School Meal Quality and Academic Performance

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Abstract

Improving the nutritional content of public school meals is a topic of intense policy interest. A main motivation is the health of school children, and, in particular, the rising childhood obesity rate. Medical and nutrition literature has long argued that a healthy diet can have a second important impact: improved cognitive function. In this paper, we test whether offering healthier meals affects student achievement as measured by test scores. Our sample includes all California (CA) public schools over a five-year period. We estimate difference-in-differences style regressions using variation that takes advantage of frequent meal-vendor contract turnover. Students at schools that contract with a healthy school-meal vendor score higher on CA state achievement tests. We do not find any evidence that healthier school meals lead to a decrease in obesity rates. The test score gains, while modest in magnitude, come at very low cost.

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1 Introduction

Improving the nutritional content of public school meals in the United States (US) is a topic of intense policy interest (Confessore 2014). A primary motivation underlying these nutritional improvements is to increase student health and reduce childhood obesity rates. A question of comparable import, however, is whether healthier meals affect student achievement. Recent research demonstrates that the provision of subsidized school meals can significantly increase school test scores (Figlio and Winicki 2005; Dotter 2014; Imberman and Kugler 2014; Frisvold 2015), but to date little evidence exists on how the *quality* of school meals affects student achievement.

To determine whether the quality of school meals affects student achievement, we exploit longitudinal variation in California school districts' meal vendors and estimate difference-in-differences type regressions. We combine two principal data sets from the California Department of Education, one covering breakfast and lunch vendors at the school level and the other containing school-by-grade-level standardized test results. Our five-year panel dataset includes all CA public elementary, middle, and high schools with non-missing state test score data (approximately 9,700 schools across 900 districts). For each California public school, we observe whether the district in which the school is located had an outside contract with a meal provider for the school year, and, if so, the name of the provider and the type of contract. The vast majority of schools provide meals using "in-house" staff, but a significant and growing fraction (approximately 12%) contract with outside vendors to provide meals. Crucially for our research design, there is substantial turnover in vendors at the school-district level during our sample period. Among schools in our panel that contract with an outside vendor, 62% switch between preparing meals in-house and contracting with a vendor.

A central obstacle in estimating the effects of healthy meal vendors on academic performance is accurate measurement of nutritional quality. We measure the nutritional quality of vendor school meals using a modified version of the Healthy Eating Index (HEI). The HEI is a continuous score ranging from 0 to 100 that uses a well-established food-component analysis to determine how well food offerings (or diets) match the Dietary Guidelines for Americans (e.g., Guenther et al. 2013b). HEI is the measure of diet quality preferred by the United States Department of Agriculture (USDA) (USDA 2006) and has previously been used by researchers to evaluate menus at fast-food restaurants and child-care centers. We contracted with trained nutritionists at the Nutrition Policy Institute to calculate vendor HEI scores for this project.[1] Using their scores, we classify a vendor as healthy if its HEI score is above the median score among all vendors in our sample and as standard otherwise.

We find that contracting with a healthy meal vendor increases test scores by 0.03 to 0.04 standard deviations relative to in-school meal provision, after conditioning on school-by-grade and year fixed effects. This result is highly significant and robust to the inclusion or exclusion of our time-varying covariates, including demographic characteristics of the students, school district expenditures, student-teacher ratios, and changes in school leadership. The point estimates are also very similar whether they are estimated on the baseline sample of all CA schools or samples restricted to those schools that ever contract with an outside vendor. When estimating effects separately for economically disadvantaged and non-disadvantaged students, we find modest evidence that the effect of contracting with a healthy vendor is larger for economically disadvantaged students than for non-disadvantaged students. There is no evidence that contracting with a standard vendor affects test scores.

We conduct various tests to support the identifying assumption that the exact timing of vendor contracts is uncorrelated with other time-varying factors that may affect test scores. The frequent turnover in meal-vendor contracts makes it less likely that an unobservable factor could explain our test score results, as this factor would need to be highly correlated with with the timing of new contracts for healthy-meal vendors but not standard vendors. Event study specifications and "placebo" tests where the treatment activates one year prior to the actual treatment year provide evidence that test scores are not correlated with *future* changes in vendors (i.e., there are no differential trends preceding a new vendor contract).

[1] http://npi.ucanr.edu/About_Us/

We also find that changes in observable characteristics of schools are uncorrelated with new vendor contracts. In particular, there is no evidence that changes in test scores predict when a school will contract with a vendor.

Introducing healthier school meals does not appear to change the *number* of school meals sold, which supports our interpretation that the change in test scores is due to the quality rather than the quantity of the food. At the same time, this result helps to alleviate concerns that offering healthier meals could lead to lower consumption by economically disadvantaged students who qualify for free or reduced price school lunch. Similarly, we do not find that healthier school meals lead to a decrease in obesity rates. One explanation for the null effect on the percent of overweight students is that all school meals – healthy vendor, standard vendor, and in-house – are subject to the same USDA calorie requirements.

Although our estimated test score effects are modest on an absolute scale, they are highly cost-effective for a human capital investment. We calculate a plausible upper bound on the cost of contracting with a healthy meal provider, relative to in-house meal preparation, of approximately $85 (2013 $) per test-taker per school year. Using our preferred estimate of 0.031 standard deviations, this result implies that it costs (at most) $27 per year to raise a student's test score by 0.01 standard deviations. Despite assuming high costs, the cost effectiveness of contracting with healthy vendors matches the most cost-effective policies highlighted by Jacob and Rockoff [2011], and it compares very favorably when measured against interventions that achieve larger absolute effects, such as the Tennessee STAR class-size reduction experiment (Krueger 1999).

2 Background and Data

2.1 Related Literature

There is a large medical and nutrition literature examining the link between diet and cognitive development, and between diet and cognitive function (e.g., Bryan et al. 2004; Sorhaindo and Feinstein 2006; Gomez-Pinilla 2008; Nandi et al. 2015). Sorhaindo and Feinstein [2006] review existing research on the link between child nutrition and academic achievement and highlight how nutrition can affect learning through three channels: physical development (e.g., sight), cognition (e.g., concentration, memory), and behavior (e.g., hyperactivity). Gomez-Pinilla [2008] outlines some of the biological mechanisms regarding how both an increase in calories and an improvement in diet quality and nutrient composition can affect cognition. For example, "diets that are high in saturated fat are becoming notorious for reducing molecular substrates that support cognitive processing and increasing the risk of neurological dysfunction in both humans and animals" (Gomez-Pinilla 2008, p. 569). Most of the direct evidence on how nutrition affects academic achievement among school-age children comes from studies of children in developing countries (Alderman et al. 2007 and Glewwe and Miguel 2008 provide reviews).

A number of recent studies have estimated the effect of increased availability of either breakfast or lunch under the National School Lunch Program (NSLP) on student test scores in the US. Many of these studies find evidence that improved access to breakfast or lunch increased test scores (e.g., Figlio and Winicki 2005; Dotter 2014; Imberman and Kugler 2014; Frisvold 2015), while others find no effect (e.g., Leos-Urbel et al. 2013; Schanzenbach and Zaki 2014). In all of these studies, the main hypothesized channel between the increased take-up of the school breakfast and lunch programs and test scores is an increase in calories consumed. The NSLP may also have broadly increased educational attainment by inducing children to attend school (Hinrichs 2010).

In the past decade policy interest has shifted towards the nutritional quality of school meals. In 2010 Congress passed the Healthy, Hunger-Free Kids Act (HHFKA) with the aim of increasing the minimum nutritional standards that school meals must meet. For example, the number of mandated servings of fruits and vegetables increased, while at the same time restrictions were placed on the number of servings of French fries (USDA 2012a). In recent years, however, policymakers have argued that the improved nutritional standards for school meals are ineffective or counterproductive (Green and Davis 2017).

Our paper contributes to this policy debate by focusing on the nutritional quality of the calories provided. We are aware of just one other study that estimates the effect of food quality on academic test scores. Belot and James [2011] estimate the effect of introducing a new, healthier school lunch menu in 80 schools during the same academic year in one borough in London, as compared to schools in a neighboring borough. The authors estimate a positive effect on test scores for elementary school students, but find that the effect is larger for higher socioeconomic students who do not qualify for reduced price or free school lunch.

Relative to Belot and James [2011], we provide evidence from a much larger sample that includes all CA public schools (roughly 9,700 schools across 900 districts), of which 1,188 (in 143 districts) contract with an outside meal provider. We observe students and contracts in grades two through eleven, while Belot and James examine only primary schools. Our estimation approach uses within-grade and school variation in the introduction *and* removal of healthy and standard meal providers that occurs in each of the five years of our panel. Thus, we can account for constant unobserved grade-by-school effects. Further, the staggered timing of the meal contracts allows us to flexibly control for unobserved (calendar) time effects, and to conduct a series of robustness checks regarding the exogeneity of the timing of the contracts. Finally, like Belot and James [2011], we estimate the effect of healthier school meals on the number of meals served; however, unlike Belot and James [2011], we are also able to test whether healthier meal provision changes obesity rates.

2.2 Data Sources

The data for this project come from the State of California Department of Education. We use information on school-level breakfast and lunch vendors, and school-by-grade-level standardized test results. We describe each type of information in detail below.

2.2.1 Vendor Data

The vendor meal contract information is provided by the California Department of Education for the school years 2008-2009 to 2012-2013.[2] All food vendor contracts with public (K-12) schools in California must be approved by the CA Department of Education. The CA Department of Education retains a list of the schools that contract with an outside meal provider for each school year, the name of the provider, and the type of contract. A total of 143 school districts covering 1,188 schools contracted with a total of 45 different vendors during our sample period. We merged the food vendor contract information with the list of all public schools (including charter schools) operating in CA during this time period to create our estimation panel.[3] Overall, 12% of CA public schools contracted for at least one academic year with an outside company to provide school meals.

Appendix Table A1 lists the 45 vendors and the percent of students served by each vendor (conditional on being served by any vendor). For each vendor, we first calculate the number of (STAR) test-takers in districts that are being served by that vendor. This vendor-level total is then divided by the total number of test-takers being served by outside vendors. A single vendor serves just over 50% of the students. Altogether, the vendors with the ten largest student test-taker market shares serve 97.5% of CA students enrolled in schools that contract with outside school meal providers.

Nearly all of the contracts (94%) are signed in the summer and cover the entire academic school year.[4] The CA Department of Education classifies all food provision contracts as one of four types: Vendor, Food Service Management Company (FSMC), Food Service Consulting Company (FSCC), and School Food Authority (SFA). A Vendor contract is when a school

[2]The data were received as part of an official information request. We thank Rochelle Crossen for her assistance in facilitating the request and in interpreting the data. Contract information for school years prior to 2008-2009 was not retained when the CA Department of Education switched computer database systems.

[3]Approximately 70% of active charter schools appear at least once in our sample. We assign charter schools the meal vendor of the district in which they are located, unless they have a separate meal contract.

[4]A small number of contracts cover less than the complete school year. These contracts correspond to the calendar year and thus cover only a fraction of the school year (August-December or January-June). Estimation results are insensitive to the inclusion of these contracts in our sample.

contracts with a private company to provide meals, but school employees (i.e., cafeteria staff) still handle and serve the food, including any additional prepping and cooking. In a FSMC contract, a private company prepares the meals and assists in staffing the school with cafeteria workers who serve the meals. In a FSCC contract, a private company provides "consulting services" on meal preparation and staffing, but does not provide any personnel for the jobs. SFA contracts usually denote that one public school district contracts with another district for meal provision. SFA contracts are unusual and account for just 1% of the contract-grade years. We do not distinguish between the four types of contracts in the main analysis of the paper and, unless otherwise specified, we refer to all such companies as "vendors."

Detailed vendor contract information is available for a subset of the contracts. Contract details include meals provided (either lunch or both breakfast and lunch), the dollar value of the contract, the number of other contract bidders (if any), the names of the companies which bid for the contract and were not selected, the dollar value of losing contracts, and the method by which the contract bids were solicited (i.e., sealed bid or negotiation). In the main analysis, we do not distinguish between vendors that provide both lunch and breakfast and those that provide only lunch, as this information is only available for a minority of the contracts.[5] We use the contract bid information to help construct counterfactual estimates for the cost to improve state test scores by contracting with healthy meal providers.

We assess the nutritional quality of the vendor school meals using the Healthy Eating Index (HEI). The HEI is the US Department of Agriculture's (USDA) preferred measure of diet quality (USDA 2006), and the USDA uses it to "examine relationships between diet and health-related outcomes, and to assess the quality of food assistance packages, menus, and the

[5]The contract details are not available for all contracts for two reasons. First, school districts are only required to provide contract details to the state for the first year of a new contract. A contract can be renewed up to four times without having to issue a new contract. Second, school officials enter the contract information via a software program that electronically stores the data in the CA Department of Education database. In practice, many of the data fields are missing for most of the new contracts. This is because, until recently, the CA Department of Education didn't have the staff to review the contract price and bid data entered into the system.

US food supply" (USDA 2016). HEI has been used by researchers to assess both individual diets (e.g., Volpe and Okrent 2012; Guenther et al. 2013a) and the diets of subpopulations (e.g., Hurley et al. 2009; Manios et al. 2009), as well as food offerings at fast food restaurants (e.g., Reedy et al. 2010) and child-care centers (e.g., Erinosho et al. 2013). The HEI scores range from 0 to 100, with higher scores representing healthier diets (or food offerings). Scores are calculated via a food component analysis done on a per calorie basis (Guenther et al. 2013b).

We contracted with nutritionists at the Nutrition Policy Institute to calculate vendor HEI scores using sample school meal menus. Over the course of one year they collected detailed vendor data, refined the HEI score methodology, and computed the scores.[6] Appendix A1 provides details of the HEI score calculations, and a link to the Nutrition Policy Institute report includes examples of menus used as part of the analysis.[7] Menu information was not available for all of the vendors, and as a result some vendors were not assigned HEI scores. Appendix Table A1 shows that this is mostly the case for vendors that contract infrequently with schools. Overall, HEI scores are calculated for 87.3% of student test-takers served under vendor contracts. The median vendor HEI score in our sample is 59.9. This median vendor score is similar to the average HEI score, 63.8, for the US population age two and older (USDA 2006, p. 21). We define a vendor as healthy if it has a vendor HEI score above the median vendor score. With this classification the median healthy vendor has an HEI score of 70.7, and the median standard vendor has an HEI score of 45.6. Healthy vendors are more likely to provide salad bars and sufficient amounts of fruits, vegetables, whole grains, dairy, and seafood or plant proteins. They serve fewer processed meats, fast-food items, fried

[6] We collected menu data retrospectively using https://archive.org. Nevertheless, menu dates ranged between 2011 and 2015, while test dates ranged between 2009 and 2013. Thus, on average, the menus lag the tests by two years. If there were significant changes in menus over time, this would introduce measurement error to our vendor categories, which would attenuate our coefficient estimates. In that scenario the statistical significance of our results would occur in spite of, not because of, any menu changes over time.

[7] In preparing their analysis, the nutritionists assumed that all vendors met the baseline USDA requirements, as they are obligated by law to do so. They also assumed that the average meal contains 650 calories, and they matched food items to foods available in the USDA food database. The classification of vendors as healthy or standard was not sensitive to any of these choices.

potatoes, chocolate milk, sweets, and chips or other salty snacks, and their meals tend to contain less refined grains, sodium, and "empty calories."[8] Alternative classifications (e.g., coding any vendor with an HEI score above the mean vendor score as healthy) generate similar results. While no classification system is perfect, it is notable that misclassifying healthy vendors as standard, and vice versa, will only attenuate our estimates.

One limitation of our data is that we do not observe HEI scores for in-house meal preparation. Nevertheless, several studies have explored this topic, and all of them find results suggesting that, prior to the implementation of HHFKA in 2012, in-house meals had average HEI scores that were similar to or slightly better than the standard vendors in our data (median HEI score: 45.6). Hanson and Olson [2013] uses national-level dietary recall data collected from 2003 to 2008 and estimates that the average school breakfast or lunch has an HEI score of 45. Bergman et al. [2016] examines school meals at four elementary schools during the 2011-12 academic year and finds a modal HEI score of 51. Finally, Smith et al. [2016] examines meals at two school districts in Washington before (and after) the implementation of HHFKA and finds an average HEI score of 52 (57).

Figure 1 plots the share of schools that employ healthy and standard meal providers over time. Although baseline levels are low, both contract types are increasing in prevalence over time.

2.2.2 Academic Test Data and Covariates

To measure academic achievement, we use California's Standardized Testing and Reporting (STAR) test data. The STAR test is administered to all students in grades 2 through 11 each spring, toward the end of the academic year. The publicly available test scores are aggregated at the grade-by-school level. We use test score data from 2009 through 2013. Beginning with the 2013-14 school year, STAR testing was replaced with the California Assessment of Student Performance and Progress test.

[8] Fast-food items include chicken nuggets, pizza or pizza pockets, hamburgers, fried chicken, nachos, hot dogs, and corn dogs. "Empty calories" are those that come from solid fats, alcohol, and added sugars.

The STAR test includes four core subject area tests (English/Language Arts, Mathematics, History/Social Sciences, and Science) and a set of end-of-course examinations (e.g., Algebra II, Biology). We create a composite test score each year for each school-grade by calculating the average test score across all of the STAR subjects and the end-of-course tests taken by students in a particular grade in each school. We use the standard deviation of each test (which differs by grade and year of test) to standardize each subject and end-of-course test score before combining the scores into a single composite score.[9] Estimates for individual subjects are qualitatively similar to those for the composite score.

Average test scores are also available separately for students who qualify for reduced price and/or free school lunch under the NSLP. A student is eligible for a free school lunch if his family's income is less than 130% of the poverty level, and a reduced price lunch if her family's income is between 130% and 185% of the poverty level.[10] The CA Department of Education refers to these students, as well as students with parents who do not have high school diplomas, as "economically disadvantaged" (California Department of Education 2011, p. 48). Students eligible for the reduced price or free lunches are more likely to eat the lunch offered at the school, for two reasons: the price is lower for them than it is for ineligible students, and eligible students are less likely to have other lunch options. Furthermore, the nutritional quality of their home-provided meals may be lower than that of the average student. Thus, we hypothesize that the academic benefit of having healthier school lunches may be larger for these students.

Finally, district-level demographic and socioeconomic information is available from the

[9]This procedure overstates the standard deviation of the composite score because it implicitly assumes perfect correlation between subject scores at the student level. Our estimates thus represent a lower bound on the true effects when expressed in standard deviation units. California does not publish covariances between different subject scores, so we cannot compute the exact standard deviation of the composite score. Back-of-the-envelope calculations, however, suggest that this issue does not seriously impact our estimates. For example, if the within-student correlation between different subject-specific scores is at least 0.8, then we overstate the standard deviation of the overall index by less than 10%.

[10]Note that eligibility does not imply participation. Dahl and Scholz [2011] estimate that 28% to 49% of eligible children participate in free or reduced-price school breakfasts, and 63% to 73% of eligible children participate in free or reduced-price school lunches. Even estimates for disadvantaged children thus represent "intent to treat" effects rather than full treatment effects.

California Department of Education, including enrollment by race, enrollment in English learner programs (i.e., English as a second language), and the number of enrolled students who are economically disadvantaged, as defined by eligibility for free or reduced price lunches. We use this information to control for time-varying differences within schools in our main econometric model.

3 Empirical Specification

Our main empirical specification is a panel regression model.

$$y_{gst} = \beta_0 + \delta_H Healthy_{st} + \delta_S Standard_{st} + X_{st}\beta + \lambda_{gs} + \gamma_t + \epsilon_{gst} \quad (1)$$

The dependent variable y_{gst} is the mean STAR test score across all tests for grade g in school s in year t. The dependent variable is measured in STAR test standard deviation units.

Our independent variables of interest are indicators for whether a student test-taker is exposed to a standard or healthy outside meal provider. Recall that a provider is classified as healthy if its HEI score is above the median score among providers. The variable $Healthy_{st}$ equals one if school s contracts with a healthy outside meal provider in year t and zero otherwise. The variable $Standard_{st}$ equals one if school s contracts with a standard outside meal provider in year t and zero otherwise. The "omitted" category for our treatment indicators corresponds to the case in which the school does not contract with an outside meal provider. In this case the school's employees (i.e., cafeteria workers) both prepare and serve the meals.

The coefficients on the $Healthy_{st}$ and $Standard_{st}$ indicators represent "intent-to-treat" (ITT) effects. Not all students eat school-provided meals; some students bring lunch from home, eat lunch off campus, or skip lunch altogether. In Section 5.3 we provide school district-level evidence on the number of meals served per student. These figures suggest that the "effect of the treatment on the treated" (TOT) is approximately twice as large as the

ITT effect that we estimate.

The model includes school-by-grade (λ_{gs}) and year (γ_t) fixed effects. The school-by-grade fixed effects control for any characteristics in a given grade and school that are stable throughout the five-year estimation period (e.g., school catchment area characteristics, school infrastructure, STAR test differences by grade, or school staffing levels and leadership). Year fixed effects control for common state-wide factors such as state economic conditions and differences in the STAR test that vary by year throughout the panel. All specifications also include an indicator for contracting with a meal vendor of unknown HEI quality, $Unscored_{st}$. This category accounts for 13% of vendors on a test-taker weighted basis. In our regressions the coefficient on $Unscored_{st}$ lies, as we would expect, between the coefficients on $Healthy_{st}$ and $Standard_{st}$ and sometimes achieves statistical significance. However, we cannot interpret the coefficient since we do not know the fraction of unscored vendors that are healthy, so we treat it as an additional control.

Most specifications of the model also include X_{st}, a vector of district-level control variables that vary over time. These control variables include the racial composition of students in the district to which school s belongs, the proportion of students in English learner programs, and the proportion of economically disadvantaged students. Because the decision to contract with a meal vendor (whether healthy or standard) almost always occurs at the district level, as opposed to the individual school level, it is sufficient to control for district-level covariates that may be correlated with this decision.[11]

Contracts typically cover all schools in a district, so we estimate Equation (1) with standard errors clustered at the school-district level. Our preferred specification uses the number of test-takers for each grade-school-year observation as weights in the regression. Weighting by the number of test-takers allows us to recover the relationship between the type of school meal served and academic performance as measured by the STAR test for the

[11] We also experimented with controlling for similar school-level covariates that we constructed directly from the STAR data. Controlling for these covariates at the school level has little impact on the coefficient estimates, but it results in many dropped observations because of frequent missing demographic information in the STAR data.

average student, rather than the average school. Our conclusions are not sensitive to the use of weights, however.

The identifying assumption is that, after controlling for time-invariant school-by-grade factors, common state factors, and the vector of time-varying, school-level characteristics, a school's decision to contract with an outside vendor for school meal provision is uncorrelated with other school-specific, time-varying factors that affect student test performance. If this is true, then we can interpret the estimate for δ_H (and δ_S) as the causal effect of contracting with a healthy (or standard) school meal provider on student learning, as measured by performance on the STAR test.

4 Results

4.1 Vendor Choice and Test-Taker Characteristics

Appendix Table A2 shows mean test-taker socioeconomic and racial characteristics for school districts in two different samples: the *All School* sample and the *Contract School* sample. The All School sample includes all school districts in the state of California. The Contract School sample is limited to the subset of districts that had a school meal vendor contract for at least one year in our five-year panel. The means for each test-taker characteristic are calculated by first taking the five-year (2009-2013) district-level mean. In the All School sample, the average district mean is then calculated separately for districts that contract with a vendor (Column 1) and do not contract with a vendor (Column 2) during our panel (2009-2013). Column (3) calculates the difference in means and reports the standard error for this difference (in parentheses). The means are statistically different from each other at the 5% level for five of the six characteristics. For example, districts that contract with a vendor during our sample period tend to have fewer economically disadvantaged students and a higher proportion of Asian students.

Appendix Table A2 also shows that, even among districts that contracted with a vendor at some time, those districts that contracted with a healthy vendor have different student characteristics (on average) than those districts that contracted with a standard vendor. These differences in test-taker characteristics in the two samples affect the generalizability of any association between test scores and vendor quality. Nevertheless, the differences in average characteristics between test-takers do not violate the identifying assumptions of Equation (1), which we analyze in Section 4.3.

4.2 Vendor Choice and Test Scores

Table 1 reports estimation results for the effect of vendor quality on STAR scores. The first three columns estimate versions of Equation (1) on the All School sample, while the last three columns use the Contract School sample. Column (1) estimates the effect of contracting with a standard or healthy meal vendor on test scores and includes school and year fixed effects as controls. Column (2) adds school-by-grade fixed effects, while Column (3) adds the vector of student test-taker characteristics. The point estimate of the effect of having a healthy vendor on test scores, relative to no outside vendor, is 0.031 standard deviations and is significant at the 1% level or better in each of the three specifications. The similarity of the point estimates as we add student characteristics suggests that observable trends do not differ with vendor adoption, which we confirm in Section 4.3. The standard vendor coefficient is an order of magnitude smaller and not statistically different from zero in any specification, and we can reject the null hypothesis that the coefficients for the healthy and standard vendors are equal at the 10% level for each specification.

The Contract School sample relies solely on differences in the timing of vendor adoption, among schools that adopt a vendor at some point, for identification. Healthy vendor coefficients in the Contract School sample are all statistically significant at the 0.1% level and are similar in magnitude to those estimated with the All School sample, ranging from 0.033 to 0.037. The estimates for the standard vendor are again an order of magnitude smaller and not statistically significant.[12]

Table 2 investigates whether the effect of contracting with a meal provider on STAR scores is different for economically disadvantaged and economically advantaged students. Recall that economically disadvantaged students are defined by the CA Department of Education as those students who qualify for reduced price and/or free school lunch under the NSLP based on family income. We expect that disadvantaged students would be more likely to eat a school meal than their classmates who do not qualify for reduced price or free school meal. Thus, we hypothesize that the effect on test scores of healthy school meal vendors should be somewhat greater for disadvantaged students than for students who do not qualify for reduced price or free school lunch. Table 2 shows evidence consistent with this hypothesis.

Table 2 again considers both the All School and Contract School samples, but limits the samples to those schools which report separate average STAR scores for both economically advantaged and economically disadvantaged students.[13] Column (1) of Table 2 estimates the effect of contracting with a meal vendor on the average test score for economically disadvantaged students. Column (2) estimates the effect on the average test scores for economically advantaged students, while Column (3) estimates the effect for all students. The point estimates for contracting with a healthy vendor are about 40 to 50% larger for the disadvantaged students in both samples. In the All School sample the estimated coefficients are 0.035 and 0.025 respectively, while in the Contract School sample they are 0.046 and 0.030 respectively. There is again no evidence that a standard vendor has a statistically significant effect on test scores relative to having meals completely prepared by school staff.

Appendix Table A4 estimates separate effects for different academic subjects. Test groups include Core tests (English, math, US history, cumulative history, and life science), En-

[12]Our results are also qualitatively similar if we estimate Equation (1) without using student enrollment weights. Appendix Table A3 presents these results. The point estimate for those vendors with an unknown HEI score (not shown in table) are positive, range between 0.01 and 0.02 standard deviations, and are statistically significant in some specifications. This is not surprising as we expect these vendors to be a mix of standard and healthy vendors.

[13]Due to privacy restrictions, the CA Department of Education releases the average test score (for a school-grade-year-subgroup) only if there are at least 10 students of the particular socioeconomic group who take the test. There is a 40% reduction in the size of the sample due to these sample restrictions.

glish/Language Arts, humanities/social science, science/technology/engineering/math (STEM), and math. The table reveals that the effects of healthy vendors are somewhat larger for STEM and math tests (0.032 to 0.035 standard deviations) than for English/Language Arts, humanities, or social science tests (0.026 standard deviations). All healthy vendor coefficients are statistically significant, but the estimates are not sufficiently precise to reject the hypothesis that effects on different test subjects are of identical magnitude.[14] Nevertheless, the pattern of larger effects for math than English/Language Arts is consistent with other recent studies that separately measure the effect of access to school breakfast on test scores in different subjects (Dotter 2014; Imberman and Kugler 2014).

4.3 Specification Tests

In this section, we probe the validity of our identifying assumption that a district's decision to contract with an outside vendor for school meal provision is uncorrelated with other school-specific, time-varying factors that affect student test performance. We begin by testing whether test scores change prior to vendor adoption and following the cancellation of a vendor contract. We then test for whether there are confounding changes to observable student body, school quality, and school district management factors that correlate with the decision to contract with a vendor.

First, we conduct a placebo test in which we incorrectly code the year before and after a vendor contract as a contract year (Currie et al. 2010). We define a *healthy (standard) pre-contract placebo* variable and a *healthy (standard) post-contract placebo* variable as equal to one if the school contracts with a healthy (standard) vendor in the following year, or in the previous year, respectively. The estimated coefficients for the healthy and standard vendor pre-contract and post-contract placebos are close to zero and not statistically significant after

[14] Treatment effects could also vary by grade. To explore this possibility we estimate our preferred specification separately for elementary school (grades 2–5), middle school (grades 6–8), and high school children (grades 9–11). We find average effect sizes of 0.028 standard deviations for elementary school children, 0.038 standard deviations for middle school children, and 0.032 standard deviations for high school children. These differences are not statistically significant, however, and the estimates are too imprecise to rule out large proportionate differences between effects at different grade levels.

controlling for the actual vendor years. There is no evidence that test scores begin to rise in the year before a school contracts with a vendor. Further, higher test scores for students at schools that contract with healthy vendors do not persist once the contract ends.[15]

We also consider an event-study style placebo model that estimates test score changes in the years leading up to a contract start date and the years following a contract end date. Estimates from the event-study model support the placebo test results described above: (1) achievement, as measured by test scores, is not changing differentially in the years prior to the contract start date, and (2) there is no sign that test score changes persist beyond the length of the contract. Appendix A3 contains details.

To further test for violations of our identifying assumptions we estimate versions of Equation (1) with a variety of observable characteristics as dependent variables. Table 3 explores how changes in the district-level characteristics correlate with the timing of a vendor contract. In Columns (1) through (5), we use test-taker characteristics as the dependent variable in place of test scores, while in Column (6) we use the fitted values from a regression of test scores on all five test-taker characteristics (and year and school-by-grade fixed effects) as the dependent variable. These fitted values summarize all of the test-taker characteristics, weighting each characteristic in relation to its correlation with test scores. In Columns (7), (8), and (9) we use district expenditures, an indicator of superintendent turnover, and the share of students that are in charter schools as dependent variables respectively.[16] All regressions in Tables 3 and 4 include school-by-grade fixed effects and thus test whether

[15]The estimated coefficients for the pre-contract healthy and standard placebos are 0.010 and 0.012. The estimated coefficients for the post-contract healthy and standard placebos are: 0.001 and -0.000. This specification also includes unknown vendor placebos.

[16]The analyses in the last three columns require additional data sources. The expenditure data come from the CA Department of Education. We convert expenditures to thousands of dollars (2013 $) per average daily student attendance. The superintendent turnover indicator equals unity in years when there is a new superintendent. To construct this measure we contacted each CA school district in our sample by email and phone between May and July 2017 and inquired whether there was a change of superintendent during our panel period. We successfully obtained information from 55% of the districts in our sample, and among these districts 59% had at least one change of superintendent during our panel. The charter school and population data come from the CA Department of Education. 306 districts include at least one charter school during our panel, and the average annual share of students enrolled in a charter school for a district during this time period is 7%.

within-school-by-grade changes in student characteristics correlate with the time at which a school adopted an outside meal provider.

Panel A of Table 3 estimates models using the All School sample, while Panel B uses the Contract School sample. The point estimates are small in magnitude, relative to dependent variable means, and precisely estimated. The estimate in Column (6) of Panel A reveals that adoption of a healthy vendor correlates with a statistically insignificant 0.005 standard deviation increase in predicted test scores. None of the estimated healthy vendor coefficients are statistically significant at conventional levels.

The estimates for adoption of a standard vendor are also small and generally statistically insignificant. The only exception occurs with the district expenditure variable, which is negative and statistically significant at the 5% level for standard vendors in the All School sample. The presence of a single significant result is not surprising given the 36 coefficient estimates in Table 3 (and another 36 in Table 4), and the statistical significance disappears in the Contract School sample.

Table 4 tests whether changes in school-level characteristics correlate with the timing of a vendor contract. In Columns (1) through (6), we use teacher characteristics, available from the CA Department of Education, as the dependent variable in place of test scores. These characteristics include the share of teachers that are female, Hispanic, black, white, college educated, and have a post-graduate degree. In Columns (7), (8), and (9) we use teacher tenure, school enrollment, and the student-teacher ratio as dependent variables respectively.

Panel A of Table 4 estimates models using the All School sample, while Panel B uses the Contract School sample. As in Table 3, the point estimates are small in magnitude and precisely estimated. We can rule out a positive coefficient on teacher tenure above 0.3 years (2% of the sample mean), for example, or a positive coefficient on the student-teacher ratio above 0.5 students per teacher (2% of the sample mean). None of the estimated healthy or standard vendor coefficients are statistically significant at conventional levels.

Overall, there is no evidence that changes in observable student body, school quality, and school district management factors correlate with the decision to contract with a meal vendor. The results in Tables 3 and 4 support our identifying assumption that a school's decision to contract with an outside vendor for school meal provision is uncorrelated with other time-varying factors that affect student test performance.

4.4 Robustness

In addition to testing for violations of our identifying assumptions, we explore the robustness of our results to alternative regression specifications. Table 5 presents the estimation results of five additional regression specifications. All five specifications can be interpreted relative to our baseline model in Table 1, Column (3). Column (1) presents results for a regression that estimates separate effects for vendors whose contracts run for the full academic year and those that end earlier. Students take STAR tests in April, and while most vendor contracts run though June, a small number end between November and February. If test scores increase solely because students have access to better food on test days, then we should expect no effect for contracts that end before the test date. The results in Column (1), however, reveal large and statistically significant effects for vendors whose contracts end several months before the test date. The coefficient for these contracts is larger than the coefficient for other healthy vendor contracts, but the difference is not statistically significant. These result suggest that healthy vendors may improve learning rather than simply improving performance on test days.

Columns (2) and (3) of Table 5 alter how we define a healthy vendor. Column (2) uses a second, slightly different, scoring method where the HEI score is supplemented by awarding additional points for healthy options that exceeded USDA requirements (e.g., salad bars) and subtracting points for unhealthy options (e.g., fast foods, certain processed foods, and high-sugar foods). The definition of a healthy vendor remains the same — one that receives a score above the median. The coefficient estimates for both the healthy and standard vendors are similar to those in the baseline model.

Column (3) uses the same HEI scores as the baseline model, but considers the scores as a continuous variable. Specifically, the model is adjusted to include an indicator variable for having a vendor with a known HEI score (rather than separate healthy and standard indicators) and an HEI score variable (divided by 100). The HEI score variable is zero if the school does not contract with a vendor that has a known HEI score, and we recenter the HEI score so that zero corresponds to the average HEI score for a standard vendor in our sample (56.0). With this recentering we may interpret the indicator for a vendor having a known HEI score as the average effect of a standard vendor. The estimated coefficient for the HEI score variable is positive and statistically significant. The difference in average HEI scores between healthy and standard vendors is 17.5, so the point estimate implies that a healthy vendor increases test scores by approximately 0.027 standard deviations relative to no vendor, or 0.022 standard deviations relative to a standard vendor. The highest and lowest rated vendors by HEI score are Revolution Foods (92.3) and Kid Chow (26.8). The model implies that the effects of contracting with each vendor on test scores are 0.050 and –0.032, respectively. Estimating nonlinear effects using a third-order polynomial in HEI does not reveal strong evidence of nonlinearity (Appendix Figure A4).

Column (4) reports a specification in which we aggregate the data to the district-by-year level, since the variation in vendor quality occurs almost exclusively at the district level. The estimated marginal effect of a healthy vendor on test scores is similar to that from our baseline specification.[17]

Column (5) considers the sub-sample of schools from the Contract Sample that ever contracted with a standard vendor. As in the contract sample, this sample excludes schools that never had an outside vendor and further restricts the sample by excluding schools whose only outside vendors have been categorized as healthy (or unknown quality). Notably, the healthy vendor coefficient is estimated on a smaller sample of schools, only a fraction of

[17]Note that the healthy and standard vendor variables are weighted averages of the school-by-grade level exposure to the vendors in each year and thus take on values between 0 and 1. The average value for the healthy vendor variable (conditional on having at least one school in the district that contracted with a healthy vendor for the year) is 0.95

which ever contract with both a standard and a healthy vendor. Nevertheless, the point estimate, while not statistically significant, is very similar to the estimate from the larger All School and Contract School samples. The similarity in the coefficient estimates across the different samples provides further evidence that our results are not driven by differential trends in test scores among the schools that contract with a healthy vendor.

5 Potential Mechanisms

We find that offering healthier school meals, as measured by the HEI score, leads to higher academic test scores. To understand the mechanisms that may underlie this result we conducted a review of the medical and nutrition literature on the subject using the PubMed database.[18] The goal of this search is to provide greater context for our findings and understand potential underlying health mechanisms that could drive the observed improvements in test scores.

The literature linking nutrition and cognition divides into three approaches. First, there are studies that examine how overall diet affects cognition. The most widely cited diet in our search is the "Mediterranean diet" (Parletta et al. 2013; Kuczmarski et al. 2014; Morley 2014; Hardman et al. 2016; Masana et al. 2017). The Mediterranean diet consists of plant-based foods (fruits, vegetables, whole grains, nuts), olive oil, seafood, and herbs and spices for flavoring, with limited consumption of red meat, salt, butter, and processed food. A MeDi scoring system, similar to the HEI, has been constructed to measure how well individual diets adhere to the Mediterranean diet. Most studies of the Mediterranean diet do not attempt to link a particular nutrient or food to cognitive function. Instead, the level of analysis is the entire diet (e.g. MeDi score). The typical study calculates a MeDi score

[18] PubMed is "maintained by the National Center for Biotechnology Information (NCBI), at the US National Library of Medicine (NLM), located at the National Institutes of Health (NIH)" (https://www.ncbi.nlm.nih.gov/pubmed) and includes over 28 million citations for the biomedical literature. We limited the search to review articles published in the previous five years, and conducted separate searches for "food and cognition" (442 articles), "diet and cognition" (211 articles), "nutrients, cognition, and children" (65 articles), "healthy eating index" (42 articles), "vegetables and cognition" (24 articles), and "sugar consumption and children" (6 articles).

and administers a cognitive test to each person in the study's sample. A number of studies have reported an association between adherence to the Mediterranean diet and improved cognition. There is also evidence that individuals with diets characterized by a higher HEI score have higher cognitive function (e.g. Cheung et al. 2014; Kuczmarski et al. 2014; van de Rest et al. 2015). However, there are fewer HEI-based studies, and results are more mixed than those on the Mediterranean diet.

A second segment of the literature focuses on the effect of obesity on cognition (e.g. Lakhan and Kirchgessner 2013; Khan et al. 2014; Liang et al. 2014; Martin et al. 2014; Grandone et al. 2015). For example, Liang et al. [2014] examines 67 studies and concludes that obesity and cognition are negatively correlated. As with the diet-level analyses, studies of obesity are often less-focused on the underlying mechanisms that could affect cognition. Hypothesized mechanisms include structural changes to the brain between obese and healthy weight individuals as measured through imaging tests (Stanek et al. 2011). To the extent that higher HEI diets lead to a healthier weight, then a reduction in obesity may itself be a channel that impacts cognitive function.

The third segment of the literature examines how particular foods or compounds impact cognition. Appendix Table A5 broadly summarizes the most common foods and compounds discussed in the literature. We divide the studies into five categories: fruits and vegetables; vitamins and omega-3 fatty acids; refined carbohydrates; refined sugars; and saturated fat/high-fat diet. All of the food and compound categories enter the HEI score directly (Column (2)), except for saturated fat/high-fat diet. This category nevertheless has an indirect effect on the HEI score, provided the consumption of foods high in saturated fat crowds out other types of foods. Our review of the link between nutrition and cognition in the literature (Column (3)) supports the HEI scoring. Column (4) lists some of the commonly hypothesized biological mechanisms responsible for the correlation between the food or compounds in each group and cognition. For example, there is evidence that consumption of refined carbohydrates leads to impairments in frontal, limbic, and hippocampal systems, which in turn lead to poorer cognitive function.

In summation, the literature review supports our use of the HEI measure and suggests a variety of potential pathways between diet and cognition. While our data do not allow us to test specific biological pathways, we can examine some potential mechanisms, such as changes in obesity, attendance, or total meal consumption.

5.1 Obesity

One possible mechanism for improved cognition, as revealed in our literature review, is a change in obesity rates among students at schools serving healthier meals. A primary goal of the HHFKA is to improve the health of school-age children via a reduction in obesity (USDA 2013), and previous research has shown that the source of a student's school meal can affect obesity rates. Schanzenbach [2009], for example, provides evidence that public school lunches have contributed to increases in childhood obesity rates. Students who are more likely to consume public school lunches, rather than other options such as bringing a brown-bag lunch, gain more weight. Currie et al. [2010] estimate that less than one academic year of exposure to fast-food restaurants near schools increases obesity rates for 9th grade students by about 5%. Currie et al. [2010] and Cutler et al. [2003] both emphasize that large increases in obesity rates could occur from as few as 100 excess calories per day.

We use the same source of physical fitness information as Currie et al. [2010] to test whether exposure to healthier school meal options decreases student obesity. The Physical Fitness Test (PFT), also called FitnessGram®, is given to students in grades 5, 7, and 9 each spring in California. Six fitness areas compose the PFT, one of which is body composition. Schools have the option to complete the body composition portion using one of three measures: Body Mass Index (BMI), skin fold measurements, or bioelectric impedance analyzer. For each of these measurements, there is a defined "healthy zone" that varies by age and gender. The data are aggregated by school and grade level and indicate the percentage of students who have a body composition measurement in the healthy fitness zone. Following

Currie et al. [2010], we define overweight as the percentage of students falling outside the healthy zone.

We do not find any evidence that contracting with a healthy meal provider reduces the percentage of overweight students. We estimate Equation (1), except that we use the percentage of students who are outside the healthy fitness zone (whom we label as "overweight") as the dependent variable and restrict the sample to grades 5, 7, and 9.[19] Columns (1) and (2) of Table 6 show estimation results for all students and economically disadvantaged students, respectively. On average, 38.6% of the students (41.7% of disadvantaged students) in our sample are overweight. All four point estimates in Columns (1) and (2) are small and statistically insignificant. However, a lack of precision prohibits us from excluding an effect size as large as that found by Currie et al. [2010] (5.2%) for all but one of the coefficient estimates (All Students, Healthy Vendor). One explanation for why we find no effect on the percent of overweight students is that both standard and healthy meal providers faced the same USDA calorie requirements, even prior to the HHFKA (USDA 2012b). Fast-food restaurants, in comparison, face no constraints on calories.

5.2 Attendance

Another possible mechanism through which healthy meals might increase student achievement is via attendance. If a healthier diet promotes wellness, students may be absent less often. To test this hypothesis we collected attendance data at the district-year level and regressed attendance rates on vendor quality indicators and district and year fixed effects. These regressions yield statistically insignificant healthy meal vendor coefficients on the order of –0.1 percentage points, and the estimates are sufficiently precise to rule out attendance effects above 0.8 percentage points, relative to an average attendance rate of approximately 90%. It thus appears unlikely that increased attendance is a primary mechanism underlying our results. This finding is consistent with results in previous studies of school breakfast

[19] The Contract School sample for this regression includes 4,006 grade-year observations at 910 schools.

and lunch programs, which have generally found statistically or economically insignificant effects of meal programs on attendance (Leos-Urbel et al. 2013; Imberman and Kugler 2014; Schanzenbach and Zaki 2014; Frisvold 2015).

5.3 Number of Meals Served

In addition to changing the nutrient content of meals, contracting with healthy vendors could change the total number of meals served. One criticism of school nutrition standards is that improving the health content of meals may have the unintended consequence of reducing the number of students eating school meals (Confessore 2014), possibly because of students' tastes. A decrease in the number of meals served to students eligible for reduced price or free lunches would be concerning because these students are considered most at risk for undernourishment and are a target population of the NSLP.

In order to estimate the impact of vendor quality on the number of meals served in a district, we obtained NSLP data from the California Department of Education's Nutrition Services Division for the school years 2008-09 through 2012-13. The data report the average number of total NSLP lunches and the average number of free, reduced-price, and paid lunches served per operating day in each school district for each month. We use the monthly averages to calculate a single operating day average for the total number of lunches served and the number of free or reduced-price lunches served over the course of the academic year.[20]

Columns (3) and (4) of Table 6 report the impact of contracting with healthy and standard vendors on the number of daily lunches served per student. Column (3) estimates the effects on total lunches, while Column (4) estimates the effects on reduced price and/or free lunches. These regressions are run with observations at the level of district-year, rather than school-grade-year, because data on lunch purchases are only available aggregated at the district level. This constraint imposes minimal cost, however, because the treatment generally

[20] We provide details of this calculation in Appendix A2.

varies at the district-year level. The dependent variable is the number of daily lunches sold per student (in Column (4), we consider the number of reduced price and/or free lunches per economically disadvantaged student). We do not find a significant effect of contracting with a healthy or standard vendor on the total number of lunches or the number of free and reduced price lunches. For example, the estimated coefficients for contracting with a healthy or a standard vendor in Column (3) are of a similar magnitude and imply a statistically insignificant reduction in the number of school lunches of approximately 10% (the sample mean of the dependent variable is 0.45).

The fact that disadvantaged students do not purchase more school lunches when the school contracts with a vendor supports the interpretation that the observed increase in test scores is due to the quality and not the quantity of school meals consumed. At the same time, these findings help allay concerns that healthier meals may actually lead to a reduction in the number of meals served to students and are consistent with recent evidence in Johnson et al. [2016] that the Healthy Hunger-Free Kids Act increased nutritional quality without affecting student meal participation rates. Nevertheless, since we cannot observe the fraction of each meal consumed, it is impossible to measure the exact change, if any, in total caloric intake.

The data on number of lunches served allow us to form a rough estimate of the effect of a school meal on performance, or the effect of the treatment on the treated. If we view the treatment as exposure to a meal, rather than exposure to a vendor, the estimates in Tables 1 through 5 represent ITT effects since a significant fraction of students do not eat school meals. Column (3) of Table 6 reveals that, on average, schools serve 0.45 lunches per test taker.[21] Since vendors do not affect lunches sold, this figure suggests that the TOT estimate is approximately $1/0.45 = 2.2$ times the ITT estimate. The meals sold data are

[21] This approximation should be reasonably accurate as long as there are not many students that eat school breakfast but bring their own lunches. This group seems likely to be small because lunch participation rates are much higher than breakfast participation rates; Dahl and Scholz [2011] estimate that the number of lunches delivered was 2.24 times greater than the number of breakfasts delivered in the most recent year in their data (2002-2003).

at the district level. Using a district-level regression result (Column (5) of Table 5) we find an ITT effect of 0.037 that translates to a TOT effect of 0.082. This effect is statistically significant at the $p < 0.01$ level.

6 Policy Implications

Public school administrators interested in improving the level of student learning and increasing test scores face decisions on how best to budget limited school resources. There are many potential changes in school policy that could improve learning. For example, school administrators could hire more teachers to decrease average classroom size (Krueger 1999), lengthen the school day (Patall et al. 2010), increase teacher training (Angrist and Lavy 2001), give bonus pay to teachers based on student test scores (Fryer 2011), or increase student access to free or reduced price breakfast and lunch (Imberman and Kugler 2014).[22]

Policies that direct resources toward teachers have been found to have a relatively large impact on student test scores in some settings. The Tennessee STAR experiment, which reduced average class size for primary school students by one-third and led to a 0.22 standard deviation test score increase, is a frequently cited benchmark. Nevertheless, these types of policies are often expensive and can be controversial (e.g., incentive pay). The Tennessee STAR experiment cost approximately $25 million (2013 $), with an implied cost of $3,009 (2013 $) per student placed in a smaller class.[23] Jacob and Rockoff [2011] highlight both the need and opportunity for cost-effective policies; lower-cost policies with modest effects on student test scores may generate a better return than costly policies with larger absolute effects.

We take advantage of contract-specific winner and loser bid information submitted to the CA Department of Education to calculate the cost of contracting with healthy meal providers. The average price per lunch in healthy meal vendor contracts is $2.59. Two comparisons

[22] This list highlights only a handful of policies and is not meant to be exhaustive.

[23] The original cost estimates reported by Krueger [1999] are adjusted to 2013 $ using the Consumer Price Index (CPI).

suggest that healthy vendor pricing is competitive with other alternatives. First, in seven contracts that appear in our data involving 18 bidders, both healthy and standard vendors bid on the same contract. A regression of log price per test taker on a healthy vendor indicator and contract fixed effects reveals that healthy vendors bid 19.9% less than other vendors in these cases, and we can reject the hypothesis that healthy vendors cost at least 6.6% more than other vendors at the 95% confidence level.[24] Second, the contract lunch price of $2.59 is close to the National School Lunch Program reimbursement rate of $2.93 per free lunch, suggesting that healthy school meal vendors do not cost dramatically more than in-house preparation.

To compute a plausible upper bound on the cost of increasing test scores via healthy school meal vendors, we assume that healthy school meal vendors cost 25% more than in-house preparation. This assumption implies that the average school makes a net profit of 30% on its school meal operations when reimbursed by the NSLP. A profit margin of this size or larger is unlikely because the NSLP specifically forbids the use of these revenues to fund non-food service operations (GPO, 7 CFR, Section 210.14(a)).

The average healthy vendor meal contract is $426 (2013 $) per test-taker per school year. Over the 180-day academic year, a healthy school meal contract costs about $2.37 per test-taker day (this figure is different than the $2.59 meal cost because not every test taker eats a school meal, and some test takers eat both breakfast and lunch). We assume that the contract is 25% more expensive than in-house meal preparation, implying a difference of $85 per test-taker per school year. To compare cost effectiveness we consider the dollar cost per 0.1 standard deviations of test score gains. This normalization does not imply that we can achieve a full 0.1 standard deviation increase with any given policy, including healthy vendor contracts (though the TOT estimate in Section 5.3 is close to 0.1). Rather, we recognize that policymakers have a menu of policies available for increasing test scores, and an optimizing

[24]This regression compares healthy vendors to all other vendors, including those with unknown quality. Limiting the comparison to known standard vendors, however, generates similar results, with a cost difference of −21.8% and a 95% confidence interval that reaches 12.5%.

policymaker will choose the combination of policies that yields a 0.1 standard deviation test score increase at the lowest possible cost.

Using a cost difference of $85 per test-taker per school year and an estimated effect of 0.031 standard deviations (Column (3) of Table 1), we find that it would cost about $274 per year to raise a student's test score by 0.1 standard deviations through switching from in-house preparation to a healthy meal provider. In contrast, it cost $1,368 per year to raise a student's test score by 0.1 standard deviations in the Tennessee STAR experiment. As additional context we consider recent estimates of the effects of changes in school spending. Lafortune et al. [2018] and Kirabo Jackson et al. [2018] estimate that spending changes of $556 and $1,713 (2013 $) per student-year respectively generate 0.1 standard deviation changes in test scores.[25] Thus, even an upper bound on the cost of raising test scores by 0.1 standard deviations through healthy meals is several times lower than a variety of benchmark estimates.

7 Conclusion

We exploit variation in the nutritional quality of school meals resulting from changes in meal providers to estimate the effect of nutritional quality on the academic performance of primary and secondary school students across the state of California. Using difference-in-differences type specifications, we find that switching to a healthy meal vendor is associated with a 0.031 standard deviation increase in test scores. While this effect is modest in magnitude, the relatively low cost of healthy vendors when compared to in-house meal preparation makes this a very cost-effective way to raise test scores.

We conduct a variety of robustness checks, including placebo tests and an event-study specification, to provide evidence that the timing of changes in meal providers is uncorrelated

[25] Lafortune et al. [2018] find that a $1,000 change in spending impacts test scores by 0.12 to 0.24 standard deviations. At the midpoint of 0.18 standard deviations, this result implies a cost of $556 per 0.1 standard deviations. Kirabo Jackson et al. [2018] find that a $1,336 change in spending impacts test scores by 0.078 standard deviations, or $1,713 per 0.1 standard deviations.

with omitted variables that could be driving changes in test scores. There is also no evidence that the introduction of healthier school meals led to a change in the number of school meals consumed. This supports our view that the observed relationship between healthier school meals and test scores is due to the nutritional quality of the meals rather than the quantity of calories consumed. An analysis of the effects of healthy meal vendors on the percentage of students who are overweight finds no effect, but it is possible that these effects could materialize on a longer time horizon.

With the implementation of the HHFKA in 2012, the baseline level of nutritional quality may have increased since our study period. It is thus possible that employing healthy meal vendors has less impact today than it did prior to 2012. Nevertheless, our results highlight the beneficial effects of meal quality on achievement and are relevant to the current debate over school meal nutrition standards.

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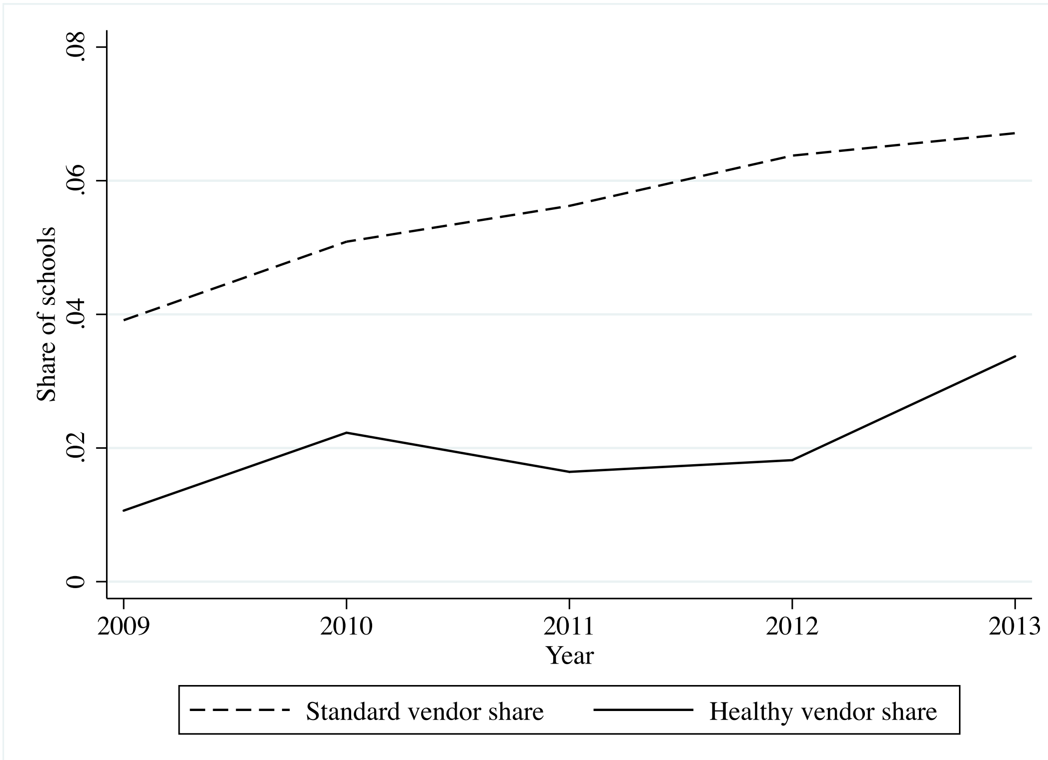
9 Figures and Tables

Figure 1: Standard and Healthy Vendor Marketshare



Notes: This figure depicts the percentage of schools with standard or healthy meal vendor contracts over time.

Table 1: The Effect of Vendor Choice on Standardized Test Scores

Dependent variable:	Standardized Test Score					
Sample:	All Schools			Contract Schools		
	(1)	(2)	(3)	(4)	(5)	(6)
Healthy Vendor	0.031***	0.031**	0.031**	0.036***	0.037***	0.033***
	(0.009)	(0.010)	(0.010)	(0.008)	(0.010)	(0.009)
Standard Vendor	-0.004	-0.005	-0.004	0.008	0.007	0.008
	(0.017)	(0.019)	(0.019)	(0.017)	(0.019)	(0.019)
School-by-grade FEs		X	X		X	X
Covariates included			X			X
R^2	0.714	0.930	0.930	0.700	0.922	0.922
N	174,818	174,818	174,818	22,133	22,133	22,133
Schools	9,719	9,719	9,719	1,188	1,188	1,188
Districts	908	908	908	143	143	143

Notes: Each column represents a separate weighted regression with weights equal to the number of test takers per observation. All regressions are estimated on a common sample that excludes observations with missing covariates. Observations are at the school-grade-year level. Standard errors clustered at the school district level appear in parentheses. All regressions include year fixed effects and school fixed effects (unless school-by-grade fixed effects are specified). The contract school sample is the subset of schools that contract with a vendor at some point during our sample. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: The Effect of Vendor Choice on Standardized Test Scores by Socioeconomic Status

Dependent variable:	Standardized Test Score					
Sample:	All Schools			Contract Schools		
	(1)	(2)	(3)	(4)	(5)	(6)
Subgroup:	Disadvantaged	Advantaged	All	Disadvantaged	Advantaged	All
Healthy Vendor	0.034*	0.025	0.028*	0.046**	0.030*	0.035**
	(0.014)	(0.015)	(0.014)	(0.017)	(0.014)	(0.012)
Standard Vendor	0.004	-0.007	0.000	0.020	0.009	0.016
	(0.018)	(0.025)	(0.020)	(0.021)	(0.027)	(0.022)
R^2	0.897	0.906	0.928	0.880	0.902	0.919
N	103,432	103,432	103,432	13,259	13,259	13,259
Schools	7,607	7,607	7,607	940	940	940
Districts	799	799	799	125	125	125

Notes: Each column represents a separate weighted regression with weights equal to the number of test takers in the subgroup indicated by the column name. All regressions are estimated on a common sample that excludes observations with missing test score data for any of the indciated subgroups. Observations are at the school-grade-year level. Standard errors clustered at the school district level appear in parentheses. All regressions include year and school-by-grade fixed effects and district-level demographic covariates. * p < 0.05, ** p < 0.01, *** p < 0.001

Table 3: The Correlation Between District-Level Covariates and the Timing of School Meal Vendor Contracts

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable:	White	Asian	Hispanic	Disadvantaged	English Learner	Predicted Test Score	Expenditures	Superintendent Change	Charter Share
Panel A. All School Sample									
Healthy Vendor	0.004	-0.006	0.003	-0.001	-0.016	0.005	0.051	-0.028	0.007
	(0.005)	(0.004)	(0.004)	(0.015)	(0.018)	(0.010)	(0.093)	(0.052)	(0.011)
Standard Vendor	-0.001	-0.001	-0.001	0.027	0.006	-0.024	-0.202*	0.120	0.002
	(0.006)	(0.002)	(0.005)	(0.023)	(0.008)	(0.019)	(0.084)	(0.125)	(0.006)
Dependent variable mean	0.284	0.084	0.492	0.545	0.225	5.389	9.160	0.186	0.083
N	174,818	174,818	174,818	174,818	174,818	174,818	168,532	103,238	174,798
Schools	9,719	9,719	9,719	9,719	9,719	9,719	9,312	5,696	9,719
Districts	908	908	908	908	908	908	830	442	908
Panel B. Contract School Sample									
Healthy Vendor	0.001	-0.005	0.006	-0.024	-0.014	0.019	0.038	-0.013	0.008
	(0.007)	(0.004)	(0.005)	(0.019)	(0.015)	(0.012)	(0.055)	(0.058)	(0.011)
Standard Vendor	-0.003	0.000	0.002	0.005	0.003	-0.006	-0.126	0.173	0.001
	(0.007)	(0.004)	(0.005)	(0.022)	(0.007)	(0.018)	(0.075)	(0.129)	(0.007)
Dependent variable mean	0.263	0.119	0.450	0.504	0.244	5.417	9.176	0.140	0.104
N	22,133	22,133	22,133	22,133	22,133	22,133	21,080	12,561	22,133
Schools	1,188	1,188	1,188	1,188	1,188	1,188	1,118	685	1,188
Districts	143	143	143	143	143	143	129	73	143

Notes: Each column represents a separate weighted regression with weights equal to the number of test takers per observation. Observations are at the school-grade-year level. Standard errors clustered at the school district level appear in parentheses. All regressions include year and school-by-grade fixed effects. The contract school sample is the subset of schools that contract with a vendor at some point during our sample. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: The Correlation Between School-Level Covariates and the Timing of School Meal Vendor Contracts

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable:	% Teachers Female	% Teachers Hispanic	% Teachers Black	% Teachers White	% Teachers College	% Teachers Post-grad	Average Tenure	Enrollment (Thousands)	Student-Teacher Ratio
Panel A. All School Sample									
Healthy Vendor	-0.008	0.001	0.002	-0.008	0.026	-0.026	-0.18	-0.23	0.01
	(0.010)	(0.008)	(0.003)	(0.012)	(0.020)	(0.019)	(0.26)	(0.67)	(0.25)
Standard Vendor	-0.006	0.002	-0.001	-0.008	-0.009	0.014	-0.29	1.57	0.22
	(0.019)	(0.014)	(0.003)	(0.021)	(0.021)	(0.020)	(0.37)	(1.14)	(0.30)
Dependent variable mean	0.753	0.161	0.036	0.697	0.604	0.388	13.80	83.92	22.85
N	173,473	173,473	173,473	173,473	173,473	173,473	173,473	174,818	174,639
Schools	9,711	9,711	9,711	9,711	9,711	9,711	9,711	9,719	9,718
Districts	904	904	904	904	904	904	904	908	907
Panel B. Contract School Sample									
Healthy Vendor	0.002	-0.002	-0.001	0.003	0.027	-0.026	-0.08	-0.31	-0.22
	(0.011)	(0.007)	(0.003)	(0.010)	(0.022)	(0.021)	(0.25)	(0.75)	(0.28)
Standard Vendor	0.011	-0.006	-0.005	0.014	-0.009	0.015	0.13	1.34	0.09
	(0.022)	(0.013)	(0.004)	(0.020)	(0.025)	(0.025)	(0.36)	(1.14)	(0.38)
Dependent variable mean	0.776	0.149	0.036	0.681	0.635	0.362	13.19	58.62	21.80
N	22,017	22,017	22,017	22,017	22,017	22,017	22,017	22,133	22,022
Schools	1,188	1,188	1,188	1,188	1,188	1,188	1,188	1,188	1,188
Districts	143	143	143	143	143	143	143	143	143

Notes: Each column represents a separate weighted regression with weights equal to the number of test takers per observation. Observations are at the school-grade-year level. Standard errors clustered at the school district level appear in parentheses. All regressions include district-level demographic covariates and year and school-by-grade fixed effects. The contract school sample is the subset of schools that contract with a vendor at some point during our sample. * p < 0.05, ** p < 0.01, *** p < 0.001

Table 5: The Effect of Vendor Choice on Standardized Test Scores: Robustness Checks

Dependent Variable:	Standardized Test Score				
	(1)	(2)	(3)	(4)	(5)
Model:	Nonconcurrent Effects	HEI Method 2	Continuous HEI	District-level Regression	Standard Only
Healthy Vendor	0.030**	0.036***		0.038**	0.031
	(0.010)	(0.009)		(0.013)	(0.028)
Standard Vendor	-0.004	-0.003		-0.010	0.006
	(0.019)	(0.016)		(0.022)	(0.021)
Healthy Vendor with Contract Ending Before Test Date	0.063***				
	(0.018)				
Vendor with HEI Score			0.005		
			(0.014)		
HEI Score / 100			0.125*		
			(0.060)		
R^2	0.930	0.930	0.930	0.985	0.931
N	174,818	174,818	174,818	4,057	12,117
Schools	9,719	9,719	9,719	N/A	649
Districts	908	908	908	908	67

Notes: Each column represents a separate weighted regression with weights equal to the number of test takers per observation. In Column (1) the Healthy Vendor indicator equals zero when the Healthy Vendor with Contract Ending Before Test Date indicator equals unity. To construct the HEI Score regressor we subtract the mean standard vendor score (56) from HEI Score and rescale it by 1/100 (we also set the variable to zero for unscored vendors and schools with no vendors). Observations are at the school-grade-year level or, in Column (4), district-year level. Standard errors clustered at the school district level appear in parentheses. All regressions include year and school-by-grade (or, in Column (4), district) fixed effects and district-level demographic covariates. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: The Effect of Vendor Choice on Percent of Overweight Students and Number of School Lunches Sold

Dependent variable:	Percent Overweight		Number Lunches Sold	
	(1)	(2)	(3)	(4)
Subgroup:	All	Disadvantaged	All	Disadvantaged
Healthy Vendor	-0.29	0.13	-0.049	-0.078
	(0.72)	(1.32)	(0.037)	(0.097)
Standard Vendor	-1.00	0.47	-0.035	-0.019
	(0.84)	(1.48)	(0.044)	(0.119)
Dependent variable mean	38.58	41.67	0.447	0.418
R^2	0.831	0.764	0.760	0.721
N	43,648	18,105	2,778	2,744
Schools	43,648	5,419	N/A	N/A
Districts	900	657	785	784

Notes: Each column represents a separate weighted regression. The dependent variable in Columns (1) and (2) is the percentage of students who are overweight. Observations are at the school-grade-year level and the weights are equal to the number of physical fitness test takers. The dependent variable in Columns (3) and (4) is the number of school lunches sold. Observations are at the school district-year level and weights are the total student enrollment in the district. The first two regressions include school-by-grade fixed effects, while the latter two include district fixed effects. All regressions include year fixed effects and district-level covariates. Standard errors clustered at the school district level appear in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix for "School Meal Quality and Academic Performance"

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A1 Calculation of vendor HEI scores

Nutritionists at the Berkeley Nutrition Policy Institute conducted an analysis of menus for those vendors for whom this information was available. A copy of the complete report can be found here: https://are.berkeley.edu/~mlanderson/pdf/Nutrition-Policy-Institute-July-2016.pdf The menus were scored using the Healthy Eating Index (HEI). The process to calculate the HEI for each vendor was the following:

1. Nutrition information was gathered from vendors. This process included obtaining the full menu of offerings and nutritional information by contacting vendors. When this information was not available, sample menus from client school districts (with or without nutritional information) were used.

2. In order to calculate HEI, it was necessary to match foods listed in vendor menus to USDA food codes.

    (a) For vendors with nutritional information available, vendor foods were matched to USDA foods using the What's in the Foods You Eat online search tool

    - Foods were first matched by names. Then, these matches were analyzed based on calories and fat content to determine how many USDA units corresponded to a vendor's portion.
    - Units were calculated so that calories, total fat, and saturated fat matched within 20% difference.
        - Entrees, meat/meat alternatives, and whole grain items were also matched by protein and fiber.
    - A coding system was created to denote the quality of the match.

    (b) For vendors without nutritional information, the number of total calories and other nutrients had to be imputed to determine the number of USDA units corresponding to a vendor's portion. In these cases, a number of methods were tested, which included using the average calories for other vendors and USDA defaults (e.g., the necessary amounts to meet USDA guidelines)

    (c) USDA HEI SAS macros were used to determine HEI scores (scoring system 1)

3. A supplemental scoring system was created to include additional food categories commonly found in school lunch menus. This method was reviewed by five nutrition experts.

4. The HEI and supplemental scores were combined to calculate alternative total scores (scoring system 2).

A2 Calculation of average school lunches served

National School Lunch Program (NSLP) data were obtained from the California Department of Education's Nutrition Services Division for the school years 2008-2009 through 2012-2013. The data report the average number of NSLP lunches served per operating day in each school district. Averages are calculated monthly, so in order to obtain an annual measure for the average number of lunches served per day, we multiply the monthly averages by the number of operating days in each month and sum the monthly totals. The months of June and July are excluded from the total because these months may correspond to summer lunch programs that are managed separately. The annual total is divided by the total number of operating days in the year, again excluding June and July, to calculate an annual average of lunches served per day. Lastly, we divide the number of lunches served per day by the total enrollment in the school district to eliminate changes in lunches served that are due only to changes in the number of enrolled students. Because we are interested in separately estimating the effect on economically disadvantaged students, we calculate averages for both total lunches served and free and reduced-price lunches. A student is eligible for a free school lunch if his family's income is less than 130% of the poverty level, and a reduced-price lunch if her family's income is between 130% and 185% of the poverty level. The CA Department of Education refers to these students as "economically disadvantaged."

A3 Specification Tests: Event-Study Models

In Section 4.3 we analyze whether student test scores change in the year immediately before or after a school contracts with a vendor. We find no evidence that student test scores change in the year immediately before or after a school contracts with a vendor. In this section, we estimate two different event study models that expand the analysis to multiple years before and after the vendor contract.

Equation (2) is an event-study model that tests whether there is a correlation between test scores and contracting with a vendor in the years before the vendor contract begins and in the years following the end of a contract.

$$y_{gst} = \beta_0 + \sum_{\tau=-4}^{4} \delta_H^{\tau} Healthy_{st}^{\tau} + \sum_{\tau=-4}^{4} \delta_S^{\tau} Standard_{st}^{\tau} + X_{st}\beta + \lambda_{gs} + \gamma_t + \epsilon_{gst} \quad (2)$$

Equation (2) is identical to our main estimating equation, except that we replace the single indicator variables for whether a school contracted with a vendor ($Healthy_{st}$ and $Standard_{st}$) with a set of indicators ($Healthy_{st}^{\tau}$ and $Standard_{st}^{\tau}$). Indicators with $\tau < 0$ are indicators for the years before a contract with a healthy (or standard) vendor begins. Indicators with $\tau > 0$ are for the years after a contract ends.[26] The indicator variables for a year before a contract are normalized to zero when we estimate Equation (2). Thus, the estimated coefficients δ_H^τ and δ_S^τ are interpreted as the change in test scores for students in grade g, school s, and year t relative to the year before a contract. In this specification, the $\tau = 0$ event study coefficients, $\delta_H^{\tau=0}$ and $\delta_S^{\tau=0}$, are averaged across all years with a healthy and standard vendor, respectively.

If our model is correctly specified, we would only expect to measure a correlation between test scores and a vendor contract for healthy vendors when $\tau = 0$.[27] Figure A1 reveals that this is indeed the case. The figure plots the estimated healthy (circles) and standard (squares) event time coefficients and the 95% confidence intervals for the All School sample. The x-axis measures event time years (i.e., τ), and the y-axis measures test scores for all test takers. All of the estimates for the standard vendor coefficients are economically small and statistically insignificant. The same is true for the healthy vendor coefficients, except during years when a school contracts with a vendor (i.e., $\tau = 0$); in those years we estimate a statistically significant effect of 0.030.[28]

There are two caveats to the analysis in Figure A1. First, the event study coefficients toward the ends of our panel are imprecisely estimated because there are fewer observations available to identify these coefficients.[29] We address this concern by also estimating a model that pools the event time coefficients. Second, we do not know whether a school contracted with a vendor in the years before our five-year panel begins. This could attenuate our estimates if there are delayed impacts in the test score effect that appear several years after contracts begin, because the model would incorrectly assume zero treatment effect in the pre-vendor years.[30] Motivated in part by this concern, we also estimate a second specification of the event-study model that tests whether there are delayed impacts from contracting with a vendor.

In a second event-study model we again estimate Equation (2), except that we define the $\tau > 0$ coefficients as indicators for the consecutive years after a vendor contract begins and *while the contract is still in effect*. The event study model results plotted in Figure A1 estimate a single coefficient for contracting with a healthy (standard) vendor. This is done by averaging across all the years that a school contracts with a healthy (standard) vendor (i.e., $\tau = 0$). In contrast, in the second model, the estimated coefficients for the indicators

[26] For example, $Healthy_{st}^{-3}$ equals unity if a school contracted with a healthy vendor three years later (and zero otherwise), and $Healthy_{st}^{3}$ equals unity if it has been three years since a school contracted with a healthy vendor (and zero otherwise).

[27] One potential exception is that we might expect the estimates for the healthy vendor to be positive when $\tau > 0$ if there is a "carry-over" effect on learning in years after the cancellation of a healthy vendor contract.

[28] As a comparison, the estimate of the effect on test scores for the year of a healthy vendor contract from Equation (1) on the same sample is 0.031 (Column (3) of Table 1).

[29] For example, the indicator for four years before a vendor contract can equal one only if a school contracted with a vendor in the last year of our panel. In contrast, an indicator for one year after a vendor contract ends could equal one for four of the five years in our panel.

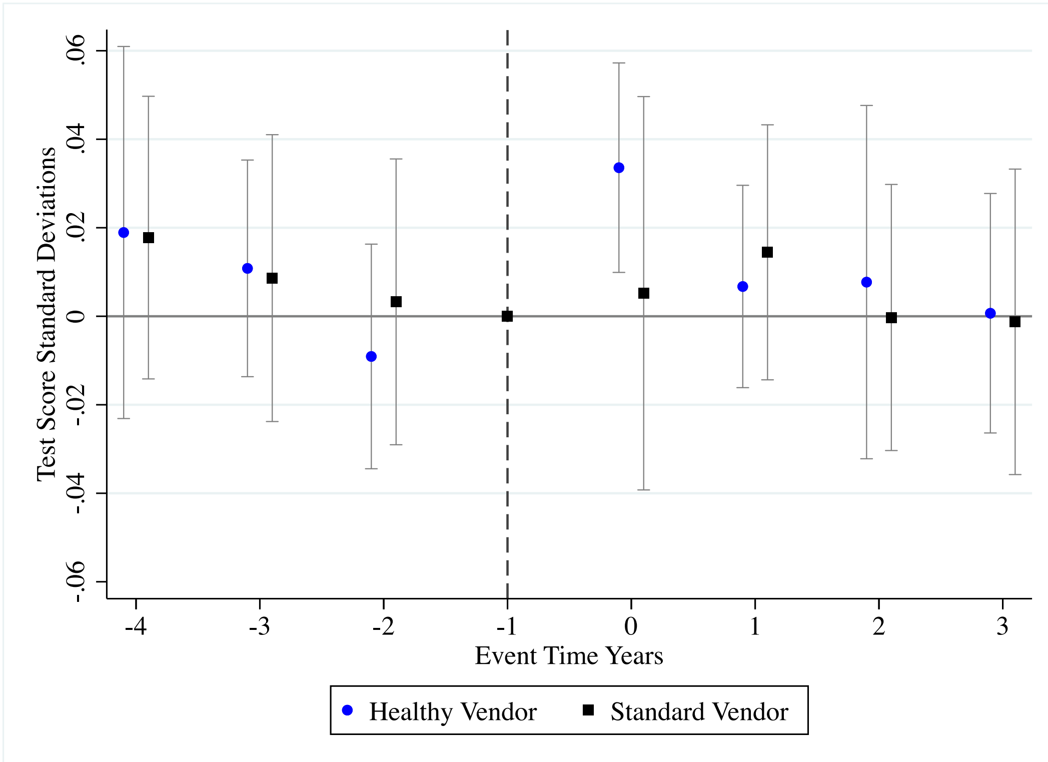
[30] For example, Gallagher [2014] examines the effect on the take-up of flood insurance after a community is flooded, using a model similar to Equation (2). He shows that the estimate for flood insurance take-up in the year of a flood is about 20% lower if the model fails to control for the lagged effect of a flood that occurred before the panel period.

$\tau > 0$ represent the additional change in test scores associated with each consecutive year of the contract (as compared to $\tau = 0$ and relative to the year before a contract).

Figure A2 plots the estimated healthy vendor event time coefficients and the 95% confidence intervals from estimating the second event study model on the All School sample. The x-axis measures event time years (i.e., τ), and the y-axis measures test scores for all test takers. The figure represents the effect for a school that adopts a healthy vendor at $\tau = 0$ and keeps it through (at least) $\tau = 3$.[31] In a healthy vendor contract year, there is an increase in test scores of 0.030 standard deviations relative to the year before a contract. There is no evidence that increases in test scores precede contracting with a vendor, nor is there evidence of an upward pre-trend in test scores. Similarly, none of the estimated coefficients in the years after a contract begins are significantly different than the $\tau = 0$ coefficient, suggesting that there are not delayed impacts that take several years to materialize. Since there is no evidence of a delayed impact, then attenuation bias from the implicit assumption of a zero treatment effect in the pre-vendor years is unlikely. Figure A3 plots analogous event time coefficients for standard vendors. None of the standard vendor coefficients, either before or after the contract's start date, are statistically significant.

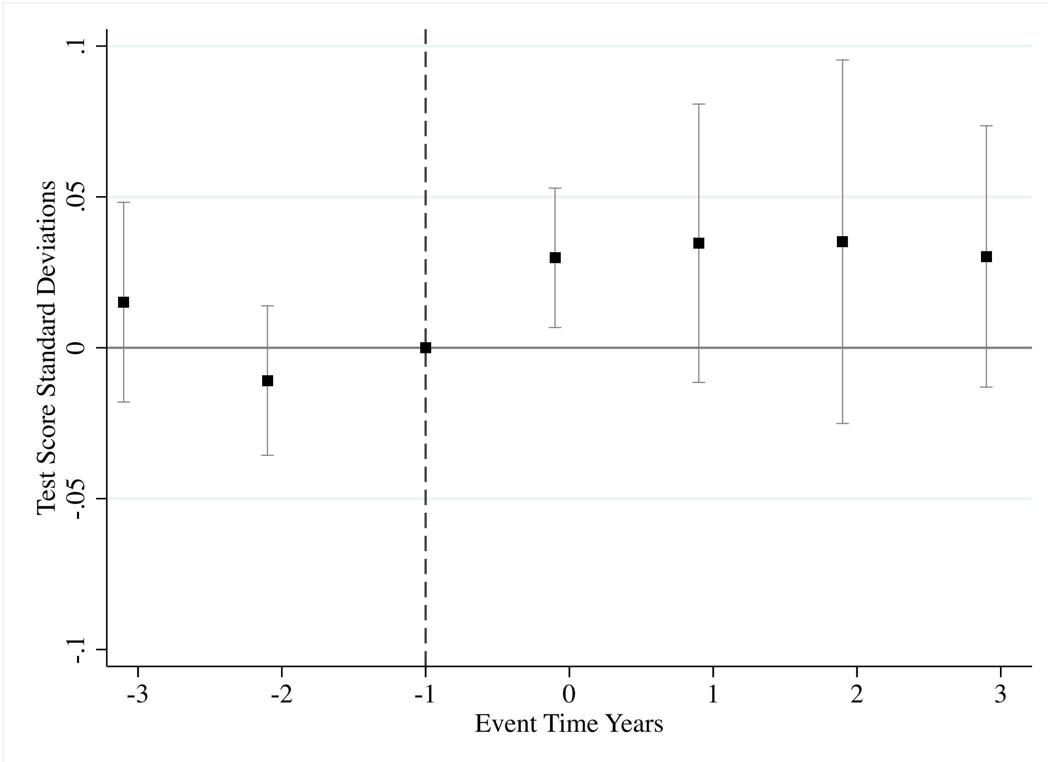
[31] The post-event coefficients compare the counterfactual of a contract that remains in effect indefinitely to one in which there is no contract; e.g., at $\tau = 2$ we plot $\delta_H^0 + \delta_H^2$. This aligns the figure with a standard event study figure in which the policy remains in effect following the event. Among schools that adopted healthy vendors in 2008 or 2009, 67% had contracts that remained in effect for at least two years, 40% had contracts that remained in effect for at least three years, and 27% had contracts that remained in effect for at least four years. In cases in which the contract was not renewed, schools switched back to in-house provision.

Figure A1: Placebo Test for the Effect of Contracting with a Vendor on Test Scores



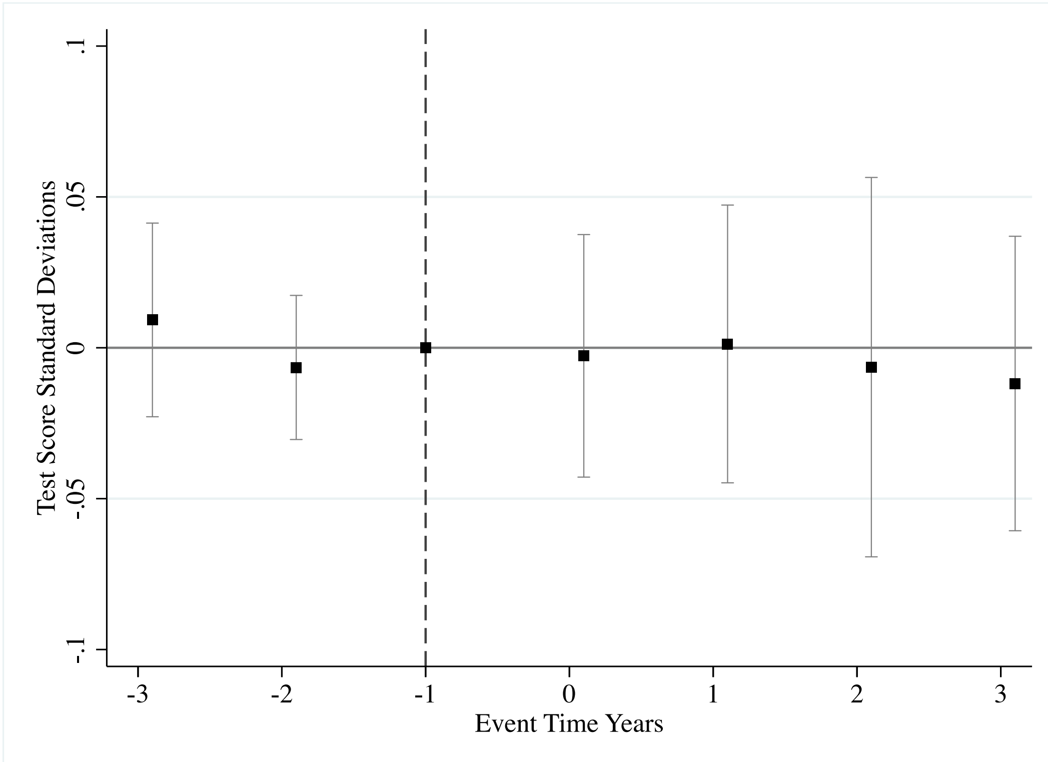
Notes: This figure depicts point estimates for treatment leads and lags with their corresponding 95% confidence intervals. Negative event time years are for years prior to having a vendor. Positive event time years are for years after a vendor contract ends. The point estimates come from a weighted regression of Equation (2), except that the coefficients for $\tau > 0$ are redefined to be years after the end of a contract. The event time period -3 (3) is pooled to include both period -3 and -4 (3 and 4) to improve precision. The regression includes the same control variables as Table 1, Column (3). Standard errors are clustered at the school district level.

Figure A2: The Effect of Healthy Vendors on Test Scores



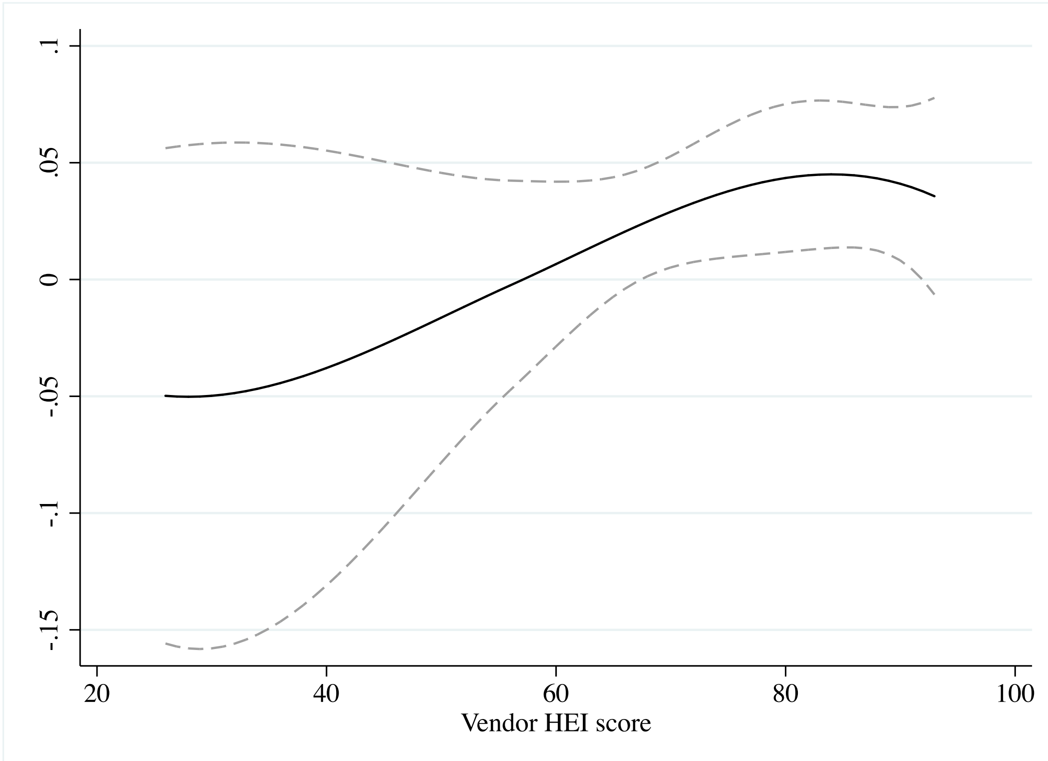
Notes: This figure depicts point estimates for treatment leads and lags with their corresponding 95% confidence intervals. Negative event time years are for years prior to having a vendor. Positive event time years are for years after the vendor contract begins (assuming that it continues). The point estimates come from a weighted regression of Equation (2) using the number of test-takers per observation as weights and can be interpreted relative to having no vendor and relative to the year before a vendor. The event time period -3 (3) is pooled to include both period -3 and -4 (3 and 4) to improve precision. The regression includes the same control variables as Table 1, Column (3). Standard errors are clustered at the school district level.

Figure A3: The Effect of Standard Vendors on Test Scores



Notes: This figure depicts point estimates for treatment leads and lags with their corresponding 95% confidence intervals. Negative event time years are for years prior to having a vendor. Positive event time years are for years after the vendor contract begins (assuming that it continues). The point estimates come from a weighted regression of Equation (2) using the number of test-takers per observation as weights and can be interpreted relative to having no vendor and relative to the year before a vendor. The event time period -3 (3) is pooled to include both period -3 and -4 (3 and 4) to improve precision. The regression includes the same control variables as Table 1, Column (3). Standard errors are clustered at the school district level.

Figure A4: Effects of Vendor HEI on Test Scores



Notes: This figure depicts the effect of vendor HEI on test scores when specifying a third-order polynomial in vendor HEI. Effects are interpreted relative to in-house meal provision. Dashed lines represent 95% confidence intervals with standard errors clustered by district.

Table A1: Vendor Healthy Eating Index (HEI) Scores
by School Meal Market Share

Vendor Name	(1) Percent of Students Served	(2) HEI Score	(3) Healthy	(4) SFA Contracts	(5) Only SFA Contracts
Sodexo	50.60	59.9	N	N	N
Compass	15.65	45.6	N	N	N
CSU Dominguez Hills	10.27	-	N	N	N
Preferred Meals	9.50	71.4	Y	N	N
Aramark	3.33	64.7	Y	N	N
Revolution Foods	2.57	92.3	Y	Y	N
Royal Dining	2.42	75.0	Y	Y	N
Choicelunch	1.21	37.1	N	N	N
The Lunchmaster	1.12	-	N	N	N
School Nutrition Plus	0.86	67.8	Y	N	N
Kid Chow	0.42	26.8	N	N	N
Morrison Management Specialists	0.32	-	N	N	N
Bellflower Unified School District	0.29	69.1	Y	Y	Y
CSU Chico	0.23	51.9	N	N	N
Unified Nutrimeals	0.16	-	N	N	N
Flour Creations	0.13	-	N	N	N
Feed You Well	0.13	-	N	N	N
La Luna On The Go	0.09	-	N	N	N
Fresno County EOC	0.09	-	N	Y	N
Preferred Choice	0.09	70.0	Y	N	N
Santa Clarita Food Services Agency	0.07	55.5	N	N	N
Oceanside Unified S.D. / Lighthouse Foods	0.07	-	N	Y	Y
Dulan's Catering	0.06	-	N	N	N
Arguello Catering	0.05	-	N	N	N
The Food Lady	0.03	-	N	N	N
Banyan Catering	0.03	-	N	N	N
Blue Lake Rancheria	0.03	72.2	Y	N	N
Food Management Associates	0.02	-	N	N	N
Good Day Cafe - San Lorenzo Unified S. D.	0.02	-	N	Y	Y
Brown Bag Naturals	0.02	-	N	N	N
Fieldbrook Family Market	0.02	39.7	N	N	N
Freshlunches	0.01	-	N	N	N
Happy Valley Conference Center	0.01	-	N	N	N
Aqua Terra Culinary	0.01	-	N	N	N
Trinidad Rancheria	0.01	-	N	N	N
Food 4 Thought	0.01	-	N	N	N
San Bernardino School District	0.01	-	N	Y	Y
Progressive Catering	0.01	-	N	N	N
Hesperia USD	0.01	-	N	Y	Y
Healthy Lunch And Lifestyle Project	0.01	-	N	N	N
James Aldrege Foundation	0.01	-	N	N	N
Taft City School District	0.00	-	N	Y	Y
Arcata School District	0.00	-	N	Y	Y
Celebrations Catering	0.00	-	N	N	N
Yosemite Unified School District	0.00	-	N	Y	Y

Notes: The table lists the 45 vendors that contracted with schools during the 2008-2009 to 2013-2014 school years. The Healthy Eating Index scores for each vendor are based on lunch menus and calculated by nutritionists at the Nutrition Policy Institute. The percent of students served by each vendor is determined by first summing the number of students in our panel that take the end of year academic (STAR) test who are in schools being served by an outside vendor for the test year, and then dividing this total by the number of students who have their meals provided by each vendor.

Table A2: Test-Taker Covariates for Schools that Contract with School Meal Vendors

Sample:	All School Sample			Contract School Sample		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable:	Vendor	No Vendor	Difference	Healthy	Standard	Difference
Disadvantaged	0.461	0.528	-0.067***	0.459	0.420	0.039
			(0.012)			(0.028)
Asian	0.079	0.053	0.026***	0.041	0.100	-0.059***
			(0.004)			(0.010)
White	0.384	0.443	-0.059***	0.404	0.327	0.077**
			(0.012)			(0.025)
Hispanic	0.408	0.406	0.002	0.364	0.408	-0.044
			(0.012)			(0.026)
Black	0.053	0.040	0.012***	0.075	0.032	0.043***
			(0.003)			(0.008)
English Learner	0.217	0.196	0.021**	0.175	0.230	-0.054***
			(0.008)			(0.016)
Districts	573	4,625		231	313	

Notes: Percentages are calculated by dividing the number of enrolled students in a given category by the total number of enrolled students in a district as reported by the California Department of Education. Standard errors reported in parentheses. The contract sample is the subset of districts that contract with any vendor at any point during our sample. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A3: The Effect of Vendor Choice on Standardized Test Scores (Unweighted)

Dependent variable:	Standardized Test Score					
Sample:	All Schools			Contract Schools		
	(1)	(2)	(3)	(4)	(5)	(6)
Healthy Vendor	0.031***	0.031***	0.030***	0.036***	0.028***	0.025**
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Standard Vendor	-0.011	-0.014	-0.013	0.008	-0.022	-0.021
	(0.020)	(0.022)	(0.022)	(0.017)	(0.023)	(0.022)
School-by-grade FEs		X	X		X	X
Covariates included			X			X
R^2	0.615	0.909	0.909	0.700	0.903	0.903
N	174,818	174,818	174,818	22,133	22,133	22,133
Schools	9,719	9,719	9,719	1,188	1,188	1,188
Districts	908	908	908	143	143	143

Notes: Each column represents a separate regression estimated on a common sample that excludes observations with missing covariates. Observations are at the school-grade-year level. Standard errors clustered at the school district level appear in parentheses. All regressions include school and year fixed effects. Regressions also include school fixed effects unless school-by-grade fixed effects are specified. The contract school sample is the subset of schools that contract with a vendor at some point during our sample. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A4: The Effect of Vendor Choice on Subject-Specific Standardized Test Scores

Test subjects:	All	Core	English/ Language Arts	Humanities/ Social Science	STEM	Math
	(1)	(2)	(3)	(4)	(5)	(6)
Healthy Vendor	0.031**	0.027**	0.026*	0.026*	0.032*	0.035*
	(0.010)	(0.010)	(0.012)	(0.011)	(0.015)	(0.016)
Standard Vendor	-0.004	-0.030	-0.032	-0.020	-0.002	-0.002
	(0.019)	(0.022)	(0.023)	(0.017)	(0.021)	(0.020)
R^2	0.930	0.932	0.919	0.922	0.939	0.921
N	174,818	174,744	174,605	174,735	172,508	170,167
Schools	9,719	9,718	9,709	9,717	9,635	9,508
Districts	908	908	908	908	908	906

Notes: Each column represents a separate weighted regression with weights equal to the number of test takers per observation. All regressions are estimated on a common sample that excludes observations with missing covariates. Observations are at the school-grade-year level. Standard errors clustered at the school district level appear in parentheses. All regressions include year fixed effects, school-by-grade fixed effects, and district-level covariates. Core tests include English, math, US history, cumulative history, and life science. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A5: HEI Mechanisms

(1) Food or Compound	(2) HEI Score	(3) Cognition	(4) Hypothesized Mechanisms	(5) Literature Reviews
Fruits and Vegetables	Positive	Positive	Bioactive substances (e.g. flavonoids and carotenoids); Effect of vitamins	Bell et al. (2015); Lamport et al. (2014); Zielinska et al. (2017)
Vitamins, Omega-3 Fatty Acid	Positive	Positive	Neuroprotective properties (vitamin D); Axioxident properties (vitamin C); Maintain neuronal function (omega-3)	Anjos et al. (2013); Goodwill et al. (2017); Hansen et al. (2014); Kurpad et al. (2013); Stonehouse (2014); Wood et al. (2015)
Refined Carbohydrates	Negative	Negative	Impairments in frontal, limbic, and hippocampal systems	Francis and Stevenson (2013)
Refined Sugars	Negative	Negative	Phosphorylation levels of insulin receptor, synapsin 1, and synaptophysin	Lowette et al. (2015); Reichelt and Rank (2017)
Saturated Fat/High-Fat Diet	Negative	Negative	Gastrointestinal tract microorganisms; Insulin resistence; Oxidative stress	Beilharz et al. (2015); Freeman et al. (2014); Morris et al. (2014); Proctor et al. (2017)

The table summarizes how five broad categories of foods and compounds relate to cognitive function, the hypothesized chemical mechanisms for the relationships, and how consumption of these foods are reflected in the scoring of the Healthy Eating Index (HEI). All of the food and compound categories have a direct positive or negative effect on the tabulation of the HEI score, except for saturated fat/high-fat diet. This category has an indirect negative effect on the HEI score provided that the consumption of foods high in saturated fat crowds out other types of foods. The table lists the most relevent review articles from a search of the PubMed database, https://www.ncbi.nlm.nih.gov/pubmed

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