extent to which the score shocks are reflected in college choice. The estimates indicate that students update in response to new information, but the overall changes are much smaller (as colleges selected prior to the exam do not change). A 100 point positive shock to SAT score leads to an increase in the selectivity of one's application portfolio of 2.9 SAT points. That is, a one standard deviation shift in score changes the selectivity of a student's portfolio by 0.05 standard deviations. By comparison, the cross-sectional estimate with controls indicates that a one standard deviation

[26]The coefficients β_1 and β_2 correspond to a_0 and b_0 in the empirical model. The coefficient β_4 represents A_{10}, the change in the coefficient on the PSAT after the SAT score is released, and β_5 represents B_{10}, the change in the coefficient on the SAT. A natural alternative to our specification is a first-differenced specification in which the change in the college portfolio is regressed on the change in the score ($SAT - PSAT$). We prefer a difference-in-differences design because it does not assume that changes in the SAT and PSAT are given equal weight by the student and the design is naturally extended to the case of two-time takers. The identification 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 due to the fact that students choose their pre-exam college portfolios shortly prior to taking the SAT, whereas the post-exam portfolios are selected after scores are released. Therefore, the pre-exam portfolio and not the post-exam portfolio should be correlated with time-varying factors that cause positive or negative performance shocks on exam day.

[27]We note that this estimate will be downward biased to the extent that students accurately anticipate changes in their scores. As discussed in the previous section, measurement error in SAT scores, and our rich set of student controls imply that this bias is likely to be small. Two time takers allow us to estimate this explicitly and reveals little score anticipation.

difference in score is correlated with a 0.4 standard deviation difference in portfolio quality. So the causal estimate is a small fraction of the naive cross-sectional estimate. This high level of inertia in college application portfolios challenges the assumption that academic determinants of admissions are the primary determinants of college choices. The fact that students select a large fraction of colleges for their portfolios prior to taking the exam (due to the availability of free reports) appears to reduce the alignment between portfolios and strength of applications.

Of course, it is possible that individuals only apply to safety schools before they receive their SAT and their reach schools afterwards, or vice-versa. If higher ability individuals have the same safety schools but better reach schools than lower ability individuals, this could cause us to spuriously overstate student updating. In Section 3.3, we showed how to correct for this using time-variance in the correlation between portfolios and measures of aptitude that are always observable to the student. The estimates of Ω_t are presented in Appendix A and indicate that higher ability students tend to be somewhat more aggressive with their post-exam applications than lower ability students. Columns (4) and (6) of Table 3 present results that are adjusted by this omega factor.[28] The resulting estimates of student responsiveness to their scores are slightly smaller than those from the unadjusted specification.

There is a similar pattern of effects when considering other measures of portfolio composition as shown in Table 4. The least selective college chosen after the score is released does not appear to be sensitive to the score shock, but the most selective is. This suggests that students may apply to a set of safety schools regardless of their SAT performance. Higher SAT score shocks result in students selecting a slightly higher fraction of private colleges, colleges with higher average tuition, and colleges with higher graduation rates.[29] For example, students who score 100 points higher on the SAT appear to add new colleges with in-state tuition that is 400 dollars greater per year. Average in-state tuition for public universities during this period is 6,900 dollars, while average tuition across all universities is 13,250 dollars. The estimates for each characteristic of the portfolio reflect decreased importance placed on the PSAT after the SAT score is released. Time-varying strategy adjusted estimates for each outcome are presented in Appendix A. They closely mirror the unadjusted estimates in terms of both sign and magnitude, indicating that the results are not due to stronger students employing systematically different application patterns.

4.3 Two-Time Takers: Updating

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, as the probability that some unobserved, time-varying confounder would coincide with the treatment on multiple occasions is quite low. Further, the second score acts as a natural test of bias during the period when only the first score has been released.

[28] As these regressions use variables modified by a scalar imputed from the same dataset and sample, we calculate our standard errors via bootstrapping.

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

Students who take the SAT twice receive two information shocks and send reports during three periods. The specification is,

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

where z_{1i} and z_{2i} are the student's 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. The coefficients β_6 and β_9 represent the corresponding reduction in importance of the PSAT. Importantly, the coefficient β_8 on the second SAT score when only the first score is known measures the extent to which students anticipate their scores using unobservables. As shown in Section 3, the difference $\beta_7 - \beta_8$ is $\pi_1 \Lambda$, the unbiased estimate of updating in response to the SAT.

The results in Table 5 are consistent with students updating their college portfolios in response to SAT scores. Newly selected colleges in the period after the first score is released reflect that score. Importantly, colleges selected during this period do not reflect the yet-to-be released second score. This can be viewed as a placebo test that would reveal bias in the design. The magnitude of the response to the first SAT score for newly selected colleges is about 5 points per 100, while the magnitude of response to the second SAT score is about 7 points per 100. These estimates are quite similar to those for one time takers. Thus the magnitude of the response is quite modest given the importance of the SAT for determining likely admissions outcomes at more and less selective colleges. As predicted by the model, students rely less on the PSAT after the first score is known, and further reduce this reliance after the second score is known.

The strategy adjusted specification in column (4) has no indication that students choose more or less selective college in response to the second SAT score during the period when only the first score has been released. The coefficient on this exam provides a direct measure of downward bias stemming from students anticipating future scores. That is, we do not find evidence that students are able to anticipate their scores in such a way that it significantly biases the estimates. This is consistent with the noisy within-student distribution of scores presented in Section 2. 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 is estimated to cause a student to increase her college portfolio selectivity by 4.5 points. Interestingly, students do not appear to use information from the first SAT in choosing new colleges after receiving the second SAT score. That is, students rely most heavily on new information when adjusting their portfolios.

The estimated effects of updating for the cumulative portfolio are presented in columns (5) and (6). After the first score has been released and prior to the second score being released, only the first score affects the portfolio. Adjusting for time-varying strategies, we see that a 100 point shock on their first SAT score causes students to adjust their portfolio by 2 points. Note that the bias generated by anticipation 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 score have identical effects on the cumulative portfolio. The estimates are nearly identical to those for one-time takers, revealing that overall portfolios are only marginally updated in response to large shocks about the strength of a student's application.

Specification (6) provides additional support for the validity of the design. First, if SAT scores are essentially random draws relative to a student's expectations, then they should be given equal weight prior to either being released.[30] 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 coefficient during this period are very similar with values of 0.015 and 0.014 and are not statistically different.

Table 6 presents alternate measures of portfolio composition.[31] We again observe that the increase in selectivity stems primarily from the most selective colleges, with the least selective colleges remaining similar regardless of the shock. A 100 point increase in the first SAT score results in a portfolio with 0.7 percentage points more private colleges and in-state tuition that is 300 dollars higher. Likewise, a positive score shock of 100 points on the second SAT produces an increase the fraction of private colleges by 1.0 percentage points and tuition by 400 dollars. Positive information shocks result in students selecting colleges that have slightly higher four-year graduation rates. These findings are supported by specifications that adjust for time-varying strategies that are correlated with aptitude as shown in Appendix A. Of particular note is that relative to the pre-score period, only released scores are significantly incorporated into portfolio choice in each period. This strongly supports the hypothesis that students do not anticipate their score shocks, but that the effect of these shocks on college portfolios is modest.

4.4 Heterogeneity in Updating

Student responses to SAT scores may vary with gender, race, household resources, or the nature of the information shock. That is, the modest average effects could obscure larger effects for population subgroups that may be especially sensitive to new information about the types of colleges they are likely to be admitted to. For example, students from higher or lower income households may respond more or less to score shocks. Students whose parents are unfamiliar with the college application process may respond less to an information shock if they apply to a fixed set of local colleges. Conversely, lower incomes students may respond more if they rely on having multiple admissions offers in order to negotiate for greater financial aid, if they prefer not to pay application fees for colleges to which they may not be admitted, or if the SAT substitutes for other forms of college counseling. The results in Table 7 indicate that students of all races and income ranges update in a

[30] Students pick period 0 colleges shortly before taking the SAT for the first time. If the student has some time-specific insight about his or her performance on the exam at that time, then these colleges will be more closely correlated with the first exam score than the second. Alternatively, if students retake the exam because their first score did not align with their beliefs, then the second exam score may be more closely correlated with baseline portfolios.

[31] As with the single test takers, we estimate these effects for newly selected colleges. Results using the cumulative portfolio yield a similar pattern of results.

way that is statistically significant but modest in magnitude. A specification with interacted effects indicates that black students update more than white students, but that there are no significant differences across income groups. Though male students have slightly larger coefficients than female students, the differences in updating are not statistically significant.

Perhaps most interestingly, students who receive positive shocks, where the SAT exceeds the predicted SAT, appear to be more responsive than students who receive negative shocks.[32] This is consistent with the finding that the change in portfolio quality is primarily driven by the most selective colleges selected. Students may apply to safer schools regardless of their performance on the SAT, but only those who receive unexpected positive news choose to add more selective colleges to their portfolios. This is consistent with students being adverse to sending applications to colleges to which they think they may not be admitted.

Table 8 presents estimates by subgroup for two-time takers. All groups 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. This supports the hypothesis that no subgroup of students accurately anticipates future scores. For example, we do not find that higher income students more accurately anticipate score shocks due to test prep classes. Again, the results do not reveal strong heterogeneity. Only two of the findings for one-time takers appear to carryover to students who take the exam twice: male students update more than female students after the first and second scores are released, which is statistically significant in this case; and those who receive two positive shocks update more than those who receive two negative shocks.

4.5 Extensive Margin Retaking and Score Reports

There are two extensive margins of interest: taking the exam once or twice; and sending additional reports after a score is released. We explicitly examine how student and household characteristics and the size of the SAT information shock appear to affect these two margins. To abstract from selection into retaking the exam, we merge one and two-time takers and replicate the primary design. This exercise reveals that splitting the sample does not result in systematically smaller estimates. While student responses to SAT scors are modest, we nonetheless estimate a lower bound by assuming that all students who do not send additional reports did not update their beliefs.

Columns (1) and (2) of Table 9 indicate that students whose SAT score are lower than their PSAT scores are more likely to retake the exam, while those whose SAT score exceeds their PSAT scores are less likely to retake it.[33] The magnitudes of these estimates are relatively modest, with a 100 point negative shock only increasing the retake rate by 2 percentage points and a 100 point positive shock decreasing the rate by 5 percentage points. By comparison, students from the

[32]See Section 2 for details about how the predicted SAT was estimated.

[33]See Vigdor and Clotfelter (2003) for an examination of retaking behavior among applicants to three selective universities.

highest income category are 9 percentage points more likely to take the exam than those in the lowest income category. One- and two-time takers are treated separately in the empirical analysis and have similar patterns of estimates. To ensure that separating the sample on this margin is not biasing the results, we present estimates for the joint sample in Table 10. The results indicate that a 100 point test score shock causes a 5.5 point increase in the average score of matriculates in the college portfolio. This is consistent with the separate estimates presented in Sections 4.2 and 4.3.

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 to new information than the population of all SAT takers. The decision to have more than four colleges in one's portfolio may be determined by factors unrelated to the newly released score, such as household income or college readiness, or it may be a response to the amount that beliefs are updated in response to the score shock. As shown in columns (3) and (4) of Table 9, students from higher income households and students with high grade point averages in high school are significantly more likely to send additional score reports.[34] These students are over-represented in the sample. In contrast, the estimates do not reveal that students who update the most are more or less likely to send additional score reports. Specifically, the coefficient on the magnitude of the information shock, approximated by the absolute value of the difference between the SAT and PSAT score, indicates that a 100 point shock changes the probability of sending additional reports by less than one percentage point.[35] So the amount of updating a student experiences as a result of the exam does not significantly affect the number of colleges in her portfolio.[36]

The number of colleges a student includes in her portfolio appears to be primarily a function of characteristics such as household income and performance in high school, and is only marginally affected by updating in response to the score shock. 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 columns (2) and (3) of Table 10. The estimates are mechanically smaller than the primary estimates and exhibit the same pattern of updating.

[34] A one point increase in grade point average (on a 4 point scale) is correlated with an 8 percentage point higher probability of adding colleges to a student's portfolio. Students from households with income exceeding 100,000 dollars are 5 percentage points more likely to send additional reports than a student from a household with income of less than 50,000 dollars.

[35] In terms of the overall number of reports sent to colleges, a 100 point score shock is estimated to increase the size of the portfolio by 0.04 score reports.

[36] If students who update their beliefs the most are more (less) likely to send more reports, then the estimated effects would over (under) represent the population average. The amount that 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 not observable). The finding that $|SAT - PSAT|$ has almost no effect on sending additional reports does not support the theory that more or less sensitive students may not be systematically over-represented in the analysis.

5 Conclusion

We find consistent evidence that students adjust their portfolios in response to new information about the strength of their applications. Information shocks associated with the SAT cause students to apply to more selective colleges that charge higher tuition and have higher graduation rates. However, the magnitude of the response is much too small to close the unexplained gaps between students who appear to have similar academic qualifications. This indicates that it is difficult to change students' college choices even when providing them with new, highly relevant information about their aptitude and probability of admission. The magnitude of the estimates is consistent across students who take the exam one and two times. The results contribute revealed preference based evidence to a growing literature that attempts to understand how students update their human capital choices in response to information about academic aptitude and likelihood of success.

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 exam results, which are revealed to nearly all students considering a four-year college, provide students with standardized feedback about their likelihood of admission and potential for success in college. The results in this paper suggest 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. The cause of this inertia is an open question and ripe for future research, and appears to stem in part from students selecting colleges prior to learning the strength of their applications. Alternatively, students may not be skilled in translating SAT performance into college admissions predictions. The magnitude of student updating may vary with both the timeliness and salience of new information about college choice. The answers to these questions may help to improve the way in which students, parents, and school counselors receive and respond to critical information in the application process.

REFERENCES

Abramitzky, Ran, and Victor Lavy. 2014. "How Responsive is Investment in Schooling to Changes in Redistributive Policies and in Returns?" *Econometrica* 82(4): 1241171272.

Altonji, Joseph G. 1993. "The Demand for and Return to Education When Education Outcomes are Uncertain." *Journal of Labor Economics* 11(1): 48-83.

Altonji, Joseph G., and Charles R. Pierret. 2001. "Employer Learning and Statistical Discrimination." *The Quarterly Journal of Economics* 116(1): 313-350.

Altonji, Joseph G., Erica Blom, and Costas Meghir. 2012. "Heterogeneity in Human Capital Investments: High School Curriculum, College Major, and Careers." *Annual Review of Economics* 4: 185-223.

Arcidiacono, Peter, Esteban Aucejo, Arnaud Maurel, and Tyler Ransom. 2015. "College Attrition and the Dynamics of Information Revelation." Working Paper.

Arcidiacono, Peter, Patrick Bayer, and Aurel Hizmo. 2010. "Beyond Signaling and Human Capital: Education and the Revelation of Ability." *American Economic Journal: Applied Economics* 2(4): 76-104.

Arcidiacono, Peter, V. Joseph Hotz, and Songman Kang. 2012. "Modeling College Major Choices Using Elicited Measures of Expectations and Counterfactuals." *Journal of Econometrics* 166(1): 3-16.

Attanasio, Orazio P., and Katja M. Kaufmann. 2009 "Educational Choices, Subjective Expectations, and Credit Constraints." NBER Working Paper 15087.

Avery, Christopher, and Thomas J. Kane. 2004. "Student Perceptions of College Opportunities: The Boston COACH Program." In *College Choices: The Economics of Where to Go, When to Go, and How to Pay For It*, ed. C. Hoxby, 355-394. Chicago: University of Chicago Press.

Behrman, Jere R., Mark R. Rosenzweig, and Paul Taubman. 1996. "College Choice and Wages: Estimates Using Data on Female Twins." *The Review of Economics and Statistics* 78(4): 672-685.

Bettinger, Eric, Bridget Terry Long, Philip Oreopoulos, and Lisa Sanbonmatsu. 2012. "The Role of Application Assistance and Information in College Decisions: The H&R Block FAFSA Experiment." *The Quarterly Journal of Economics* 127(3): 1205-1242.

Black, Dan A., and Jeffrey A. Smith. 2006. "Estimating the Returns to College Quality with Multiple Proxies for Quality." *Journal of Labor Economics* 24(3): 701-728.

Bond, Timothy N. and Kevin Lang. 2013. "The evolution of the Black-White test score gap in Grades K173: The fragility of results." *Review of Economics and Statistics*, 95 (5): 1468-1479.

Bond, Timothy N. and Kevin Lang. 2014. "The Sad Truth About Happiness Scales." NBER Working Paper 19950.

Bulman, George. 2015. "The Effect of Access to College Assessments on Enrollment and Attainment." *American Economic Journal: Applied Economics* 7(4): 1-37.

Card, David, and Alan B. Krueger. 2005. "Would the Elimination of Affirmative Action Affect Highly Qualified Minority Applicants? Evidence from California and Texas." *Industrial and Labor Relations Review* 58(3): 414-434.

Carrell, Scott and Bruce Sacerdote. 2012. "Late Interventions Matter Too: The Case of College Coaching in New Hampshire." NBER Working Paper 19031.

Chade, Hector, Gregory Lewis, and Lones Smith. 2014. "Student Portfolios and the College Admissions Problem." *Review of Economic Studies* 81(3): 971-1002.

Cohodes, Sarah R., and Joshua S. Goodman. 2014. "Merit Aid, College Quality, and College Completion: Massachusetts' Adams Scholarship as an In-Kind Subsidy." *American Economic Journal: Applied Economics* 6(4): 251-285.

Dillon, Eleanor, and Jeffrey Smith. 2016. “Determinants of the Match between Student Ability and College Quality.” *Journal of Labor Economics*, forthcoming.

Dizon-Ross, Rebecca. 2014. “Parents’ Perceptions and Children’s Education: Experimental Evidence from Malawi.” Working Paper.

Epple, Dennis, Richard Romano, and Holger Sieg. 2006. “Admission, Tuition, and Financial Aid Policies in the Market for Higher Education.” *Econometrica* 74(4): 885-928.

Farber, Henry S., and Robert Gibbons. 1996. “Learning and Wage Dynamics.” *The Quarterly Journal of Economics* 111(4): 1007-1047.

Fu, Chao. 2014. “Equilibrium Tuition, Applications, Admissions, and Enrollment in the College Market.” *Journal of Political Economy* 122(2): 225-281.

Goodman, Sarena F. 2013. “Learning from the Test: Raising Selective College Enrollment by Providing Information.” Working Paper.

Hoekstra, Mark. 2009. “The Effect of Attending the Flagship State University on Earnings: A Discontinuity-Based Approach.” *The Review of Economics and Statistics* 91(4): 717-724.

Hoxby, Caroline, and Sarah Turner. 2014. “Expanding College Opportunities for High-Achieving, Low Income Students.” Stanford Institute for Economic Policy Research Discussion Paper 12-014.

Hoxby, Caroline M., and Christopher Avery. “The Missing “One-Offs”: The Hidden Supply of High-Achieving, Low-Income Students.” NBER Working Paper 18586.

Brookings Papers on Economic Activity, Spring 2013

Hurwitz, Michael, Jonathan Smith, Sunny Niu, and Jessica Howell. 2014. “The Maine Question: How Is 4-Year College Enrollment Affected by Mandatory College Entrance Exams?” *Educational Evaluation and Policy Analysis.*

Jacob, Brian A., and Tamara Wilder Linkow. 2011. “Educational Expectations and Attainment.” in *Whither Opportunity*, ed. Greg Duncan and Richard Murnane, New York: Russell Sage.

Jensen, Robert. 2010. “The (Perceived) Returns to Education and the Demand for Schooling.” *The Quarterly Journal of Economics* 125(2): 515-548.

Kahn, Lisa B., and Fabian Lange. 2014. “Employer Learning, Productivity, and the Earnings Distribution: Evidence from Performance Measures.” *Review of Economic Studies* 81: 1575-1613.

Klasik, Daniel. 2013. “The ACT of Enrollment: The College Enrollment Effects of State-Required College Entrance Exam Testing.” *Educational Researcher* 42: 151-159.

Lange, Fabian. 2007. “The Speed of Employer Learning.” *Journal of Labor Economics* 25(1): 1-35.

Manski, Charles. 1989. “Schooling as Experimentation: A Reappraisal of the Post-Secondary Drop-Out Phenomenon.” *Economics of Education Review* 8(4): 305-312.

Oreopoulos, Phillip and Reuben Ford. 2016. “Keeping College Options Open: A Field Experiment to Help All High School Seniors Through the College Application Process.” NBER Working Paper No. 22320.

Pallais, Amanda. 2015. “Small Differences that Matter: Mistakes in Applying to College.” *Journal of Labor Economics* 33(2): 493-520.

Papay, John P., Richard J. Murnane, and John B. Willett. 2016. “The Impact of Test Score Labels on Human-Capital Investment Decisions.” *Journal of Human Resources.* 51 (2): 357-388.

Rockoff, Jonah E., Douglas O. Staiger, Thomas J. Kane, and Eric S. Taylor. 2012. “Information and Employee Evaluation: Evidence from a Randomized Intervention in Public Schools.” *American Economic Review* 102(7): 3184-3213.

Smith, Jonathan, Matea Pender, and Jessica Howell. 2013. “The Full Extent of Student-College Academic Undermatch.” *Economics of Education Review* 32: 247-261.

Stange, Kevin M. 2012. "An Empirical Investigation of the Option Value of College Enrollment." *American Economic Journal: Applied Economics* 4(1): 49-84.

Stinebrickner, Todd, and Ralph Stinebrickner. 2012. "Learning About Academic Ability and the College Drop-Out Decision." *Journal of Labor Economics* 30(4): 707-748.

Stinebrickner, Todd, and Ralph Stinebrickner. 2013. "A Major in Science? Initial Beliefs and Final Outcomes for College Major and Dropout." *Review of Economic Studies* 81(1): 426-472.

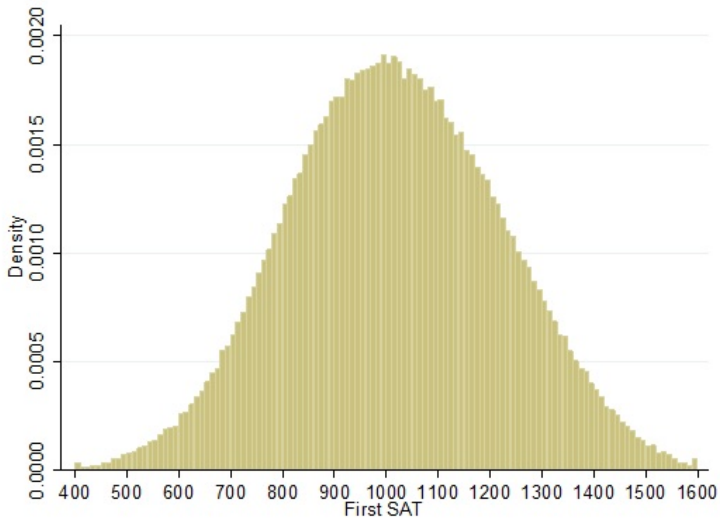
Vigdor, Jacob L., and Charles T. Clotfelter. 2003. "Retaking the SAT." *Journal of Human Resources* 38(1): 1-33.

Wiswall, Matthew and Basit Zafar. 2015. "Determinants of College Major Choice: Identification using an Information Experiment." *Review of Economic Studies* 82: 791-824.

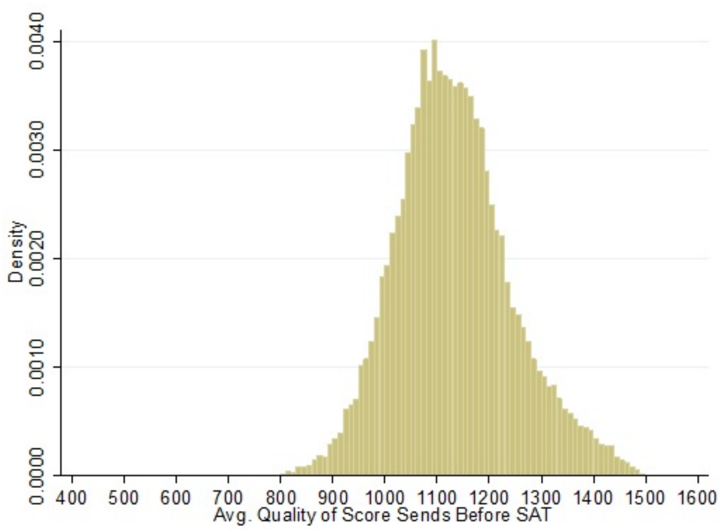
Zafar, Basit. 2011 "How Do College Students Form Expectations?" *Journal of Labor Economics* 29(2): 301-348.

Figure 1: Distribution of SAT Scores and Portfolio Quality

A. Distribution of First SAT Scores



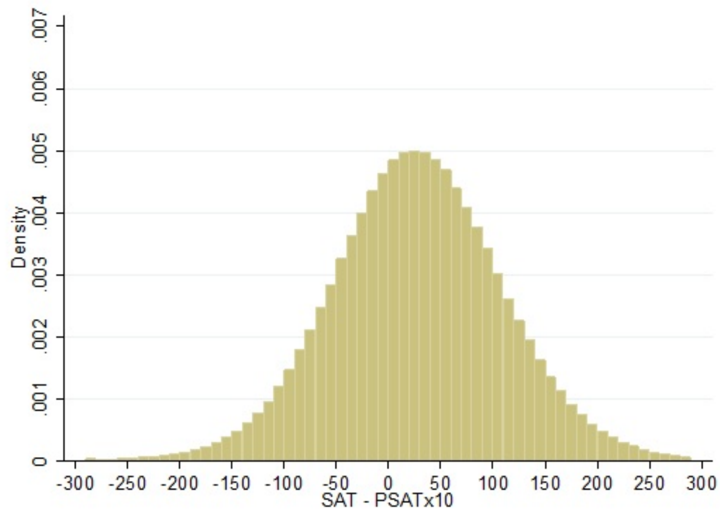
B. Distribution of Pre-Exam College Portfolios



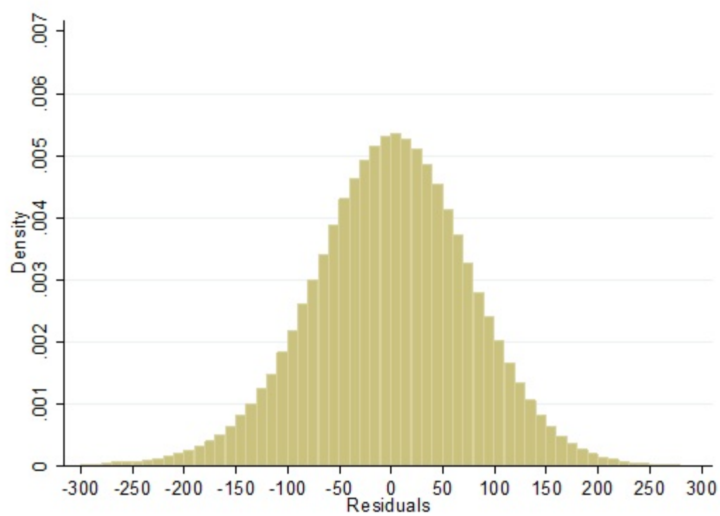
Note: The top figure presents the score distribution of students' first SAT scores. The score is measured in multiples of 10 points. The standard deviation of the distribution is 200 points. The bottom figure presents the distribution of the average SAT scores of matriculates of colleges in each students'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

Figure 2: Within-Student Variation in Scores: First SAT vs PSAT and Predicted SAT

A. First SAT - PSAT



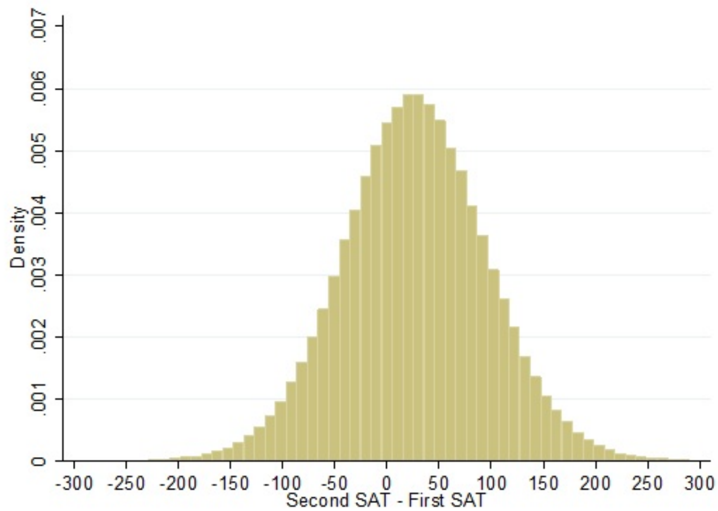
B. First SAT - Predicted First SAT



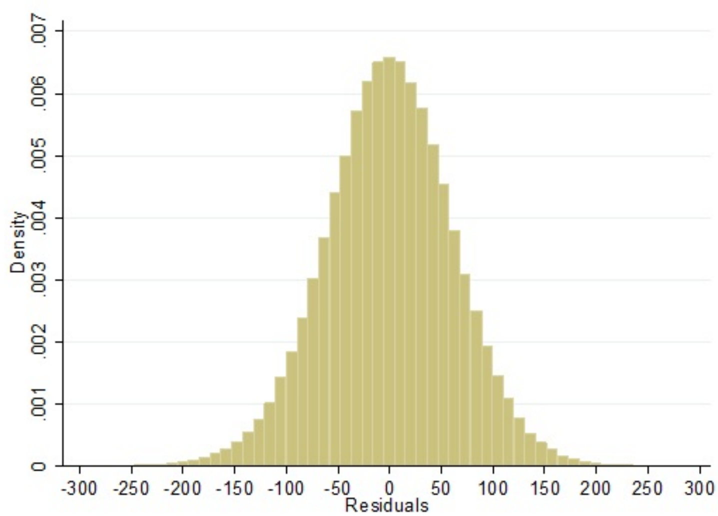
Note: The top figure presents the difference between a student's SAT and PSAT scores. The PSAT score has been multiplied by 10 to be on the same scale as the SAT. The standard deviation of the difference is 86.5 points. The bottom figure presents the difference between the first SAT score and the predicted SAT. The SAT score is predicted using the PSAT, grade point average, gender, race, parental income, and the average score for matriculates of colleges selected to receive score reports prior to taking the exam. The standard deviation of the difference is 80.5 points.

Figure 3: Within-Student Variation in Scores: Second SAT vs First SAT and Predicted SAT

A. Second SAT - First SAT



B. Second SAT - Predicted Second SAT



Note: The top figure presents the difference between a student's second SAT and first SAT scores. The standard deviation of the difference is 70.3 points. The bottom figure presents the difference between the second SAT score and the predicted second SAT. The SAT score is predicted using the PSAT, first SAT, grade point average, gender, race, parental income, and the average score for matriculates of colleges selected to receive score reports prior to taking the exam. The standard deviation of the difference is 63.6 points.

Table 1: Summary Statistics

	Observations (1)	Mean (2)	Std. Dev. (3)
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
Took PSAT as Junior	627,190	0.811	0.392
SAT Score	627,190	1009.3	213.5
Number Reports Before SAT	627,190	3.169	1.600
Sent Reports After SAT	627,190	0.206	0.404
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
Took PSAT as Junior	534,399	0.857	0.350
First SAT	534,399	1038.0	190.6
Second SAT	534,399	1064.4	196.6
Number Reports Before First SAT	534,399	3.674	1.859
Number Reports After First SAT	534,399	2.778	2.545
Sent Reports After First SAT	534,399	0.698	0.459
Sent Reports After Second SAT	534,399	0.324	0.468

Note: This table presents summary statistics for students who took the SAT one time (top panel) and two times (bottom panel) and who took the PSAT as a sophomore or junior in high school. The cohorts included in the analysis graduated between 2007 and 2009. "Reports" refer to Score Sends sent by the College Board to colleges at the request of the student. Note that the PSAT score has been multiplied by 10 to be on a comparable scale to the SAT score.

Table 2: 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 SAT and PSAT scores on college portfolio quality. 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. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table 3: One-Time Takers: Portfolio Updating in Response to the SAT

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		0.397	

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 high school grade point average, race, and household income. Each specification includes the interaction of the controls with an indicator for the post period. 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: One-Time Takers: Alternate Measures of Portfolio Quality

	Min SAT (1)	Max SAT (2)	Percent Private (3)	In-State Tuition (4)	4-Year Grad Rate (5)
PSAT Score	0.097***	0.126***	0.021***	7.471***	0.015***
	(0.004)	(0.004)	(0.001)	(0.298)	(0.001)
SAT Score	0.127***	0.147***	0.020***	7.475***	0.020***
	(0.004)	(0.004)	(0.001)	(0.304)	(0.001)
After SAT * PSAT Score	-0.044***	-0.017***	-0.012***	-2.993***	-0.005***
	(0.006)	(0.006)	(0.002)	(0.444)	(0.001)
After SAT * SAT Score	0.011*	0.118***	0.011***	4.093***	0.010***
	(0.006)	(0.007)	(0.002)	(0.459)	(0.001)
Observations	258,036	258,036	258,036	257,919	256,947
R-squared	0.212	0.322	0.081	0.171	0.291

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 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 (rather than public or for-profit). Column (4) considers the average in-state tuition for colleges in the portfolio and column (5) is the average graduation rate within four years for colleges in the portfolio. Student controls include high school grade point average, race, and household income. Each specification includes the interaction of the controls with an indicator for the post period. Standard errors are clustered at the zip code level. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table 5: Two-Time Takers: Portfolio Updating in Response to Each SAT

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		0.442	

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. Standard errors are clustered at the zip code level. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table 6: Two-Time Takers: Alternate Measures of Portfolio Quality

	Min SAT (1)	Max SAT (2)	Percent Private (3)	In-State Tuition (4)	4-Year Grad Rate (5)
PSAT Score	0.070***	0.082***	0.017***	5.483***	0.010***
	(0.005)	(0.005)	(0.001)	(0.362)	(0.001)
SAT 1 Score	0.089***	0.102***	0.020***	6.735***	0.015***
	(0.006)	(0.006)	(0.002)	(0.425)	(0.001)
SAT 2 Score	0.109***	0.100***	0.010***	4.819***	0.015***
	(0.005)	(0.005)	(0.002)	(0.411)	(0.001)
After SAT 1 * PSAT Score	-0.017**	-0.021***	-0.004*	-1.164**	-0.003***
	(0.007)	(0.007)	(0.002)	(0.506)	(0.001)
After SAT 1 * SAT 1 Score	0.042***	0.057***	0.007***	2.937***	0.007***
	(0.008)	(0.008)	(0.002)	(0.600)	(0.001)
After SAT 1 * SAT 2 Score	0.011	0.010	0.003	0.977*	0.001
	(0.008)	(0.007)	(0.002)	(0.576)	(0.001)
After SAT 2 * PSAT Score	-0.059***	-0.022***	-0.009***	-2.858***	-0.006***
	(0.007)	(0.007)	(0.002)	(0.553)	(0.001)
After SAT 2 * SAT 1 Score	0.024***	0.017*	-0.001	0.449	0.003**
	(0.008)	(0.009)	(0.003)	(0.645)	(0.001)
After SAT 2 * SAT 2 Score	0.015**	0.131***	0.010***	4.036***	0.011***
	(0.008)	(0.008)	(0.003)	(0.622)	(0.001)
Observations	334,506	334,506	334,506	334,378	333,687
R-squared	0.241	0.336	0.095	0.182	0.315

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 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 (rather than public or for-profit). Column (4) considers the average in-state tuition for colleges in the portfolio and column (5) is the average graduation rate within four years for colleges in the portfolio. Student controls include high school grade point average, race, and household income. Each specification includes the interaction of the controls with an indicator for the post period. Standard errors are clustered at the zip code level. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table 7: One-Time Takers: Updating by Gender, Race, Household Income, and Type of Shock

	Gender		Race			HH Income			Type of Shock	
	Male	Female	White	Black	Hisp	$0-50k$	$50-100k$	$>100k$	Positive	Negative
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PSAT Score	0.125***	0.112***	0.117***	0.131***	0.111***	0.117***	0.101***	0.128***	0.109***	0.126***
	(0.005)	(0.005)	(0.005)	(0.011)	(0.011)	(0.009)	(0.008)	(0.007)	(0.006)	(0.010)
SAT Score	0.134***	0.147***	0.150***	0.109***	0.110***	0.103***	0.146***	0.159***	0.166***	0.100***
	(0.005)	(0.005)	(0.005)	(0.011)	(0.011)	(0.009)	(0.008)	(0.007)	(0.006)	(0.010)
After SAT * PSAT Score	-0.039***	-0.024***	-0.032***	-0.047***	-0.030*	-0.038***	-0.027**	-0.025**	-0.032***	-0.012
	(0.008)	(0.008)	(0.007)	(0.015)	(0.016)	(0.013)	(0.012)	(0.010)	(0.009)	(0.014)
After SAT * SAT Score	0.081***	0.064***	0.067***	0.105***	0.064***	0.084***	0.067***	0.068***	0.083***	0.037**
	(0.008)	(0.008)	(0.007)	(0.016)	(0.016)	(0.013)	(0.012)	(0.011)	(0.009)	(0.015)
Observations	126,422	131,614	156,830	35,074	34,456	54,314	65,250	65,270	162,834	95,202
R-squared	0.387	0.332	0.364	0.259	0.260	0.276	0.334	0.3736	0.385	0.289

Note: This table presents the estimated effect of newly released SAT scores on choice of college portfolio for various population subgroups. 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), race (black, Hispanic, and white), by 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 a zip code fixed effect interacted with an indicator for the post period. Note that some characteristics are missing from student surveys. Standard errors are clustered at the zip code by period level. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table 8: Two-Time Takers: Updating by Gender, Race, Household Income, and Type of Shock

	Gender		Race			HH Income			Type of Shock	
	Male	Female	White	Black	Hisp	$0-50k$	$50-100k$	$>100k$	Two Pos	Two Neg
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PSAT Score	0.087***	0.068***	0.076***	0.070***	0.092***	0.065***	0.067***	0.076***	0.062***	0.124***
	(0.006)	(0.006)	(0.005)	(0.016)	(0.015)	(0.012)	(0.009)	(0.007)	(0.010)	(0.012)
First SAT Score	0.099***	0.101***	0.105***	0.088***	0.063***	0.093***	0.096***	0.106***	0.117***	0.063***
	(0.007)	(0.007)	(0.006)	(0.018)	(0.017)	(0.014)	(0.011)	(0.008)	(0.010)	(0.012)
Second SAT Score	0.099***	0.120***	0.119***	0.124***	0.092***	0.094***	0.117***	0.121***	0.126***	0.077***
	(0.007)	(0.007)	(0.006)	(0.017)	(0.016)	(0.013)	(0.010)	(0.008)	(0.009)	(0.012)
After SAT 1*PSAT Score	-0.016**	-0.022***	-0.017**	-0.010	-0.037*	-0.008	-0.011	-0.010	-0.027**	-0.022
	(0.008)	(0.008)	(0.007)	(0.022)	(0.020)	(0.017)	(0.012)	(0.010)	(0.013)	(0.017)
After SAT 1 * SAT 1 Score	0.059***	0.046***	0.055***	0.049*	0.072***	0.034*	0.043***	0.058***	0.078***	0.045***
	(0.009)	(0.009)	(0.008)	(0.025)	(0.023)	(0.019)	(0.015)	(0.012)	(0.014)	(0.016)
After SAT 1 * SAT 2 Score	0.002	0.018**	0.005	0.012	0.011	0.019	0.016	-0.002	-0.003	0.018
	(0.009)	(0.009)	(0.008)	(0.025)	(0.022)	(0.018)	(0.014)	(0.011)	(0.013)	(0.017)
After SAT 2 * PSAT Score	-0.050***	-0.027***	-0.041***	-0.006	-0.058***	-0.041**	-0.028**	-0.038***	-0.048***	-0.044**
	(0.009)	(0.009)	(0.008)	(0.023)	(0.021)	(0.018)	(0.014)	(0.011)	(0.014)	(0.018)
After SAT 2 * SAT 1 Score	0.015	0.018*	0.016*	0.027	0.039	0.011	0.013	0.013	0.023	0.038**
	(0.010)	(0.010)	(0.009)	(0.026)	(0.025)	(0.021)	(0.016)	(0.013)	(0.016)	(0.017)
After SAT 2 * SAT 2 Score	0.092***	0.066***	0.075***	0.072***	0.060**	0.092***	0.077***	0.075***	0.083***	0.065***
	(0.010)	(0.010)	(0.009)	(0.025)	(0.024)	(0.020)	(0.016)	(0.013)	(0.014)	(0.018)
Observations	154,923	179,583	202,278	37,893	38,781	56,058	83,571	96,372	131,286	104,490
R-squared	0.415	0.369	0.399	0.332	0.301	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. 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), race (black, Hispanic, and white), by 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 a zip code fixed effect interacted with an indicator for the post period. Note that some characteristics are missing from student surveys. Standard errors are clustered at the zip code level. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table 9: Extensive Margins: Retaking and 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 prior to taking the SAT as additional control variables. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Table 10: Joint Sample and Lower Bounds

	Joint Sample One and Two Time Takers (1)	Lower Bound One-Time Takers [No Updating] (2)	Lower Bound Two-Time Takers [No Updating] (3)
PSAT Score	0.129***	0.086***	0.067***
	(0.002)	(0.001)	(0.002)
SAT 1 Score	0.128***	0.086***	0.084***
	(0.003)	(0.001)	(0.002)
SAT 2 Score			0.087***
			(0.002)
After SAT 1 * PSAT Score	-0.009***	-0.002	-0.008***
	(0.003)	(0.002)	(0.002)
After SAT 1 * SAT 1 Score	0.055***	0.014***	0.025***
	(0.003)	(0.002)	(0.003)
After SAT 1 * SAT 2 Score			0.007**
			(0.003)
Students	240,541	627,190	534,399
Observations	481,082	1,254,380	1,603,197
R-squared	0.388	0.233	0.336

Note: This table presents the estimated effect of newly released SAT scores on a student's choice of college portfolio for a joint sample of one- and two-time takers in column (1) and under the assumption of no updating for students who do not send additional reports in columns (2) and (3). Each column presents the change in the average SAT of matriculating students at colleges selected before and after a student's score is released. Student controls include high school grade point average, race, and household income. Each specification includes the interaction of the controls with an indicator for the post period. Standard errors are clustered at the zip code level. The symbols *, **, and *** represent statistical significance at 10, 5, and 1 percent respectively.

Appendix

A Strategy Adjusted Estimates

The section presents revised estimates after accounting for strategies that are correlated with student aptitude. This is important if higher aptitude students systematically apply more or less aggressively after receiving their scores.

A.1 Estimating Strategy

As introduced in Section 3.3, we can estimate time-varying strategies that are correlated with aptitude by estimating $y_t = d_t s + \epsilon_t$ for the outcome of interest y_t on a measure of aptitude 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 period as a function of the measure of student aptitude.

Table A1 presents estimates of Ω_t using the PSAT as the measure of aptitude 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 aptitude (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 5 of the 7 outcomes, suggesting that higher aptitude students are generally more aggressive with their post-exam portfolio than are lower aptitude students.

A.2 Adjusted Estimates for Alternative Outcomes

The strategy adjusted estimates are included for the primary measure of college quality, SAT of matriculates, in Tables 3 and 5 of the text. We present the equivalent estimates for alternative outcomes in Tables A2 and A3. These estimates indicate strong evidence of updating in response to new information. For one-time takers, post-exam portfolios significantly discount the information in the PSAT while placing significantly 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. This provides strong evidence that students do not anticipate future scores. This evidence is strengthened by the timing of when students select their portfolios. 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 is taken should be more correlated with the second score than the first score.

Table A1: Estimates of Strategy Adjustment: Omega

	New SAT (1)	Cumulative SAT (2)	Min SAT (3)	Max SAT (4)	Percent Private (5)	In-State Tuition (6)	Grad Rate (7)
One-Time Takers							
Omega (t=0)	0.883	0.949	1.206	0.751	1.063	0.967	0.898
	(0.010)	0.010	(0.020)	(0.009)	(0.031)	(0.018)	(0.012)
Two-Time Takers							
Omega (t=0)	0.861	0.919	1.135	0.712	1.061	0.948	0.866
	(0.010)	(0.009)	(0.019)	(0.009)	(0.026)	(0.016)	(0.011)
Omega (t=1)	0.972	0.980	1.258	0.810	1.180	1.073	0.978
	(0.010)	(0.009)	(0.019)	(0.010)	(0.029)	(0.018)	(0.011)

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. The resulting estimates are used to adjust the outcomes presented in Tables A2 and A3.

Table A2: One-Time Takers: Alternate Measures of Portfolio Quality (Adjusted)

	Min SAT (1)	Max SAT (2)	Percent Private (3)	In-State Tuition (4)	4-Year Grad Rate (5)
PSAT Score	0.081***	0.169***	0.020***	7.733***	0.017***
	(0.003)	(0.005)	(0.001)	(0.280)	(0.001)
SAT Score	0.106***	0.195***	0.019***	7.726***	0.023***
	(0.004)	(0.006)	(0.001)	(0.343)	(0.001)
After SAT * PSAT Score	-0.027***	-0.061***	-0.011***	-3.346***	-0.007***
	(0.005)	(0.006)	(0.002)	(0.405)	(0.001)
After SAT * SAT Score	0.032***	0.071***	0.012***	3.924***	0.008***
	(0.006)	(0.007)	(0.002)	(0.475)	(0.001)
Observations	258,036	258,036	258,036	257,919	256,947

Note: This table presents the estimated effect of newly released SAT scores on a student's choice of college portfolio after adjusting for application strategies. The outcomes are adjusted as detailed in Section 3.3 prior to estimation. 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 (rather than public or for-profit). Column (4) considers the average in-state tuition for colleges in the portfolio and column (5) is the average graduation rate within four years for colleges in the portfolio. Student controls include high school grade point average, race, and household income. Each specification includes the interaction of the controls with an indicator for the post period. Bootstrapped standard errors are used to account for the fact that the outcomes incorporate the estimates of Ω_t.

Table A3: Two-Time Takers: Alternate Measures of Portfolio Quality (Adjusted)

	Min SAT (1)	Max SAT (2)	Percent Private (3)	In-State Tuition (4)	4-Year Grad Rate (5)
PSAT Score	0.061***	0.115***	0.016***	5.779***	0.012***
	(0.004)	(0.006)	(0.001)	(0.350)	(0.001)
SAT 1 Score	0.078***	0.145***	0.019***	7.166***	0.017***
	(0.005)	(0.008)	(0.002)	(0.433)	(0.001)
SAT 2 Score	0.096***	0.139***	0.010***	5.035***	0.017***
	(0.005)	(0.008)	(0.001)	(0.411)	(0.001)
After SAT 1 * PSAT Score	-0.019***	-0.039***	-0.005	-1.736	-0.004
	(0.005)	(0.009)	(0.002)	(0.446)	(0.001)
After SAT 1 * SAT 1 Score	0.026***	0.052***	0.004**	1.755***	0.006***
	(0.007)	(0.011)	(0.002)	(0.569)	(0.001)
After SAT 1 * SAT 2 Score	-0.002	-0.003	0.002	0.392	-0.001
	(0.007)	(0.010)	(0.002)	(0.536)	(0.001)
After SAT 2 * PSAT Score	-0.051***	-0.055***	-0.009***	-3.169***	-0.007***
	(0.006)	(0.008)	(0.002)	(0.518)	(0.001)
After SAT 2 * SAT 1 Score	0.034***	-0.026**	0.000	0.010	0.000
	(0.007)	(0.011)	(0.003)	(0.691)	(0.001)
After SAT 2 * SAT 2 Score	0.029***	0.092***	0.010***	3.848***	0.009***
	(0.008)	(0.010)	(0.002)	(0.644)	(0.001)
Observations	334,506	334,506	334,506	334,378	333,687

Note: This table presents the estimated effect of newly released SAT scores on a student's choice of college portfolio after adjusting for application strategies. The outcomes are adjusted as detailed in Section 3.3 prior to estimation. 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 (rather than public or for-profit). Column (4) considers the average in-state tuition for colleges in the portfolio and column (5) is the average graduation rate within four years for colleges in the portfolio. Student controls include high school grade point average, race, and household income. Each specification includes the interaction of the controls with an indicator for the post period. Bootstrapped standard errors are used to account for the fact that the outcomes incorporate the estimates of Ω_t.