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Article

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Abstract: This study investigates the effect that Leadership in Energy and Environmental Design (LEED) had on academic performance using a difference-in-differences (DID) estimator using data from the years 2006–2016. By obtaining data from the Ohio Department of Education and the Ohio Facilities Construction Commission, this investigation examines the effect that LEED design had on the Student Performance Index for schools that opened in the year 2012. Each LEED school was matched with a non-LEED school based on several criteria. The study determined that LEED did not have an impact on the Student Performance Index. Though we find no relationship, green schools do provide educational opportunities that standard buildings do not. We suggest that the state of Ohio should take advantage of potentially untapped opportunities in their green schools program that could enhance both social and ecological sustainability.

Keywords: green schools; LEED schools; Ohio schools; academic performance

1. Introduction

According to the United States Environmental Protection Agency (EPA) [1], there are three pillars of sustainability—environmental, social, and economic. Thus, community projects and policy legislation invoking the concept of sustainability must not only address environmental concerns but also the social and economic realms that allow for all three pillars to interact and reinforce one another. One non-governmental entity that has pushed for a multidimensional approach to sustainability is the United States Green Building Council (USGBC), which administers the Leadership in Energy and Environmental Design (LEED) building certification program. The USGBC offers various LEED certification rating systems depending on the type of building project (e.g., commercial, neighborhood development, home, etc.). Pertinent to this study is the LEED for Schools rating system, which is intended to recognize best practices in design, construction, operation and maintenance for K-12 schools. This LEED standard involves third-party recognition for high performance schools that are healthy for students, comfortable for teachers, and cost-effective [2].

In the United States, the state of Ohio is the country's leader in building green schools [3]. The Ohio Facilities Construction Commission (OFCC) requires public K-12 schools that receive public funds from the state to design for LEED Silver, Gold, or Platinum certification [4]. This was passed in 2007 legislation, (Ohio Revised Code, Resolution 07-124, passed 27 September 2007), calling for energy efficiency and sustainable design. Eligibility for state funding is determined through a ranking of school districts by assessed property valuation per student, updated every year by the Ohio Department of Education. School districts with the lowest property wealth are funded first and receive a higher percentage of state funding. Whereas the state funding for schools is intended to give an incentive to design for LEED Silver or above; there is no financial penalty for not acquiring a Silver certification [5]. As of late 2016, there were 277 public K-12 schools that had received LEED certification levels of certified and above.

Prior research has demonstrated that the benefits of green buildings often extend beyond their direct ecological impact and into the social realm by potentially improving occupant health and well-being (see Reference [6] for a review) and creating business opportunities for local and regional enterprises. As previously noted, the Ohio green schools program also attempts to address issues of resource inequality by giving funding preference to resource-deprived schools. Thus, this program provides an important case study of supposed legislation built around the three pillars of sustainability that address not only ecological concerns, but also social and economic issues simultaneously.

Building off of prior research that has demonstrated that school facilities may also impact academic achievement (e.g., [7–9]), this article evaluates the effect that LEED schools have had on academic performance as measured by the Student Performance Index (SPI) by employing a quasi-experimental design and a difference-in-differences (DID) estimator. This analysis is important as it examines whether LEED buildings have an academic impact; in addition to the health, environmental, and energy efficiency benefits that are often attributed to environmentally sustainable building designs. In other words, this study tests whether LEED school certification not only addresses the ecological aspect of sustainability but also bolsters test scores, which are one aspect of student achievement.

School Building Conditions, Academic Performance, and LEED

A multitude of previous studies have investigated the relationship between school building conditions and student academic performance, finding mixed results. An early review of the literature by McGuffey [10] argued that there was an association between a school's built environment and academic achievement, mediated through features such as building age, lighting, thermal comfort, indoor air quality, and amenities such as science laboratories. Subsequent research has found similar results. Earthman, Cash and Van Berkum [7] studied student test scores in high schools in North Dakota and compared them for "standard" and "substandard" school buildings. They concluded that the condition of the school building did impact student performance [7]. Studies of school building conditions in the state of Virginia also found that better facilities were associated with higher academic achievement [8,9,11]. A synthesis of the literature by Earthman [12] concluded that building condition was positively associated with academic achievement, and he argued that the five most important building features for academic achievement are temperature control, indoor air quality, lighting, acoustical control, and the availability of science laboratories.

Others such as Schneider [13] made similar observations, arguing that air quality, lighting, a quality acoustic environment, temperature control, and a comfortable and safe overall environment were the most important building attributes that impact student learning. In a 2008 study, Duran-Narucki [14] found that the condition of the school building had a significant effect on Mathematics and English language arts test scores, with attendance acting as a mediator between building condition and achievement. Berner [15] examined how socioeconomic status and parental involvement affected building condition and, in turn, academic outcomes. Using a standardized achievement test score as her dependent variable, she showed that parental involvement, socioeconomic status, and racial makeup of an area had a statistically significant impact on building conditions. She then demonstrated that school condition was statistically related to student academic achievement [15]. Uline and Tschannen-Moran also found that school climate acted as a mediator between facilities and academic achievement [16]. In other words, they observed that there tended to be a greater and more serious focus on academics in nicer schools buildings [16]. Lastly, a more recent and longitudinal study by Neilson and Zimmerman [17] found that new construction of school buildings raised test scores.

More nuanced arguments were made by Baker and Bernstein [18] who indicated that the acoustic environment of a classroom had a substantial impact on student learning, but the effect of indoor air quality and lighting on student performance is not straight forward [18]. However, other studies have shown opposing outcomes. Picus, Marion, Calvo and Glenn [19], Bowers and Urick [20], and Martorell, Stange, and McFarlin [21] all concluded that there was no relationship between academic performance and building condition. The National Research Council (NRC) conducted a review of the literature

regarding green schools and their benefits, and called into question some of the earlier literature on building conditions and academic achievement. One of their main findings was that given the complexity of the relationships between humans, the environment, and many other factors, it is difficult to estimate any association [22]. Additionally, the impact on learning appeared small [22]. They argued that the research on green schools and learning outcomes has been flawed and additional examination and new approaches are needed [22]. The NRC noted that many of these studies have had two major limitations: omitted variable bias and the fact that minority students do not end up in poor buildings by chance [22]. Both of these conditions can have a significant impact on the outcomes of models. Magzamen et al. [23] also critiqued the prior research for its reliance on cross-sectional study designs, which are weak for establishing causal inference.

Though there has been much research on the relationship between school conditions and academic achievement, little has been done specifically on LEED-certified schools and achievement. One exception is Davis [24], who used data from LEED schools and non-LEED schools to evaluate whether LEED certification had an effect on various school performance indicators. Her research did not show a statistically significant relationship between being LEED schools and student performance index scores or student and teacher attendance rates [24]. However, the report demonstrated that LEED schools had fewer disciplinary actions per 100 students than non-LEED schools [24]. Though other LEED studies have not examined the rating system's impact on academic achievement, it is conceivable to believe it may improve academic performance by enhancing productivity and well-being through an improved acoustic environment, better indoor air quality, lighting, and thermal comfort. However, like building conditions and academic achievement, the effect of LEED buildings on occupant well-being is complex. Recent studies have found that LEED has no impact on occupant satisfaction [25], and that the effect of green buildings on well-being and satisfaction is mixed [26].

Given the disparate results found in prior research, the reliance on correlational and cross-sectional study designs, and the importance of the Ohio green schools program, we seek to test whether LEED certified school buildings impact student achievement in the state of Ohio, the U.S. leader in LEED schools. We employ a difference-in-differences (DID) estimator, which uses a quasi-experimental design in an attempt to parse out the effect that LEED itself has had on academic performance compared to non-LEED schools.

2. Materials and Methods

The present study relies on panel data from school years 2006 to 2016 (school year 2015–2016). The occupation date (or opening) of each LEED school was provided to the authors by the Ohio Facilities Construction Commission (OFCC). Because this study employs a DID model, the year 2012 was chosen as the "treatment" year because it had the most LEED schools open (46 schools). To create a quasi-experimental design, we matched each LEED school with a non-LEED school, which is an advantage over prior studies that have relied primarily on correlational study designs.

2.1. Matching

Each LEED school that opened in 2012 was matched with a non-LEED school based on several criteria. First, LEED schools were matched with Non-LEED schools based on whether they were elementary, middle, intermediate, or high schools. Second, non-LEED schools in the same school district were used if available. Otherwise, schools within the same county were employed. If there were no adequate matches in the county, athletic conferences (a group of schools who compete in athletics against one another) were used because schools in the same conference tend to be similar. To match schools, socio-economic status (percentage of students economically disadvantaged) and racial composition (the percentage of White, Black, and Hispanic students) were the first criteria used. Next, schools were matched based on the Student Performance Index (SPI). In total, there were 92 total schools used in the analysis, 46 LEED schools and 46 non-LEED schools (see Table 1).

Table 1. LEED and non-LEED schools included in the analysis.

LEED Schools		Non-LEED Schools	
- Arbor ES (Euclid City)	- Maple Heights HS (Maple Heights)	- Akron East CLC (Akron)	- Lincoln ES (Wadsworth City)
- Arrowood ES (Xenia City)	- McGuffey ES (Newark City)	- Arcanum ES (Arcanum-Butler)	- Main ES (Beavercreek)
- Austinburg ES (Geneva City)	- McKinely ES (Xenia City)	- Arcanum HS (Arcanum-Butler)	- Marlington HS (Marlington)
- Barberton East ES (Barberton)	- Midview MS (Midview Local)	- Bedford HS (Bedford)	- Matamoras ES (Frontier Local)
- Barberton West ES (Barberton)	- Mt. Washington ES (Cincinnati)	- Betty Jane CLC (Akron)	- Mt. Airy ES (Cincinnati)
- Bellevue ES (Bellevue City)	- Olde Orchard ES (Columbus)	- Binns ES (Columbus)	- Noble ES (Cleveland Heights- University Heights)
- Bellevue MS (Bellevue City)	- Ostego ES (Otsego Local)	- Caledonia ES (East Cleveland)	- Norwalk MS (Norwalk)
- Bloom Carroll MS (Bloom Carroll)	- Oyler School (Cincinnati)	- CF Holiday ES (West Carrollton)	- Pandora-Gilboa ES (Pandora-Gilboa)
- Bluestone ES (Euclid City)	- Overlook ES (Wadsworth City)	- Cherry Valley ES (Newark)	- Pandora-Gilboa MS (Pandora-Gilboa)
- Buchtel CLC (Akron)	- Pickerington ES (Pickerington Local)	- Clinton-Massie MS (Clinton-Massie)	- Pandora-Gilboa HS (Pandora-Gilboa)
- Chardon Hills ES (Euclid City)	- Pickett ES (Toledo)	- Covedale ES (Cincinnati)	- Richmond Heights ES (Richmond Heights)
- Clinton ES (Columbus)	- Shoreview ES (Euclid City)	- Mt. Airy ES (Cincinnati)	- Ritzman ES (Akron)
- Columbus Grove ES (Columbus Grove)	- Talawanda HS (Talawanda)	- Elmwood ES (Elmwood)	- Riverview East Academy (Cincinnati)
- Columbus Grove MS (Columbus Grove)	- Tecumseh ES (Xenia City)	- Fairfield Union Rushville MS (Fairfield Union)	- Rock Creek ES (Jefferson Area Local)
- Columbus Grove HS (Columbus Grove)	- Valley View ES (Wadsworth City)	- Franklin ES (Delphos)	- Rosa Parks ES (Toledo)
- Cork ES (Geneva City)	- Van Wert ES (Van Wert City)	- Franklin ES (Wadsworth)	- Ross HS (Ross)
- Edgewood HS (Edgewood)	- Violet ES (Pickerington Local)	- Greenon HS (Greenon)	- Rowland ES (South Euclid/Lyndhurst)
- Fairfield ES (Pickerington)	- Wayne HS (Huber Heights)	- Hale ES (Riverside)	- Shady Lane ES (Columbus)
- Franklin-Monroe ES (Franklin-Monroe)	- Westwood ES (Cincinnati)	- Harold Schnell ES (West Carrollton)	- Springfield HS (Springfield)
- Franklin-Monroe HS (Franklin-Monroe)	- Woodsfield (Switzerland of Ohio Local)	- Heritage ES (Medina)	- William Henry Harrison HS (Southwest Local)
- Georgian Heights ES (Columbus)		- Heritage ES (Pickerington)	- Winchester Trail ES (Canal Winchester)
- Graham HS (Graham Local)		- Indian Springs ES (Columbus)	- Woodcrest ES (Columbus)
- Greeneview MS (Greeneview Local)		- Keystone MS (Keystone)	
- Isham ES (Wadsworth City)		- League ES (Norwalk)	
- Liberty ES (Columbus)		- Lincoln ES (Gahanna-Lincoln)	
- Louisville HS (Louisville)			

2.2. Dependent Variable

The Student Performance Index (SPI) was used as the dependent variable; it was obtained from the Ohio Department of Education [27]. SPI is a measure of how well students perform on standardized achievement tests in grades 3, 4, 5, 6, 7, 8 and 10, and is measured on a scale from zero to 120. The SPI is specific to individual buildings. The SPI is logged to correct for skewness.

A DID estimator is only an appropriate estimator if the outcome of interest is trending in the same direction for the treatment and comparison groups. Otherwise, the comparison group is not a good counterfactual. Figure 1 illustrates that the treatment and comparison group are in fact trending in the same direction, and a t-test indicated that the means of the SPI between each group are not statistically different from one another.

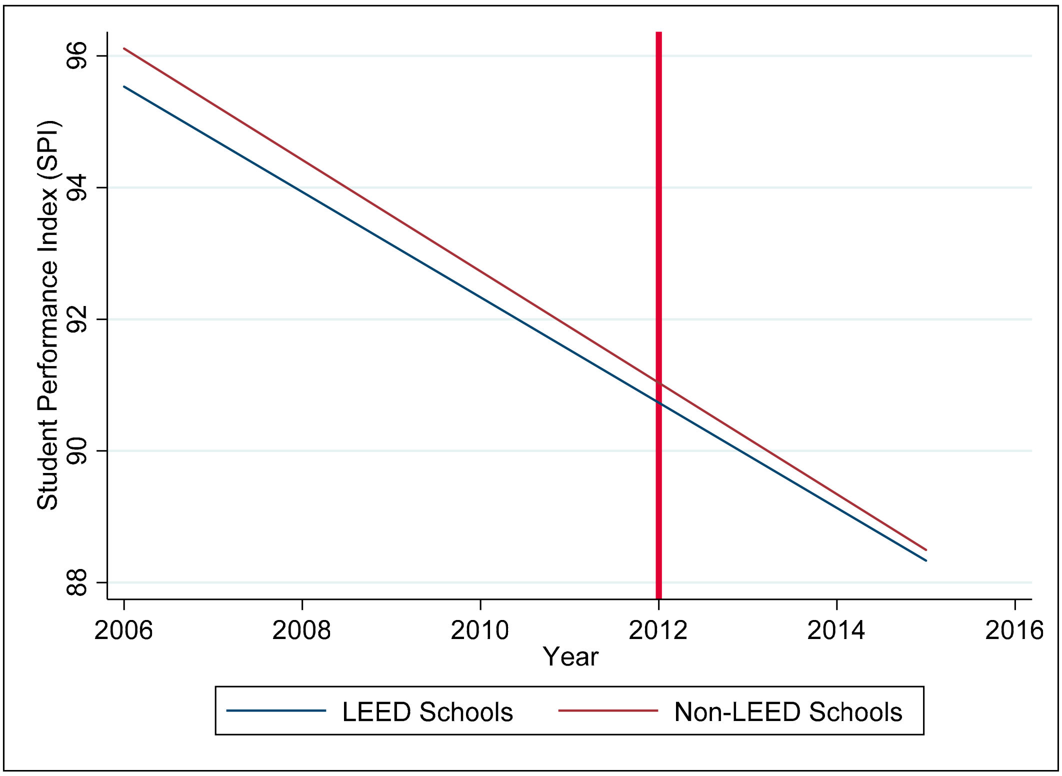

Figure 1. Student Performance Index (SPI) trends.

2.3. Independent Variables

A total of 10 independent variables were collected from the Ohio Department of Education [27] for each school building regarding socioeconomic status, school funding, teacher salaries, and classroom makeup. The variables are as follows: percentage of economically disadvantaged students, the building attendance rate, total enrollment in the building, percentage of female students, percentage of Black students, percentage of White students, percentage of Hispanic students, classroom instruction expenditures per pupil (funds used for classroom instruction per pupil), median teacher salary, and student–teacher ratio (calculated by dividing total enrollment by the total number of full time teachers). Table 2 below provides the descriptive statistics of the treatment (LEED schools) and comparison (non-LEED schools) groups for the dependent and independent variables. Overall, the two groups are very similar. Univariate analyses were conducted to test whether the means between the two groups were different. Of the 11 variables examined for each group, three were statistically different from each other (percentage of female students, classroom instruction per pupil expenditures, and student-teacher ratio).

Table 2. Descriptive statistics of LEED and non-LEED schools.

	LEED Schools		Non-LEED Schools		*p*-Value
	Mean	**SD**	**Mean**	**SD**	
Student Performance Index (SPI)	91.9	12.4	92.3	11.9	0.64
Percent Economically Disadvantaged	47.4%	0.27	48.6%	0.28	0.53
Attendance	94.5%	0.01	94.6%	0.01	0.48
Enrollment	527.8	303.3	491.8	295.1	0.07
Female ***	48.6%	0.02	48.1%	0.03	0.00
Black	22.8%	0.33	22%	0.31	0.71
White	69.1%	0.33	69.4%	0.33	0.87
Hispanic	1.8%	0.03	2.1%	0.03	0.15
Classroom Instruction Per Pupil Expenditures **	$7044.7	1415.6	$7321.0	1665.8	0.01
Median Teacher Salary	$56,938.2	8889.9	$57,126.5	9554.8	0.76
Student-Teacher Ratio ***	18.1	3.1	17.1	2.8	0.00
Number of Schools	46		46		
Total Observations	460		460		

** $p < 0.01$; *** $p < 0.001$. SD refers to the standard deviation.

2.4. Model Estimation Technique

As previously stated, the model employed in this analysis is a difference-in-differences (DID) estimator. The DID estimator is theoretically simple, as it is the change of the treatment group from pre-to-post intervention compared to the comparison group pre-to-post intervention. To employ a DID model in this context, the occupation date (or opening) of each LEED school was provided to the authors by the Ohio Facilities Construction Commission (OFCC). According to the spreadsheet obtained from the OFCC, the first LEED schools in Ohio opened in 2009. However, the year 2012 was chosen as the "treatment" year because 2012 had the most LEED schools open, and it provides sufficient time for post-treatment effects to be observed. Only schools that opened beginning in the Fall of 2012 were included in the analysis. Vocational and Technical Schools were excluded, and the only 2012 school not encompassed in the analysis was Louisa May Alcott Elementary School in Cleveland because no adequate match was found.

The DID model was estimated with the *xtreg* command in Stata 15. The model was estimated using a random-effects model with robust standard errors clustered by school building. Clustering the standard errors in this way makes the model robust to heteroskedasticity and autocorrelation. Two models were estimated. The first model controls for only the variables that were statistically different between the treatment and comparison groups (% female, classroom expenditures per pupil, and student teacher ratio). The second model controls for the additional variables listed in Section 2.3 and Table 2. The partial and full models are as follows:

Partial Model: $\ln(\text{SPI}_{it}) = \beta_1 \ln(\%\ \text{Female}_{it}) + \beta_2 \ln(\text{Classroom Exp}_{it}) + \beta_3 \ln(\text{Student-Teacher Ratio}_{it}) + \beta_4\ \text{LEED}_i + \beta_5\ \text{Post-Opening}_t + \beta_{\text{DID}}\ \text{LEED}_i \times \text{Post-Opening}_t + e_{it}$

Full Model: $\ln(\text{SPI}_{it}) = \beta_1 \ln(\%\ \text{Female}_{it}) + \beta_2 \ln(\text{Classroom Exp}_{it}) + \beta_3 \ln(\text{Student-Teacher Ratio}_{it}) + \beta_4 \ln(\%\text{Economically Disadvantaged}_{it}) + \beta_5 \ln(\text{Attendance Rate}_{it}) + \beta_6 \ln(\text{Total Enrollment}_{it}) + \beta_7\%\ \text{Black}_{it} + \beta_8\%\ \text{Hispanic}_{it} + \beta_9 \ln(\text{Median Teacher Salary}_{it}) + \beta_{10}\ \text{LEED}_i + \beta_{11}\ \text{Post-Opening}_t + \beta_{\text{DID}}\ \text{LEED}_i \times \text{Post-Opening}_t + e_{it}$

β_1, β_2, and β_3 in both models control for the variables found to be statistically different in LEED schools compared to non-LEED schools. β_1 controls for the percentage of female students in the school building, β_2 controls for classroom expenditures per pupil, and β_3 controls for the student–teacher ratio. In the partial model, β_4 is a dummy variable equal to 1 if the school is LEED and 0 otherwise. B_5 is a dummy variable equal to 1 for the years 2012–2015, i.e., post-intervention years, and 0 for

pre-intervention years. β_{DID} is the coefficient of interest (the DID coefficient), which estimates the impact of LEED design on test scores for LEED schools relative to non-LEED schools from before and after LEED buildings opened. Subscript i indexes each school, whereas subscript t indexes each year, and e_{it} is the disturbance term for each school in each year. The full model builds on the partial model by including the other socioeconomic and education-related indicators listed in Table 2 (percentage of economically disadvantaged students, the school attendance rate, total building enrollment, percentage of black students, percentage of Hispanic students, and the median teacher salary at the school building). The percentage of white students is not included in the model for collinearity reasons. All the variables are naturally logged except for the percentage of black and Hispanic students because a number of schools do not have any students that fit this demographic, and zero is not able to be logged.

This research design offers several advantages, the main one being that it is relatively robust against omitted variable bias. The DID estimator controls for unobserved, time-invariant differences between LEED and non-LEED schools. It also controls for unobservable effects that change between pre-LEED and post-LEED years that effect both LEED and non-LEED schools (e.g., changes in state funding). Though this is a relatively robust research design, there are several time-variant variables that were not controlled for, most importantly, the building condition of each school. The building conditions of the non-LEED schools are not held constant. It is also possible that some of the comparison group schools built a new building during the time-period used in this study. However, the schools used in this analysis are part of school districts that are largely similar to each other. Because of the state funding mechanism for building schools in Ohio, it is not likely that the non-LEED schools built new schools during this time. The only known school that did build a new building during this period was Springfield High School, which combined two high schools together. Additionally, the specific credits obtained by each LEED school are not controlled for in the models. Schools obtain different credits, and may elect to not pursue certain credits that potentially have the most impact on student performance.

3. Results

Table 3 below reports the estimates for the partial and full models. For the partial model, the results indicate those of the three time-variant variables included, only the coefficient for classroom expenditures per pupil is statistically significant (coefficient = −0.245). The percentage of female students and the student–teacher ratio are not statistically significant. Of the dummy variables, the Post-Opening coefficient is negative and statistically significant. However, it is not a variable of interest. The negative coefficient simply indicates that the SPI scores for non-LEED schools after 2012 were 96 percent (or 4 percent lower than) the SPI scores before 2012 (antilog of −0.045 = 0.96) for non-LEED schools. The main coefficient of interest, (Post-Opening × LEED) is not statistically significant, indicating that LEED design has no effect on academic achievement as measured by the SPI.

Moving to the full model, which has the full set of controls, we observe a similar finding. In this model, classroom expenditure per pupil, the percentage of economically disadvantaged students, the attendance rate, the percentage of black students, and the Post-Opening dummy variable are statistically significant. Classroom expenditure, the percentage of black students, and Post-Opening all were negatively associated with the SPI, whereas attendance positively affected the SPI. As in the partial model, the DID coefficient was found not to be statistically significant. This indicates that LEED buildings have no effect on student performance, as measured by the SPI. ("Placebo" year dummies were used in the sensitivity analysis to test the robustness of the findings (see Appendix A). The years 2010, 2011, and 2013 were employed and none were found to be statistically significant. These findings further support the robustness of the results.)

Table 3. Difference-in-Differences Model for the SPI, 2006–2016.

Variables	Partial Model	Full Model
ln (% Female)	0.097 (0.64)	0.116 (0.068)
ln (Classroom Expenditures Per Pupil)	−0.245 *** (0.36)	−0.126 ** (0.040)
ln (Student-Teacher Ratio)	−0.008 (0.33)	−0.015 (0.030)
ln (% Economically Disadvantaged)		−0.025 ** (0.008)
ln (Attendance Rate)		2.391 *** (0.650)
ln (Total Enrollment)		0.011 (0.012)
% Black		−0.243 *** (0.035)
% Hispanic		−0.276 (0.143)
ln (Median Teacher Salary)		0.108 ** (0.038)
Post-Opening	−0.045 *** (0.010)	−0.039 *** (0.010)
LEED	−0.012 (0.019)	−0.009 (0.013)
Post-Opening × LEED	−0.004 (0.013)	0.002 (0.012)
R^2 within	0.130	0.208
R^2 between	0.441	0.785
R^2 overall	0.339	0.637
N	919	913
Mean Observations	10	9.9

Robust standard errors clustered by school are in parentheses; ** $p < 0.01$; *** $p < 0.001$.

4. Discussion

Using a robust quasi-experimental design, the results suggest that LEED does not have an effect on academic performance as measured by the SPI in the state of Ohio. This study's employment of a DID estimator moves beyond previous analyses that have relied on cross-sectional and correlational study designs and provides results that are more robust to omitted variable bias. The findings of this study conflicts with some of the earlier research regarding building condition and academic achievement but is consistent with recent literature that has employed more robust statistical designs and techniques (e.g., [21]). One limitation of this study is that it only observed the effect of LEED on the SPI for schools that opened in 2012, so the generalizability of these findings to other years is limited. However, the LEED schools used in this study represent a diverse set of schools from rural, suburban, and urban areas, encompassing most of the state. Therefore, it is unlikely that the results would vary for a different sample of schools. However, the results could vary across different states in the United States.

Though the findings of this study were null, it is important to acknowledge that the primary purpose of the LEED certification program is to promote sustainable buildings, best construction, management practices, and well-being of occupants. The USGBC indicates, "In school terms, LEED

is like a report card for buildings, demonstrating to the community that a facility is built and/or operated in a way that supports the health and well-being of occupants and saves energy, resources and money" [28] (p. 9). However, this does not mean that LEED, or green schools in general, do not have an effect on academic outcomes. Prior research has demonstrated that green buildings can provide students with hands-on learning experiences regarding sustainability, which may in turn positively affect academic achievement (e.g., [29–31]). Thus, one way in which the state of Ohio may improve their green schools program is by requiring schools to use the building as a teaching tool, which creates experiences for students to learn about sustainable practices and living. The design of the school *itself* may only modestly, or not at all, affect academic outcomes, but planning and requiring it to be used as a teaching tool can provide benefits that standard buildings cannot. Therefore, Ohio's green schools program offers potentially untapped opportunities for further environmental education that can enhance sustainable practices and awareness among students, on top of its ecological and cost-saving benefits.

As was previously noted, LEED schools largely vary in what credits they obtain. In the newest version of LEED (v4), there are eight categories to obtain credits from: Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation, and Regional Priority. From the existing literature, Indoor Environmental Quality (IEQ) would likely have the most significant impact on student academic performance. However, it is possible to earn the highest LEED certification (Platinum) without earning a single IEQ credit. It is assumed that when designing a school for LEED certification, a wide range of factors must be considered. Each decision to earn an additional point in LEED certification requires a potential additional expenditure. An interview with a LEED consultant verified that some of the highest cost credits include IEQ2 (Increased Ventilation), IEQ 9 (Enhanced Acoustical Performance), and IEQ8 (Daylight & Views), which are, compared to the other credits, the ones that would likely have the most impact on student productivity and performance. An analysis of costs for each IEQ credit was beyond the scope of this report. Some communities may choose to focus on low-emitting materials versus views and should be free to make the choice based on the added costs for the added points. However, the state should also require certain credits that enhance acoustical performance, daylight, dryness, thermal comfort, indoor air quality, ventilation, etc., which are consistent with the prior literature [22].

Furthermore, given the extent of the LEED schools program in Ohio, future research to evaluate the success of this program should focus on particular building credits, energy use, health outcomes of faculty, staff and students, resources use, and cost savings. Other measures of academic performance related to attendance or student/faculty well-being may also be interesting measures for future research. A holistic evaluation of the program would better address the effectiveness of the green schools program in terms of its sustainability benefits and provide policymakers in Ohio and other states key information with regards to what works and what does not.

5. Conclusions

Overall, LEED for schools is a complex rating system that can have positive impacts on a multitude of human and environmental outcomes. This study used a longitudinal, difference-in-differences (DID) estimator to investigate the potential effect that LEED schools had on academic achievement in Ohio. The study found that there was no relationship. However, the null finding should not deter the state of Ohio from further advancing this program. Rather, policymakers should actively seek to maximize the unrealized opportunities of this program by requiring that schools use the building as a learning tool and adopt certain credits that have been shown to positively affect learning. Doing so could potentially impact academic achievement, while simultaneously teaching students about sustainable practices. Steering the program in this direction and extending its reach further into the social realm by improving educational outcomes and learning experiences would allow the program to maximize its potential to facilitate sustainable outcomes, beyond its current and primarily ecological and cost-saving concerns.

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Appendix A

Table A1. Placebo years 2010, 2011, and 2013.

Variables	PY 2010 Partial Model	PY 2010 Full Model	PY 2011 Partial Model	PY 2011 Full Model	PY 2013 Partial Model	PY 2013 Full Model
ln (% Female)	0.126 (0.068)	0.125 (0.070)	0.114 (0.067)	0.124 (0.069)	0.066 (0.063)	0.090 (0.067)
ln (Classroom Expenditures Per Pupil)	−0.270 *** (0.038)	−0.098 * (0.040)	−0.251 *** (0.036)	−0.105 ** (0.040)	−0.204 *** (0.034)	−0.101 ** (0.037)
ln (Student-Teacher Ratio)	−0.017 (0.036)	−0.014 (0.034)	−0.010 (0.035)	−0.014 (0.032)	−0.004 (0.032)	−0.012 (0.029)
ln (% Economically Disadvantaged)		−0.044 *** (0.008)		−0.035 *** (0.008)		−0.019 * (0.008)
ln (Attendance Rate)		2.585 *** (0.693)		2.520 *** (0.679)		2.168 *** (0.631)
ln (Total Enrollment)		0.007 (0.013)		0.007 (0.012)		0.010 (0.012)
% Black		−0.229 *** (0.038)		−0.239 *** (0.036)		−0.259 *** (0.035)
% Hispanic		−0.533 *** (0.150)		−0.426 ** (0.147)		−0.184 (0.138)
ln (Median Teacher Salary)		0.086 * (0.039)		0.099 * (0.038)		0.094 * (0.037)
Post-Opening	−0.009 (0.009)	−0.006 (0.010)	−0.028 ** (0.009)	−0.022 * (0.009)	−0.065 *** (0.010)	−0.059 *** (0.010)
LEED	−0.012 (0.019)	−0.014 (0.014)	−0.012 (0.019)	−0.012 (0.013)	−0.011 (0.020)	−0.007 (0.013)
Post-Opening*LEED	−0.004 (0.012)	0.009 (0.012)	−0.003 (0.012)	0.008 (0.012)	−0.003 (0.014)	−0.001 (0.014)
R^2 within	0.041	0.161	0.073	0.171	0.203	0.268
R^2 between	0.437	0.792	0.441	0.791	0.441	0.777
R^2 overall	0.324	0.630	0.329	0.632	0.335	0.646
N	919	913	919	913	919	913
Mean Observations	10	9.9	10	9.9	10	9.9

PY refers to "placebo year." Robust standard errors clustered by school are in parentheses; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

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