Fiscal and Education Spillovers from Charter School Expansion

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APPENDIX

Table A.1: Timing of District Aid Received by Districts for Charter School Tuition

| | | | | Reimbursement | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Change in | Individual | Current | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | |
| | charter | tuition | Year | 100 pct | 25 pct | 25 pct | 25 pct | 25 pct | 25 pct | End of | |
| Year | enrollment | rate | Tuition | reimb | reimb | reimb | reimb | reimb | reimb | reimb | Total Aid |
| 2017 | 0 | 9,900 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2018 | 10 | 10,000 | 100,000 | 100,000 | 0 | 0 | 0 | 0 | 0 | 0 | 100,000 |
| 2019 | 0 | 0 | 0 | 0 | 25,000 | 0 | 0 | 0 | 0 | 0 | 25,000 |
| 2020 | 0 | 0 | 0 | 0 | 0 | 25,000 | 0 | 0 | 0 | 0 | 25,000 |
| 2021 | 0 | 0 | 0 | 0 | 0 | 0 | 25,000 | 0 | 0 | 0 | 25,000 |
| 2022 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25,000 | 0 | 0 | 25,000 |
| 2023 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25,000 | 0 | 25,000 |
| 2024 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Aid Disbursed for 2017 change in tuition | | | | | | | | | | 0 | 225,000 |

† This table presents an example of the timeline for the temporary aid received by districts for Commonwealth charter tuition. In Massachusetts, school districts receive a full refund of the individual tuition the year following the increase in charter school enrollment and a 25% refund for the next five years. In this example, 10 students switch from a traditional public school to a charter school in the year 2017. The district's individual charter tuition equals $US 10,000, so the total charter school tuition payment equals $US 100,000 in 2017. In 2018, the first year after the 10 students have transferred to a charter school, the Chapter 46 aid refunds 100 percent of the total charter school tuition payment, hence $US 100,000. The state then reimburses 25% of the 2017 increase amount for each of the subsequent five years, which amounts to a $US 25,000 refund for each of the years 2019 to 2024. In 2025, the state stops reimbursing the sending district. In the end, the sending district receives $US 225,000 in state refund during the six years following the switch.

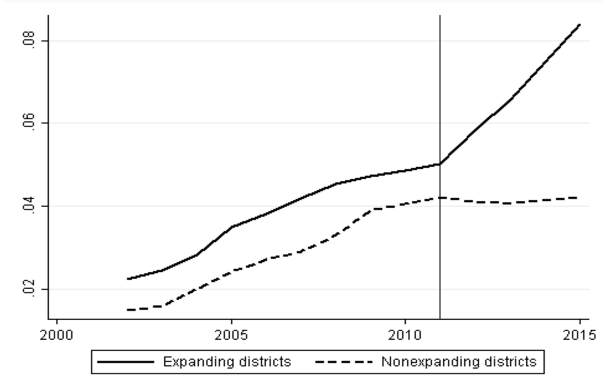
Table A.2: Massachusetts Charter Schools Eligible for the Lottery Instrument, and Grades of Lottery

| Charter School Name | Town | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Academy Of the Pacific Rim | Boston | | | 6 | 6 | 5-6 | 5 | 5 | 5 | 5 | 5 | 5 | |
| Boston Collegiate | Boston | | | | | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Boston Preparatory | Boston | | | | | | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Brooke - Roslindale | Boston | | | | | 5 | 5 | 5 | | | | | |
| Codman Academy | Boston | | | | | | | | | | | | 5 |
| Excel Academy - East Boston | Boston | | | | | | 5 | 5 | 5 | 5 | 5 | 5 | |
| MATCH Community Day | Boston | | | | | | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Roxbury Preparatory | Boston | | | | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 |
| Brooke - East Boston | Boston | | | | | | | | | | 5 | 5 | 5 |
| Brooke - Mattapan | Boston | | | | | | | | | 5 | 5 | 5 | 5 |
| Excel Academy - Orient Height | Boston | | | | | | | | | | 5 | 5 | |
| Grove Hall 2011 (UCS) | Boston | | | | | | | | | 5 | | | |
| KIPP Academy Boston | Boston | | | | | | | | | | 5 | 5 | 5 |
| Cape Cod Lighthouse | Orleans | | | | | 6 | 6 | 6 | 6 | | | | |
| Four Rivers | Greenfield | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | | | | |
| Francis W. Parker | Devins | | | | 7 | 7 | 7 | 7 | 7 | | | | |
| Global Learning | New Bedford | | | | 5 | 5 | | 5 | | | | | |
| Kipp Academy Lynn | Lynn | | | 5 | 5 | 5 | 5 | 5 | | | | | |
| Murdoch Middle - Innovation | Tyngsboro | | | | | 5 | 5 | 5 | 5 | | | | |
| Pioneer Valley Performing Arts | South Hadley | | | | 7 | 7 | 7 | 7 | 7 | | | | |
| Rising Tide | Plymouth | | | | | | | 5 | | | | | |
| Salem Academy | Salem | | | | | | | | 6 | | | | |

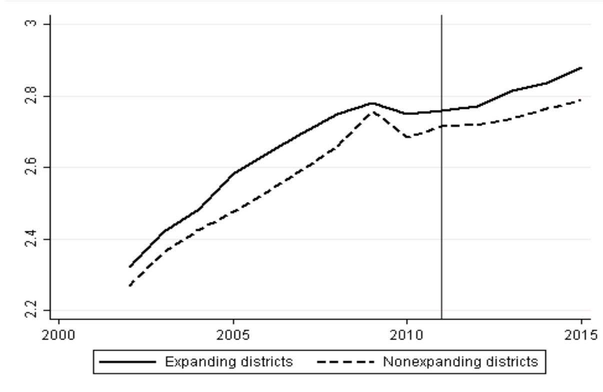
† Notes: This table lists all charter schools in Massachusetts eligible for the lottery instrument in middle school. The number in each cell indicates the grade of lottery.

Figure A.1: Pre-trends in Charter Share and Districts' Per-Pupil Expenditures

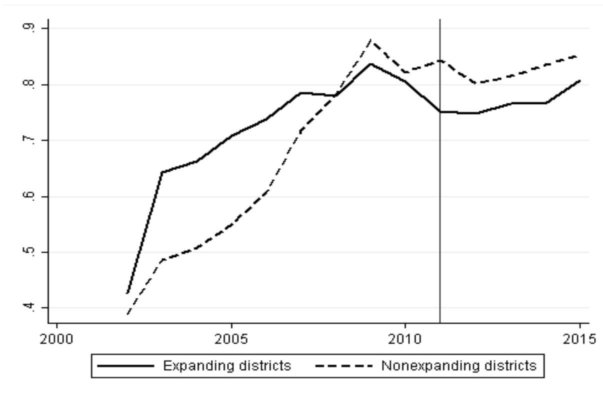
(a) Charter share



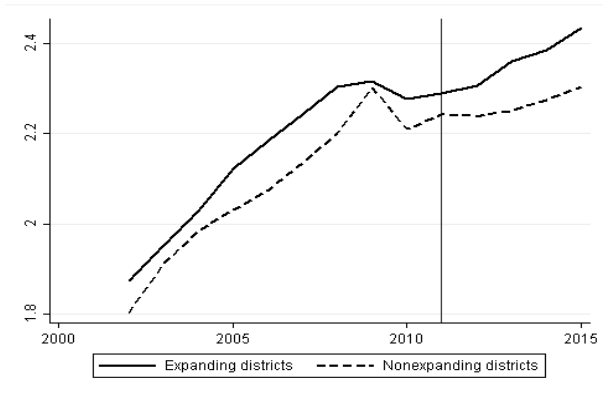

(b) Total spending



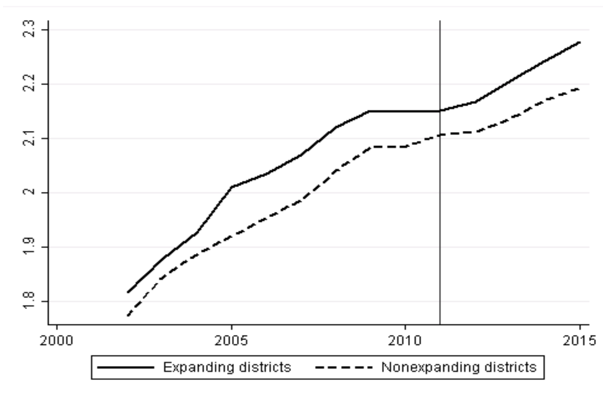

(c) Spending on fixed costs



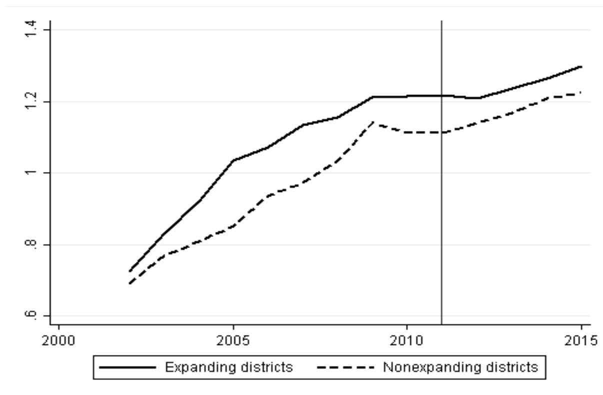

(d) Spending on instruction




(e) Spending on salaries




(f) Spending on support services




Notes: This figure plots the share of students attending a charter school (plot a); districts' per-pupil expenditures (plot b); and their per-pupil expenditures on fixed costs (plot c), instruction (plot d), salaries (plot e), and support services (plot f). For all expenditure variables, we use the log of the variable. The plain lines represent districts that saw an increase in charter school attendance after the 2011 reform (expanding districts), and the dotted lines represent districts in the lowest 10th percentile of student achievement that did not experience an increase in charter school attendance.

Table A.3: First Stage Estimates of Fiscal Spillovers

| | Control group: | | | | | |
|---|---|---|---|---|---|---|
| | Synthetic control districts | | | | | Bottom 10 districts |
| | Per-pupil expenditures on: | | | | | |
| | Total (1) | Instruction (2) | Fixed costs (3) | Support services (4) | Salaries (5) | (6) |
| Post-Reform * Boston | 0.0497*** | 0.0502*** | 0.0491*** | 0.0526*** | 0.0497*** | 0.0469*** |
| | (0.0095) | (0.0095) | (0.0092) | (0.0093) | (0.0091) | (0.0091) |
| Post-Reform * Other urban | 0.0159*** | 0.0164*** | 0.0153*** | 0.0188*** | 0.0159*** | 0.0131*** |
| | (0.0050) | (0.0049) | (0.0043) | (0.0046) | (0.0041) | (0.0041) |
| Post-Reform * Nonurban | 0.0144** | 0.0149*** | 0.0138*** | 0.0174*** | 0.0144*** | 0.0117** |
| | (0.0056) | (0.0055) | (0.0049) | (0.0052) | (0.0048) | (0.0048) |
| N | 196 | 196 | 280 | 224 | 252 | 392 |
| F-Stat | 9.5 | 9.9 | 10.9 | 12.4 | 11.9 | 10 |

† Notes: This table reports first stage estimates of charter expansion effects on districts' per-pupil expenditures. For all expenditure variables, we use the log of the variable. The dependent variable is the charter share, which is a continuous variable that ranges from 0 to 1. In this over-identified model, we use three instruments: (i) the interaction between a post-reform years dummy and a Boston dummy, (ii) the interaction between a post-reform years dummy and a dummy for other urban expanding districts, and (iii) the interaction between a post-reform years dummy and a dummy for nonurban expanding districts. All regressions control for expanding districts, post-reform years, and district time trends. For standard errors, we use the White estimator of variance. When using the synthetic control districts as a control group, the first stage coefficients and the number of observations vary depending on how many synthetic control districts were identified for each outcome.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table A.4: 2SLS Estimates of Fiscal Spillovers - Just-identified model

| | Per-pupil expenditures on: | | | | |
|---|---|---|---|---|---|
| | Total | Instruction | Fixed costs | Support services | Salaries |
| | (1) | (2) | (3) | (4) | (5) |
| | Control group: Synthetic control districts | | | | |
| Charter share | 1.9218 | 4.4483* | 2.2171 | -3.3946 | 0.7523 |
| | (2.0438) | (2.2917) | (3.0962) | (2.7929) | (1.4828) |
| N | 196 | 196 | 280 | 224 | 252 |
| R2 | 0.873 | 0.820 | 0.687 | 0.694 | 0.830 |
| First stage F-Stat | 15.2 | 16.6 | 19.7 | 24.3 | 22.8 |
| First stage coefficient | 0.0191*** | 0.0196*** | 0.0186*** | 0.0221*** | 0.0191*** |
| | (0.0049) | (0.0048) | (0.0042) | (0.0045) | (0.0040) |
| | Control group: Districts in the lowest 10th percentile | | | | |
| Charter share | 0.4432 | 2.0078 | 2.8589 | -3.8848 | -0.5244 |
| | (1.6718) | (1.7837) | (2.9886) | (2.6931) | (1.4644) |
| N | 392 | 392 | 392 | 392 | 392 |
| R2 | 0.872 | 0.849 | 0.700 | 0.720 | 0.829 |
| First stage F-Stat | 16.6 | 16.6 | 16.6 | 16.6 | 16.6 |
| First stage coefficient | 0.0164*** | 0.0164*** | 0.0164*** | 0.0164*** | 0.0164*** |
| | (0.0040) | (0.0040) | (0.0040) | (0.0040) | (0.0040) |

† Notes: This table reports 2SLS estimates of charter expansion effects on district spending. The endogenous variable is the charter share, which is a continuous variable that ranges from 0 to 1. In this just-identified model, the instrument is the interaction between a post-reform years dummy and a dummy for expanding districts. All regressions control for expanding districts, post-reform years, and district time trends. For standard errors, we use the White estimator of variance. When using the synthetic control districts as a control group, the number of observations varies for each outcome depending on how many synthetic control districts were identified. The first stage coefficient is the coefficient of the interaction between a post-reform years dummy and a dummy for expanding districts.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

Table A.5: First Stage Estimates of Charter School Expansion's Impact on Student Achievement

| | Control group: Synthetic control districts | | | | Control group: Bottom 10 pctile districts | | | |
|---|---|---|---|---|---|---|---|---|
| | Single instrument | | Multiple instruments | | Single instrument | | Multiple instruments | |
| | Math (1) | ELA (2) | Math (3) | ELA (4) | Math (5) | ELA (6) | Math (7) | ELA (8) |
| Post Reform * Expanding district | 0.0385** | 0.0344* | | | 0.0322* | 0.0326* | | |
| | (0.0194) | (0.0186) | | | (0.0174) | (0.0170) | | |
| Post-Reform * Boston | | | 0.0676*** | 0.0639*** | | | 0.0612*** | 0.0621*** |
| | | | (0.0114) | (0.0098) | | | (0.0078) | (0.0070) |
| Post-Reform * Other urban | | | 0.0116 | 0.0075 | | | 0.0052 | 0.0057 |
| | | | (0.0113) | (0.0100) | | | (0.0077) | (0.0072) |
| Post-Reform * Nonurban | | | 0.0080 | 0.0013 | | | 0.0016 | -0.0006 |
| | | | (0.0117) | (0.0100) | | | (0.0083) | (0.0072) |
| N | 529206 | 528156 | 529206 | 528156 | 778756 | 712531 | 778756 | 712531 |
| F-Stat | 3.942 | 3.429 | 82.847 | 250.406 | 3.431 | 3.662 | 86.239 | 261.572 |

† Notes: This table reports first stage estimates of charter school expansion's impact on student achievement. The dependent variable is the charter share, which is a continuous variable that ranges from 0 to 1. In the just-identified model, the instrument is the interaction between a post-reform dummy and an expanding district dummy. In the over-identified model, we use three instruments: (i) the interaction between a post-reform years dummy and a Boston dummy, (ii) the interaction between a post-reform years dummy and a dummy for other urban expanding districts, and (iii) the interaction between a post-reform years dummy and a dummy for nonurban expanding districts. All regressions control for expanding districts, post-reform years, and district time trends. Standard errors are clustered at the individual and district levels.

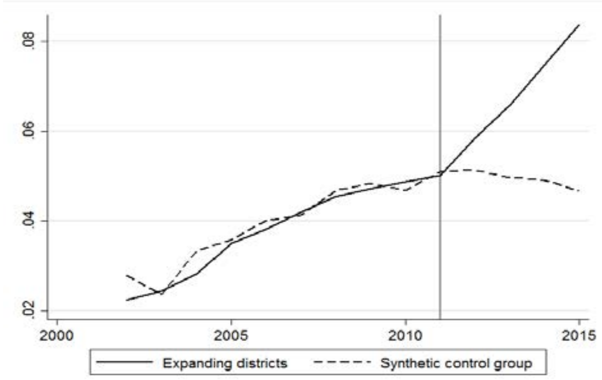
*** Significant at the 1 percent level.

** Significant at the 5 percent level.

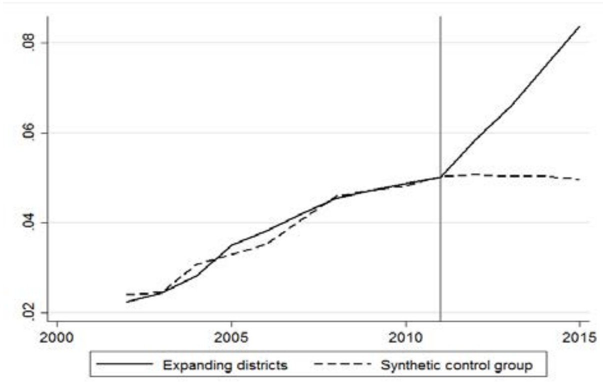
* Significant at the 10 percent level.

Figure A.2: Charter Share in the Synthetic Control Group for each Per-Pupil Expenditure Variable

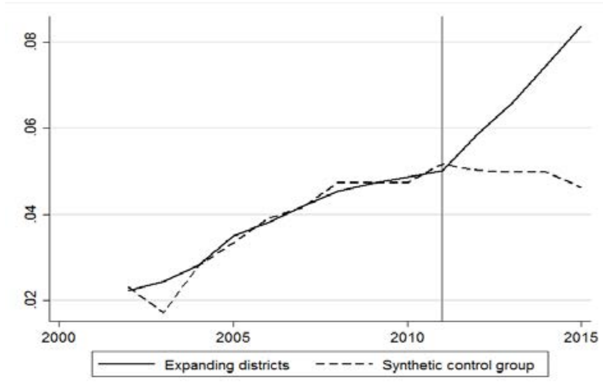
(a) Total spending



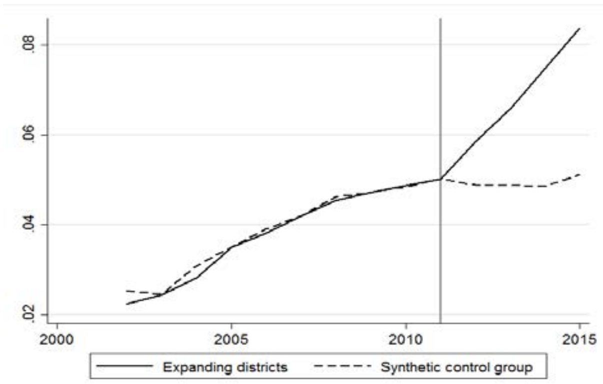

(b) Spending on fixed costs



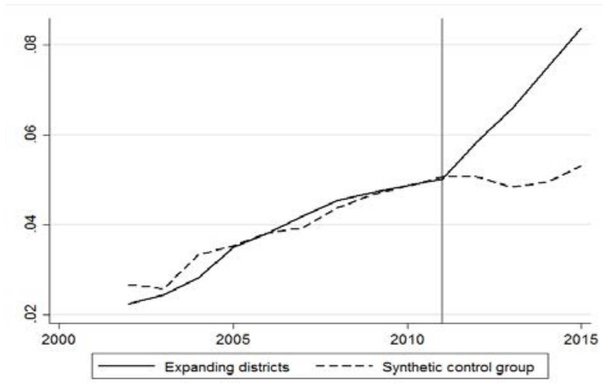

(c) Spending on instruction




(d) Spending on salaries



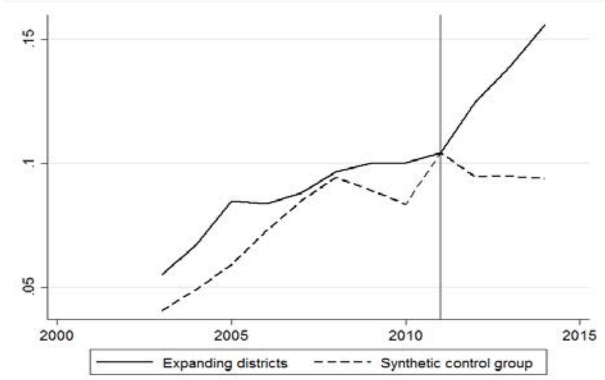

(e) Spending on support services



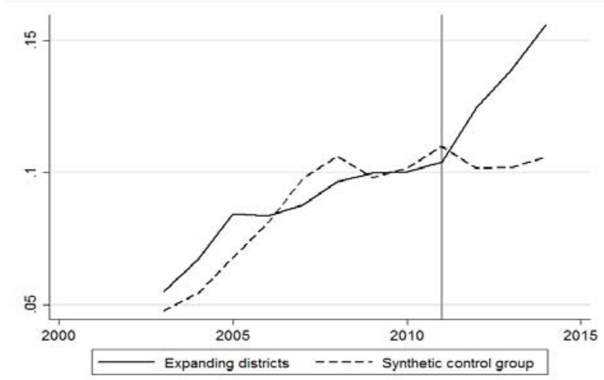

Notes: This figure plots the share of students attending a charter school in the synthetic control group for each financial outcome variable, as a test of the 'fuzzy-DiD' assumption that the treated share in the control group remains constant. The graphs differ from one another only because different weights are used to construct the synthetic control for each outcome variable. The charter share in the treatment group is provided for comparison.

Figure A.3: Charter Share in the Synthetic Control Group for each Achievement Variable

(a) Math

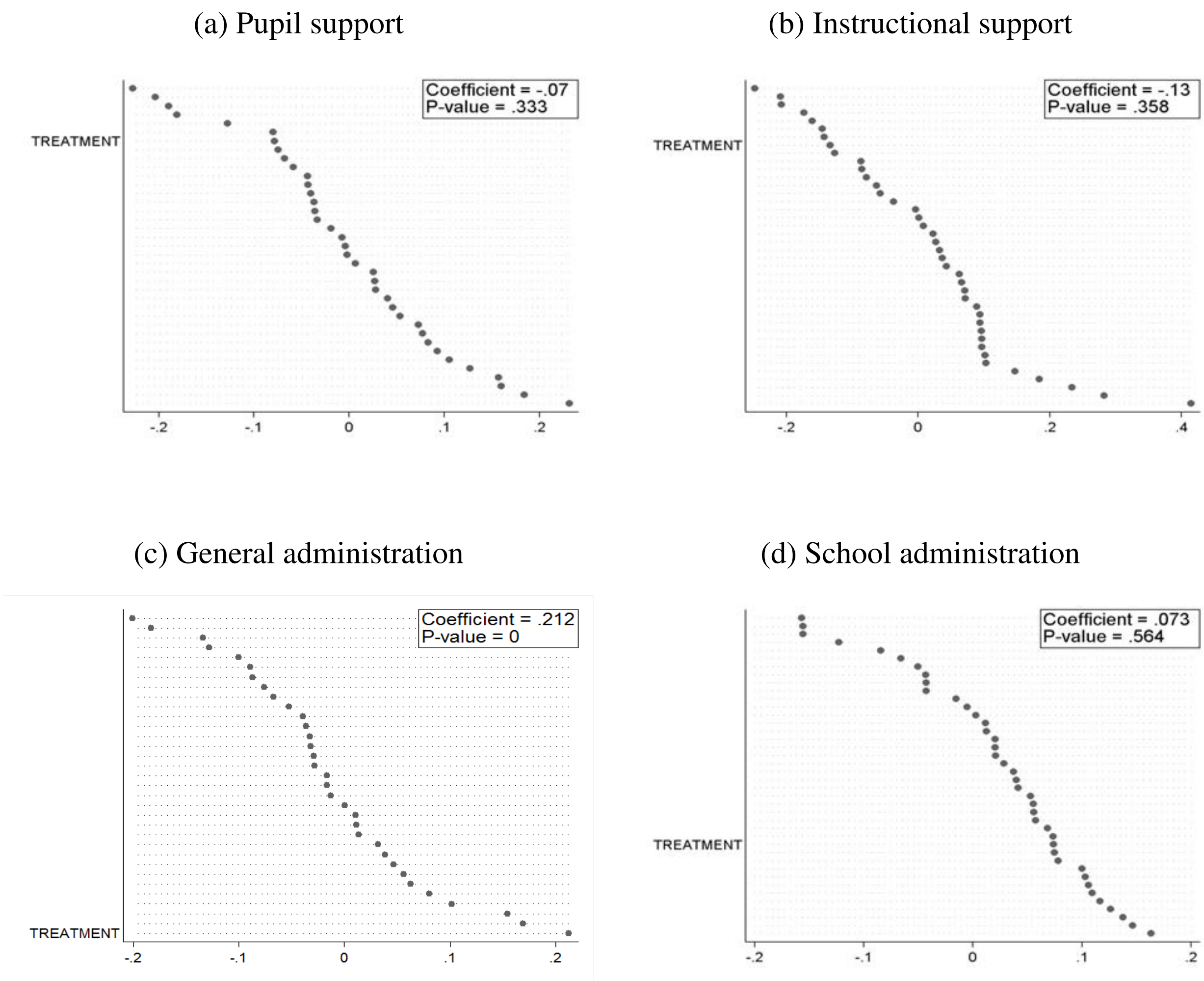



(b) ELA




Notes: This figure plots the share of students attending a charter school in the synthetic control group for each achievement outcome variable, as a test of the 'fuzzy-DiD' assumption that the treated share in the control group remains constant. The graphs differ from one another only because different weights are used to construct the synthetic control for each outcome variable. The charter share in the treatment group is provided for comparison.

Figure A.4: Placebo Inference for the Impact of Charter Expansion on Components of Per-Pupil Support Services Spending




Notes: This figure plots the distribution of charter expansion's impact on components of support spending: pupil support (plot a), instructional support (plot b), general administration (plot c), and school administration (plot d). The "TREATMENT" lines report the coefficients when expanding districts are compared to their synthetic control districts. The exact value of each coefficient is reported in the top right corner of each figure. The other lines in the figures report the coefficients when a placebo group of non-expanding districts is compared to its identified group of synthetic control districts. The p-value is calculated as the probability of obtaining a placebo estimate greater than the actual estimated treatment effect (less than it when the effect is negative), multiplied by two to approximate a two-tailed test.

Table A.6: Event Study Estimates of the Effect of Charter Openings

| | Charter Share | Per-pupil expenditures on: | | | | | Achievement in: | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Instruction | Fixed costs | Support services | Salaries | Math | ELA |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| t-5 | 0.0042 | 0.0158 | 0.0270 | 0.0396 | -0.0458 | -0.0101 | -0.0230 | -0.0413 |
| | (0.0049) | (0.0170) | (0.0223) | (0.0307) | (0.0573) | (0.0183) | (0.0220) | (0.0255) |
| t-4 | 0.0014 | 0.0223 | 0.0275 | -0.0175 | 0.0143 | -0.0196 | 0.0084 | -0.0318 |
| | (0.0049) | (0.0298) | (0.0258) | (0.0536) | (0.0605) | (0.0312) | (0.0148) | (0.0229) |
| t-3 | 0.0005 | -0.0057 | 0.0314 | -0.0098 | -0.1206 | -0.0165 | 0.0026 | -0.0491*** |
| | (0.0055) | (0.0281) | (0.0229) | (0.0404) | (0.0732) | (0.0232) | (0.0237) | (0.0121) |
| t-2 | -0.0073 | -0.0163 | -0.0244 | 0.0210 | -0.0418 | -0.0216 | -0.0171 | -0.0323 |
| | (0.0123) | (0.0160) | (0.0301) | (0.0415) | (0.0658) | (0.0189) | (0.0322) | (0.0287) |
| t-1 | -0.0112 | -0.0237 | -0.0404 | -0.0026 | 0.0168 | -0.0223 | 0.0179 | -0.0054 |
| | (0.0088) | (0.0218) | (0.0285) | (0.0392) | (0.0281) | (0.0135) | (0.0379) | (0.0259) |
| t+1 | 0.0154* | 0.0374*** | 0.0479*** | 0.0189 | 0.0158 | 0.0117 | 0.0128 | -0.0005 |
| | (0.0068) | (0.0111) | (0.0141) | (0.0159) | (0.0155) | (0.0093) | (0.0240) | (0.0239) |
| t+2 | 0.0196* | 0.0552*** | 0.0667*** | 0.0160 | 0.0506* | 0.0292** | 0.0638* | 0.0294 |
| | (0.0091) | (0.0145) | (0.0185) | (0.0349) | (0.0223) | (0.0098) | (0.0300) | (0.0216) |
| t+3 | 0.0214* | 0.0727*** | 0.0807*** | 0.0391 | 0.0678** | 0.0529*** | 0.0777* | 0.0552* |
| | (0.0099) | (0.0173) | (0.0222) | (0.0435) | (0.0217) | (0.0126) | (0.0385) | (0.0230) |
| t+4 | 0.0199 | 0.0738*** | 0.0814*** | 0.0582 | 0.0713** | 0.0421*** | 0.1039** | 0.0698** |
| | (0.0104) | (0.0162) | (0.0189) | (0.0343) | (0.0221) | (0.0081) | (0.0395) | (0.0250) |
| t+5 | 0.0225 | 0.0768*** | 0.0917*** | 0.0735* | 0.0431* | 0.0473*** | 0.0982** | 0.0665*** |
| | (0.0118) | (0.0177) | (0.0242) | (0.0318) | (0.0214) | (0.0090) | (0.0340) | (0.0193) |
| t+6 | 0.0189 | 0.0554* | 0.0701** | 0.0636 | -0.0036 | 0.0226 | 0.0919*** | 0.0598*** |
| | (0.0106) | (0.0226) | (0.0249) | (0.0579) | (0.0278) | (0.0136) | (0.0222) | (0.0169) |
| t+7 | 0.0166 | 0.0485* | 0.0614** | 0.0458 | -0.0069 | 0.0240 | 0.0317** | 0.0021 |
| | (0.0112) | (0.0217) | (0.0217) | (0.0496) | (0.0260) | (0.0204) | (0.0116) | (0.0176) |
| N | 4139 | 4139 | 4139 | 4139 | 4139 | 4139 | 3408 | 2856 |

† Notes: This table reports the coefficients corresponding to the graphs in figures 10 and 11. These figures plot the estimated coefficients on lags and leads of charter openings in our event study regression. The dependent variable is districts' average achievement in math (plot a) and ELA (plot b). All regressions control for district and time fixed effects, as well as district-specific linear time trends. Coefficients on line $t + k$ correspond to the coefficient on the $k^{th}$ lag of a dummy for a charter opening. All regressions included district and time fixed effects and district-specific linear trends. Achievement is measured as MCAS scores standardized to have mean zero and variance 1 in each year. Standard errors, clustered at the district level, are in parentheses. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

# A Decomposing the Effect of Charter Expansion on Support Services

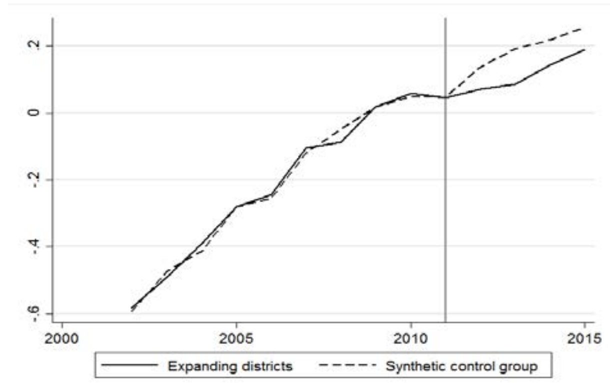
Our results suggest that districts facing the largest charter expansion tend to reduce their per-pupil expenditures on support services while increasing their expenditures on instruction. Yet, evidence shows that cutting spending on support services is detrimental to students' attainment, in particular when cuts target pupils' support such as guidance, health and psychological support, or social work (Carrell and Hoekstra, 2014; Carrell and Carrell, 2006; Reback, 2010).[51]

The results, reported in Figures A.5 and A.6, show that spending cuts in expanding districts mostly target pupil support and instructional staff support. Conversely, spending on general and school administration increases more in expanding districts than in nonexpanding districts. However, our permutation inference shows that (except for general administration) these estimates are not statistically significant. Given that pupil support includes expenses related to counselors, cutting down this spending might negatively impact student achievement, unless other mechanisms compensate for this effect (such as class size reduction).

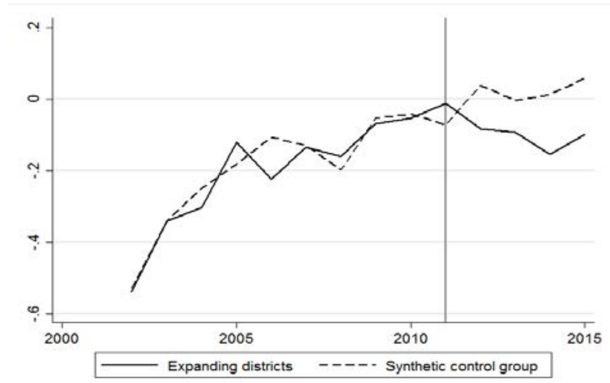
[51] Carrell and Hoekstra (2014) use within-school variation in the number of counselors in elementary school in Florida. They find that an additional counselor significantly increases achievement (particularly for boys), and reduces misbehavior by 20% for boys and 29% for girls. Using a similar identification, Carrell and Carrell (2006) find that lower student to counselor ratios reduce student disciplinary problems, in particular for minority and low-income students. Reback (2010) exploit discontinuities in Alabama's elementary school counselor subsidies to show that additional counselor subsidies reduce the likelihood of disciplinary incidents (such as weapon-related incidents and student suspensions). They do not find any effect on student educational outcome however. To shed light on the effect that cutting down spending on support services could have on student achievement, we decompose overall support spending into its largest components: spending on pupil support, instructional staff support, general administration, and school administration.[52]

Figure A.5: Decomposition of Per-Pupil Expenditures on Support Services

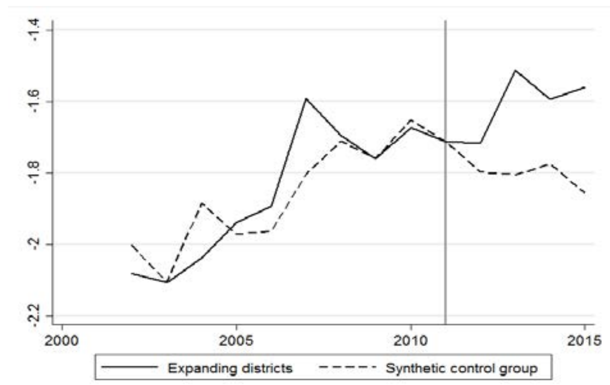
(a) Pupil support



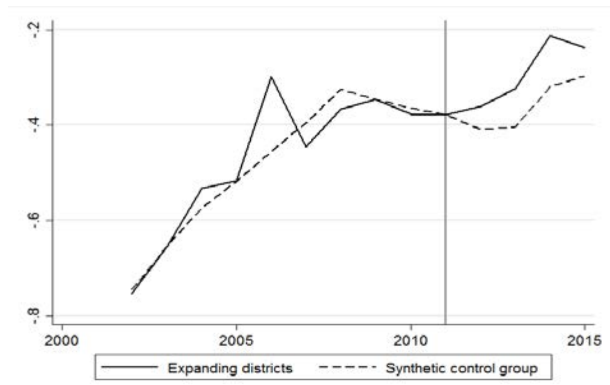

(b) Instructional staff support




(c) General administration



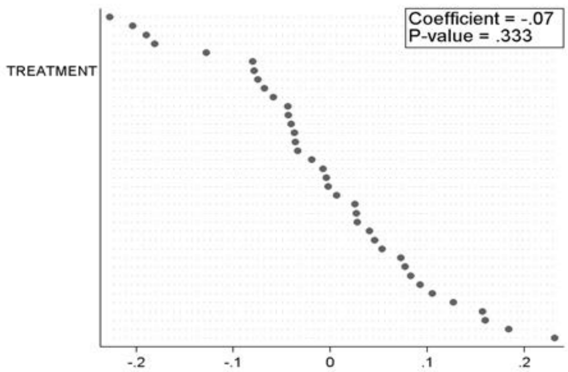

(d) School administration



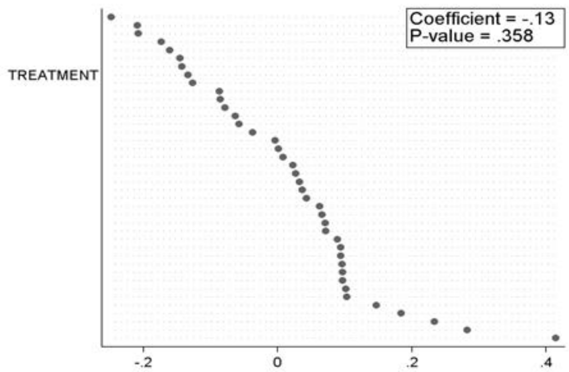

Notes: This figure decomposes districts' per-pupil expenditures on support services into expenditures on pupil support (plot a), instructional staff support (plot b), general administration (plot c), and school administration (plot d). For all expenditure variables, we use the log of the variable. The plain lines represent districts that experienced an increase in the share of students attending charter schools after the 2011 reform (expanding districts), and the dotted lines represent the synthetic control districts. For expanding districts, we plot the average charter share and expenditures. For synthetic control districts, we plot the weighted average of the charter share and expenditures. We use the weights defined by the synthetic control method.

Figure A.6: Placebo Inference for the Impact of Charter Expansion on Components of Per-Pupil Support Services Spending

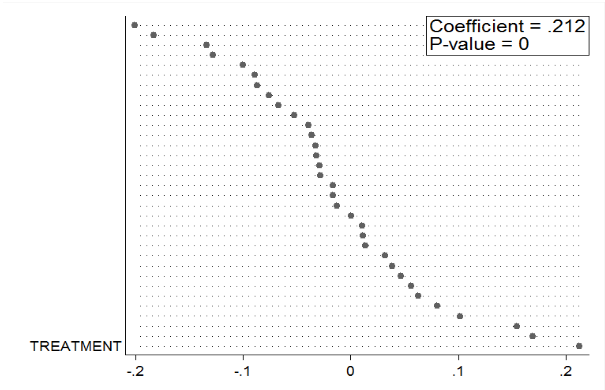
(a) Pupil support



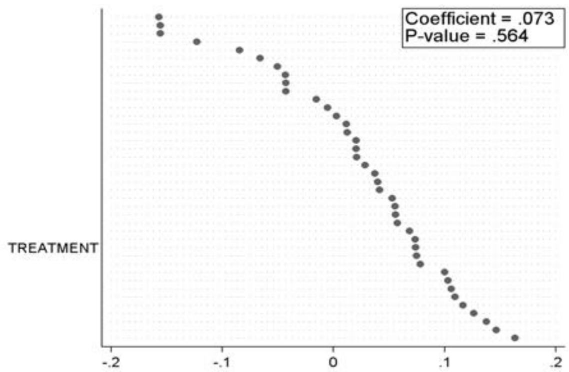

(b) Instructional support




(c) General administration




(d) School administration




Notes: This figure plots the distribution of charter expansion's impact on components of support spending: pupil support (plot a), instructional support (plot b), general administration (plot c), and school administration (plot d). The "TREATMENT" lines report the coefficients when expanding districts are compared to their synthetic control districts. The exact value of each coefficient is reported in the top right corner of each figure. The other lines in the figures report the coefficients when a placebo group of non-expanding districts is compared to its identified group of synthetic control districts. The p-value is calculated as the probability of obtaining a placebo estimate greater than the actual estimated treatment effect (less than it when the effect is negative), multiplied by two to approximate a two-tailed test.

# B Sensitivity Tests for the Synthetic Control Specifications

### Sensitivity tests for predictor variables

For all results presented in the paper, we use five years of lagged outcome variables as predictor variables and five years of charter share. As explained in the methodological section, including lagged outcome variables and lagged charter share is crucial to ensuring that these variables' pre-reform trends are as similar as possible in expanding districts and the synthetic control. However, including too many lagged outcome variables might render other outcome predictors irrelevant (Kaul et al., 2017). In our case, the IV-SC method requires a good fit for both the outcome variable (for the reduced form estimates) and the charter share (for the first stage estimates). Therefore, it is important to check if the number of outcome and charter share lagged values impacts the fit quality for the reduced form and the first stage. In particular, we might worry that adding too many lagged values of the outcome variable makes it more difficult to get a good fit for the charter share.

The sensitivity tests reveal that reducing the number of lagged values for the outcome variable and charter share from five to either three or one systematically yields a worse fit on outcomes, while fit on charter share is sometimes better and sometimes worse. For instance, when looking at districts' total per-pupil expenditures, the pre-reform RMSPE of the reduced form goes up from 0.0179 with five lagged values to 0.0237 with three lagged values and 0.0248 with only one lagged value. Most importantly, reducing the number of lagged values often significantly increases the number of synthetic districts identified, a result that indicates overfitting. For instance, for districts' total per-pupil expenditures, the number of synthetic districts jumps from five to 19 when the number of lagged outcomes shrinks. Including the entire pre-reform path of the outcome variable and charter share as predictors systematically worsens fit quality for districts' expenditures. Such inclusion also generates a significantly worse fit for the charter share and a larger number of synthetic control districts when the outcome is districts' test scores.

**Sensitivity tests for predictor variable weights**

We test two options for the method used to compute the predictor variable weights: a standard method and a cross-validation method. For the results presented throughout the paper, we employ the standard method, which is an iterative optimization procedure that searches among all predictor weights matrices and sets of districts weights for the best-fitting convex combination of the control units. Best-fitting refers to the fit between the pre-reform outcomes of the treated districts and synthetic control. More specifically, the optimization problem uses four inputs: $X_1$, the vector of pre-reform characteristics for the treated district (that is, the expanding districts), $X_0$ the matrix of the vectors of the untreated districts' pre-reform characteristics, $Y_1$ the vector of pre-reform outcomes for the treated district, and $Y_0$ the matrix of the vectors of the untreated districts' pre-reform outcomes.

In the standard optimization method, the optimization proceeds in three steps:

1. For given predictor weights $V = (v_1, ..., v_k)$, the donor weights $w^*(V)$ are chosen to minimize the distance $\|X_1 - X_0 w\|V = \sqrt{(X_1 - X_0 w)' V (X_1 - X_0 w)}$ so that $w^*(V) > 0$ and the donor weights sum up to one.

2. Given the donor weights $w^*(V)$, optimal predictor weights $V^*$ are chosen to minimize

$\|Y_1 - Y_0 w^*(V)\|^2$ so that $V^* > 0$ and the predictor weights sum up to one.

3. The final donor weights are computed as $w^*(V^*)$.

The second method we test is the cross-validation method. This consists of dividing the pre-intervention period into two sub-periods: a training period and a validation period. The optimization follows the three steps presented above, with two exceptions: in step 1, the minimization only applies to the *training period*, while in step 2, the minimization only applies to the *validation period*.

The results in Tables A.8 and A.9 show that using the cross-validation method produces lower-quality fit for outcome variables than the optimization method we use throughout the paper. Quality fit for charter share, however, is not always worse.

**Sensitivity tests for donor pools**

For most fiscal results presented in the paper, we use as a donor pool the districts in the lowest 10th percentile of test scores. For achievement results and results on districts' per-pupil expenditures on fixed costs, we use the districts in the lowest 25th percentile of test scores. For the latter outcomes that are more difficult to match, the larger donor pool markedly increases fit quality. That said, increasing the donor pool size also raises the risk of overfitting: a larger donor pool increases the chance that donor districts are matched because of idiosyncratic noise rather than an underlying trend shared with the expanding districts. Overfitting occurs when expanding districts are matched to a large number of donor districts, many of which have very small weights. Needless to say, we must strike a balance between having a sufficiently large donor pool, in order to have enough donor districts similar to the expanding districts, and not having too large a donor pool, to avoid overfitting. The results in tables A.8 and A.9 rule out concerns about overfitting for results on achievement and per-pupil expenditures on fixed costs. For these outcomes, the number of synthetic districts identified remains relatively constant when we increase the donor pool from the bottom 10th percentile districts to the bottom 25th percentile districts. For all other outcomes, however, overfitting is systematic with the larger donor pool. When looking at districts' average test scores for instance, more than 50 districts are often identified as synthetic controls.

Finally, and perhaps most importantly, for most sensitivity tests we run, the 2011 reform's reduced form effect value is notably consistent across specifications. This is particularly true for districts' expenditures, with the exception of per-pupil expenditures on fixed costs. For that outcome, as mentioned in the section on fiscal spillover, the reduced form estimate seems very sensitive to the specification adopted.

Table A.7: Sensitivity Tests for Synthetic Control Specifications

| | Specification name | Predictor variables | Number of lags | Variable weight method | Donor pool |
|---|---|---|---|---|---|
| | | Outcomes: Districts' Per-Pupil Expenditures | | | |
| 1 | Results reported in Figures 3 and 4 | Expenditures + charter share | 5 | Standard | Bottom 10 |
| 2 | 1 lag for outcome and charter share | Expenditures + charter share | 1 | Standard | Bottom 10 |
| 3 | 3 lags for outcome and charter share | Expenditures + charter share | 3 | Standard | Bottom 10 |
| 4 | All lags for outcome and charter share | Expenditures + charter share | 9 | Standard | Bottom 10 |
| 5 | Additional predictor variables | Expenditures + charter share + cov | 5 | Standard | Bottom 10 |
| 6 | Variable weights: Cross-validation | Expenditures + charter share | 5 | Cross-validation | Bottom 10 |
| 7 | Donor pool: Bottom 25th percentile | Expenditures + charter share | 5 | Standard | Bottom 25 |
| | | Outcomes: Districts' Average Test Scores | | | |
| 8 | Results reported in Figures 7 and 8 | Test score + charter share | 5 | Standard | Bottom 25 |
| 9 | 1 lag for outcome and charter share | Test score + charter share | 1 | Standard | Bottom 25 |
| 10 | 3 lags for outcome and charter share | Test score + charter share | 3 | Standard | Bottom 25 |
| 11 | All lags for outcome and charter share | Test score + charter share | 9 | Standard | Bottom 25 |
| 12 | Additional predictor variables | Test score + charter share + cov | 5 | Standard | Bottom 25 |
| 13 | Variable weights: Cross-validation | Test score + charter share | 5 | Cross-validation | Bottom 25 |
| 14 | Donor pool: Bottom 10th percentile | Test score + charter share | 5 | Standard | Bottom 10 |

† Notes: This table presents the features of each synthetic control sensitivity test. For purposes of comparison, the first row of each panel presents the baseline specification used throughout the paper. The specifications 2 and 9 include only one lagged value for the outcome variable and charter share. They use the average value of the outcome variable over the pre-reform years 2003 to 2011. The specifications 3 and 10 include 3 years of lagged values. They use years 2003, 2007, and 2011 for the lags. The specifications 4 and 11 include all lagged values, that is, the entire pre-reform path of the outcome variable and charter share as predictors (for the years 2002 to 2011). For outcomes on districts' expenditures, the additional predictor variables (specification number 5) are the percentage of black, Hispanic, female, special education, limited English proficient, subsidized lunch, and minority female students. For outcomes on districts' test scores, the additional predictor variables (specification number 12) are districts' per-pupil total expenditures and per-pupil expenditures on fixed costs, instruction, support services, and salaries. Details on specifications number 6, 7, 13, and 14 are provided in the text.

Table A.8: Results of Sensitivity Tests for the Synthetic Control Specifications

| | Number of SC districts (1) | RMSPE of the first stage (2) | RMSPE of the reduced form (3) | Treatment effect (reduced form) (4) |
|---|---|---|---|---|
| | Outcome: Districts' Total Per-Pupil Expenditures | | | |
| Results reported in Figures 3 and 4 | 5 | 0.0026 | 0.0179 | 0.0487 |
| 1 lag for outcome and charter share | 19 | 0.0025 | 0.0248 | 0.0179 |
| 3 lags for outcome and charter share | 19 | 0.0012 | 0.0237 | 0.0477 |
| All lags for outcome and charter share | 7 | 0.0028 | 0.0159 | 0.0500 |
| Additional predictor variables | 7 | 0.0064 | 0.0163 | 0.0514 |
| Variable weights: Cross-validation | 4 | 0.0070 | 0.0401 | 0.0179 |
| Donor pool: Bottom 25th percentile | 55 | 0.0014 | 0.0162 | 0.0160 |
| | Outcome: Districts' Per-Pupil Expenditures on Fixed Costs | | | |
| Results reported in Figures 3 and 4 | 4 | 0.0174 | 0.0469 | -0.0149 |
| 1 lag for outcome and charter share | 19 | 0.0022 | 0.0808 | -0.0833 |
| 3 lags for outcome and charter share | 4 | 0.0103 | 0.0477 | -0.0190 |
| All lags for outcome and charter share | 4 | 0.0071 | 0.0428 | -0.0388 |
| Additional predictor variables | 5 | 0.0071 | 0.0450 | -0.0310 |
| Variable weights: Cross-validation | 6 | 0.0020 | 0.1210 | 0.0299 |
| Donor pool: Bottom 25th percentile | 11 | 0.0015 | 0.0379 | 0.0623 |
| | Outcome: Districts' Per-Pupil Expenditures on Instruction | | | |
| Results reported in Figures 3 and 4 | 5 | 0.0025 | 0.0229 | 0.0724 |
| 1 lag for outcome and charter share | 19 | 0.0019 | 0.0287 | 0.0520 |
| 3 lags for outcome and charter share | 19 | 0.0017 | 0.0306 | 0.0702 |
| All lags for outcome and charter share | 6 | 0.0025 | 0.0151 | 0.0592 |
| Additional predictor variables | 6 | 0.0058 | 0.0199 | 0.0678 |
| Variable weights: Cross-validation | 4 | 0.0036 | 0.0326 | 0.0525 |
| Donor pool: Bottom 25th percentile | 54 | 0.0013 | 0.0239 | 0.0125 |
| | Outcome: Districts' Per-Pupil Expenditures on Support Services | | | |
| Results reported in Figures 3 and 4 | 7 | 0.0024 | 0.0176 | -0.0457 |
| 1 lag for outcome and charter share | 19 | 0.0028 | 0.0424 | -0.0304 |
| 3 lags for outcome and charter share | 18 | 0.0054 | 0.0241 | -0.0439 |
| All lags for outcome and charter share | 8 | 0.0035 | 0.0162 | -0.0424 |
| Additional predictor variables | 7 | 0.0046 | 0.0190 | -0.0348 |
| Variable weights: Cross-validation | 5 | 0.0034 | 0.0532 | -0.0497 |
| Donor pool: Bottom 25th percentile | 54 | 0.0010 | 0.0128 | -0.0346 |

† Notes: See next table.

Table A.9: Sensitivity Tests for the Synthetic Control Specifications (continued)

| | Number of SC districts (1) | RMSPE of the first stage (2) | RMSPE of the reduced form (3) | Treatment effect (reduced form) (4) |
|---|---|---|---|---|
| | Outcome: Districts' Per-Pupil Expenditures on Salaries | | | |
| Results reported in Figures 3 and 4 | 9 | 0.0013 | 0.0177 | 0.0508 |
| 1 lag for outcome and charter share | 19 | 0.0020 | 0.0235 | 0.0303 |
| 3 lags for outcome and charter share | 19 | 0.0009 | 0.0220 | 0.0479 |
| All lags for outcome and charter share | 8 | 0.0023 | 0.0110 | 0.0305 |
| Additional predictor variables | 7 | 0.0072 | 0.0130 | 0.0372 |
| Variable weights: Cross-validation | 9 | 0.0005 | 0.0229 | 0.0452 |
| Donor pool: Bottom 25th percentile | 53 | 0.0014 | 0.0122 | 0.0264 |
| | Outcome: Districts' Average Test Scores in Math | | | |
| Results reported in Figures 7 and 8 | 7 | 0.0139 | 0.0090 | 0.0288 |
| 1 lag for outcome and charter share | 55 | 0.0446 | 0.1314 | 0.0496 |
| 3 lags for outcome and charter share | 270 | 0.0089 | 0.0211 | -0.0088 |
| All lags for outcome and charter share | 54 | 0.0543 | 0.0001 | -0.0086 |
| Additional predictor variables | 8 | 0.0253 | 0.0165 | 0.0440 |
| Variable weights: Cross-validation | 5 | 0.0094 | 0.0327 | 0.0284 |
| Donor pool: Bottom 10th percentile | 7 | 0.0143 | 0.0090 | 0.0296 |
| | Outcome: Districts' Average Test Scores in ELA | | | |
| Results reported in Figures 7 and 8 | 6 | 0.0090 | 0.0150 | 0.0198 |
| 1 lag for outcome and charter share | 49 | 0.0245 | 0.0686 | 0.0075 |
| 3 lags for outcome and charter share | 228 | 0.0196 | 0.0143 | 0.0126 |
| All lags for outcome and charter share | 49 | 0.0617 | 0.0003 | 0.0029 |
| Additional predictor variables | 11 | 0.0118 | 0.0097 | 0.0289 |
| Variable weights: Cross-validation | 6 | 0.0087 | 0.0475 | -0.0515 |
| Donor pool: Bottom 10th percentile | 6 | 0.0122 | 0.0118 | -0.0112 |

† Notes: This table reports results of sensitivity tests done for the synthetic control method. For purposes of comparison, the first row of each panel presents the baseline specification used throughout the paper. The upper panel shows results when the outcome variable is districts' total per-pupil expenditures. Moving down the table, we document results when the outcome variable is districts' per-pupil expenditures on fixed costs, instruction, and support services. The first column shows the number of synthetic control districts identified by the synthetic control algorithm. The root mean squared prediction error (RMSPE) measures the fit quality between expanding districts' pre-reform path and nonexpanding districts' outcome path (column 2) and charter share path (column 3). In column 4, the reduced form treatment effect estimate is the average post-reform gap between the expanding districts' outcome and the weighted average outcome of the synthetic control districts.