TEPP

WORKING PAPER

N° 2026-4

EXTERNALITY EFFECTS OF CLIMATE ADAPTATION POLICIES IN URBAN AREAS : THE CASE OF GREEN SCHOOLS IN PARIS

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TEPP – Theory and Evaluation of Public Policies - FR CNRS 2042

Externality Effects of Climate Adaptation Policies in Urban Areas: the Case of Green Schools in Paris

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Abstract

This study measures the external effects of climate adaptation policies in cities. It focuses specifically on transforming schoolyards into green, cooled environments in the Paris metropolitan area. This adaptation strategy aims to reduce urban heat islands and improve livability. Using a large, geolocated dataset of housing transactions and a difference-in-differences (DiD) approach, we estimate the effect of the staggered implementation of the green school program on property values at various distances from treated schools. Our results reveal a substantial increase in the value of residences located within 20 meters of a green school. On average, the price of these residences increased by 8% compared to residences close to non-green schools. Additionally, we find that the externality effect of schoolyard renovation declines steeply with distance. These findings demonstrate that greening schools significantly enhances local amenities by creating cooling islands and shaded areas and improving environmental quality. This benefits not only pupils, but also surrounding residents.

Keywords : Climate resilience, Green Schools, Externalities, Difference-in-differences.

Jel codes : *R21, Q51, Q54*

1 Introduction

There is a long literature in economics on agglomeration externalities (Fujita and Thisse, 1996; Glaeser, 2010), both in developed and developing countries (Guevara et al., 2018). They discuss the pros and the cons of agglomeration. On the one hand, agglomerations allow for savings in transport costs, that translate into an easier exchange of goods, people, and ideas (Glaeser, 2010). For example, larger cities offer more cultural amenities and a greater variety of shopping and dining options than smaller cities (Waldfogel, 2008). Urban concentration can also have health and environmental benefits: such as reducing accidents (Ewing et al., 2003) and health problems (Ewing et al., 2014), transport-related emissions (Nechyba and Walsh, 2004), at least in partial equilibrium (Gaigné et al., 2012), and the amount of artificially created land.

However, these benefits are limited by the fact that, due to urbanisation, metropolitan areas tend to have higher temperatures than surrounding areas, and more frequent, longer and more intense heat waves are expected by 2050 (IPCC, 2023).[1] These heat waves will be even more intense in metropolitan areas, which will become urban heat islands with very high night and summer temperatures, with major consequences for the well-being of urban populations. With global warming, heat-related health risks are expected to increase and may be exacerbated by the urban heat island (UHI) effect. A recent study by Huang et al. (2023) shows that heat extremes have a significant impact on the health of urban populations, with a median 45% increase in mortality risk associated with UHI. On average, they estimate that heat and cold related mortality caused by UHI is associated with an economic impact of €192/€314 per urban adult per year in Europe.

These adverse effects of urban warming influence household residential location choices. It has been shown that, in warmer climates, households exhibit 'sprawling behaviour': they settle on larger plots of land, further away from city centres (Grout et al., 2016). Consequently, global warming and urban sprawl may reinforce each other.

It is therefore necessary to find public policies that mitigate these heat island phenomena. There are several possible solutions, ranging from changes in the behaviour of urban dwellers (e.g. opening windows at night, changing work schedules or reducing outdoor activities) to "grey" solutions based on the modification and adaptation of urban infrastructures (e.g. bioclimatic buildings, high-albedo coatings and irrigation of outdoor

[1]Large cities tend also to have more congestion, pollution, and crime than smaller cities (Glaeser, 1998; Glaeser and Sacerdote, 1999).

urban spaces). Another important option is to increase the amount of green space in cities. Numerous studies have shown that vegetation plays an important role in cooling cities (Iungman et al., 2023). In Paris, it is estimated that an additional 300 hectares of vegetation could reduce the temperature by 0.5 to 1°C on a hot day (based on a scenario from the Météo-France (2012) study). According to the Paris urban Planning Agency, in a town 5km from Paris (Aubervilliers), where a car park was transformed into a cool island by planting 70 trees, the average perceived temperature has dropped by -2.5°C (Météo-France, 2012). The limitation, however, is that large cities generally do not have the space to create new parks. Therefore, the possibility of greening existing areas must be explored, as this greening can take place on streets, pavements and schoolyards, but also in buildings: courtyards, roofs and walls.

The aim of this paper is to evaluate the impact of such a policy. We are interested in the greening of schoolyards in Paris, a large agglomeration. We will assess the effect of this program on housing prices. If the greening of schools leads to envrionmental services in the surrounding areas, this should be reflected in private housing prices. To identify the externality of a green schools programme, we use a combination of hedonic regression and a difference-in-differences (DiD) strategy. We compare the variation in the prices of dwellings located near green (renovated) schools with those located near non-green (un-renovated) schools. Identification relies on the exogeneity of green school selection relative to neighborhood dynamics, and on the subsequent parallel trends between dwellings in the treatment and control groups. As Paris schools were renovated between 2018 and 2023, we also address the potential bias of staggered DiD research designs by using the method robust to heterogeneous treatment effects proposed by Borusyak et al. (2024). Our main dataset is the DV3F dataset, which records housing transactions in Paris between 2010 and 2023. For each transaction, we have information on various characteristics of the dwelling as well as its geographic location. We merge this dataset with a geolocated dataset of schools in Paris, which includes information on green renovations and renovation dates.

Like all metropolitan areas, Paris is no exception to the increasing summer heat. In this context, the "Resilience Strategy" was created in 2017 to address the current climate challenges, and the "OASIS" (Openness, Adaptation, Sensitisation, Innovation, Solidarity) programme, launched in 2018, is one of the nature-based solutions adopted by the city. It aims to develop green urban open spaces and create cooling islands using school and college playgrounds. The planning strategies for schoolyards are linked to a large number of environmental and social issues. Firstly, as urban green spaces, green schools could provide many urban ecosystem services, such as: cooling islands, flood mitigation, aesthetics and well-being, food and urban vegetable gardens, environmental awareness, leisure activities and social interaction (Revi et al., 2014). In addition, green schools could be an important vector for children's health, well-being and environmental awareness (van Dijk-Wesselius, 2020).

Therefore, while the primary objective is to reduce the urban heat island effect, greening schools can also enhance the visual appeal of the school environment and potentially increase its attractiveness to parents. Consequently, it may influence housing prices through not only the reduction of temperatures in the surrounding area, but also *via* at least two additional mechanisms: improved visual amenities and increased school attractiveness. School quality is indeed a key factor in neighbourhood desirability (Hussain, 2023), particularly for primary schools, which are generally located near residential areas. In France, where location significantly impacts access to public education, this is particularly pertinent. The presence of multiple potential mechanisms makes studying the external effects of such environmental policies even more pertinent, as it suggests these initiatives could have broader social and economic benefits beyond their environmental goals.

The results from DiD estimates indicate a 8% increase in the price of dwellings located within 20 metres of a green school compared to those located near a non-green school. However, the externality effect of school greening declines sharply with distance. While it is not possible to exclude an effect of renovation up to 40m from the school, the estimated effect becomes very close to zero from the 40m buffer. Consequently, our results strongly suggest a preference for living close to a green school. The results suggest that temperature reduction and enhanced visual amenities are the most likely mechanisms at play.

Our first contribution is to assess the externalities of greening policies. Although many evaluations exist of the externalities of other urban policies, such as urban renewal policies (Rossi-Hansberg et al., 2010; Ahlfeldt et al., 2016; Chareyron et al., 2022; Aarland et al., 2017), these evaluations do not address the same issues as greening policies. Unlike urban renewal policies, which aim to enhance neighborhood attractiveness through building renovation or redevelopment, greening policies focus on improving local amenities. These policies generate positive externalities, delivering environmental benefits and improving neighborhood attractiveness through a single intervention.

Our second contribution is to the literature on the valuation of environmental amenities. We aim to assess the valuation of environmental amenities using a quasi-natural experiment. Although there is a substantial body of literature on the valuation of climate or environmental amenities (Nilsson, 2014; Sander and Haight, 2012), few studies use exogenous variation to obtain a causal effect (Rouwendal and Bouwknegt, 2023; Han et al., 2025).

Section 2 presents the relevant literature and describes the green schoolyard project in Paris. The data and summary statistics are presented in section 4. The empirical strategy is presented in section 3. The results are presented in Section 5 and we conclude in section 6.

2 Background

2.1 Literature review and studied mechanisms

While there are very few economic evaluations of public policies aimed at adapting metropolitan areas to global warming, our study is related to two strands of literature based on hedonic analysis: one assessing the valuation of climate and the other assessing the valuation of environmental amenities.

Studies that have used hedonic analysis to examine climate valuation in Europe and the US have consistently found that higher winter temperatures are valued with a positive and significant willingness to pay. However, the disamenities of hot summer temperatures appear to be substantial in the US (Koirala and Bohara, 2014; Ma and Yildirim, 2023) but not in relatively cold countries such as Germany and Great Britain (Rehdanz, 2006; Rehdanz and Maddison, 2009). In Asia, some articles have also been interested in the effect of climate, such as Li et al. (2018), which examines the effect of temperature on house prices in Hong Kong. In line with the literature, our first mechanism is the following: [M1: Cooling Islands and Shaded Areas] Planting vegetation in schoolyards can lower local temperatures and improve thermal comfort by providing shade and cooling the air. These areas can provide nearby residents with cool, shaded spots during periods of high heat.

Moreover, a substantial number of studies have investigated the valuation of environmental amenities, associated with proximity to urban green spaces (UGS). These studies have examined the impact of various factors, such as the type of green space (e.g., forest, park, or cemetery), its size, and its location. Examples of these studies include those examining open spaces (Nilsson, 2014), parks (Czembrowski and Kronenberg, 2016; Liebelt et al., 2019), trees (Rouwendal and Bouwknegt, 2023; Han et al., 2025), and a combination of both (Sander and Haight, 2012). The results are unequivocal, showing the high value that the public places on green spaces in urban areas, especially for their aesthetic qualities. Thus, the second mechanism is: [M2 Aesthetic Quality] The positive effect of green school grounds on the value of neighbouring properties is partly due to an improvement in the urban environment's aesthetic and visual quality, which reinforces the neighbourhood's perceived attractiveness.

Studies show that UGS play an important role in cities by meeting many quality of life and health needs of residents (Mckinney and VerBerkmoes, 2020; Revi et al., 2014). First, they can provide many environmental benefits and ecosystem services such as landscape aesthetics, air quality and cooling (Motazedian et al., 2020; Aram et al., 2019; Norton et al., 2015), recreational activities (Hofmann et al., 2012; Arnberger and Eder, 2011) or noise reduction (Rey Gozalo et al., 2017). They can also provide social benefits such as increased social cohesion (Jennings and Bamkole, 2019), reduced crime (Escobedo et al., 2018) and improved public health (Iungman et al., 2023). Furthermore, the establishment of an urban park generates significant spillover effects, potentially increasing the size and number of urban parks in surrounding areas (Choumert and Cormier, 2011).

If we now look at school renovation and greening strategies, they are linked to a large number of environmental and social issues. As an UGS, green schools could be an important vector for children's healthy development, well-being and environmental awareness (Bikomeye et al., 2021; van Dijk-Wesselius, 2020; van Dijk-Wesselius et al., 2018). Barenie et al. (2023) used a natural experiment to demonstrate the effects of the Little Rock Green Schoolyard Initiative in Arkansas (USA) on air quality and lower temperatures, physical activity, obesity, sleep quality and children's pro-social behaviour. The results of these studies show that green school programmes have a positive impact on children's enjoyment of the schoolyard, on their return to calm and attention after recess, on their pro-social orientation, and that these renovated schoolyards significantly increase physical activity (Bikomeye et al., 2021). In light of these findings regarding the educational quality of green schools, we propose the third mechanism: [M3 School Attractiveness] Greening school grounds makes the school itself more attractive, for example through environmental commitment or health benefits for children. This may increase demand for housing near the school, even in the absence of a direct need to live nearby.

All these studies mentioned above that deal with the effects and outcomes of UGS take the form of economic evaluations (Cortinovis and Geneletti, 2019) that support and guide urban planning decisions, or are naturally occurring experiments and quasi-experiments that observe the externalities of UGS on environmental quality or health (Benton et al., 2018; Mayne et al., 2015). However, in addition to these values, UGS can have other positive or negative impacts on cities and their inhabitants : the economic externalities. If these externalities are not fully taken into account, the importance of UGS will be underestimated or overestimated, which will affect public decisions. To the best of our knowledge, very few studies have evaluated the impacts and economic externalities of implementing urban greening policies on a large scale. An exception is the study by Long and Shi (2021), which used a DiD model and measured positive and significant spillover effects of the opening of urban parks on surrounding consumer services such as restaurants, retail, clothing, accommodation and services of daily living.

2.2 The green schools programme in Paris

In response to new social, economic and climatic challenges, Paris developed its resilience strategy in 2017. This strategy includes the European OASIS project (Openness, Adaptation, Awareness, Innovation, Solidarity). The project's two main objectives are to reduce the local health risks associated with heatwaves and to promote social cohesion by gradually transforming schoolyards into green spaces. According to the Paris Council for Architecture, Town Planning and the Environment (CAUE 75), schoolyards cover a total of 70 hectares in Paris. This represents a significant amount of space that can be turned into green areas in an urban environment where land is in high demand, making the creation of new urban parks difficult.

Around the world (in Spain, Italy, Belgium, Denmark, Colombia, Canada, etc.), other local authorities are implementing "cool-schools" or "green-schools" projects to make schoolyards more inclusive and climate-friendly spaces. Urban well-being and the role of green spaces in the environmental and social development of all are also at the heart of the Paris *Oasis* project. By planting vegetation, they help to reduce urban heat islands (Antoniadis et al., 2020), improve children's mental health, well-being and awareness of nature (van Dijk-Wesselius, 2020), provide a tree-lined view for neighbouring houses, and offer a space for social interaction and neighbourhood life for those that are open to the public at weekends[2](Jennings and Bamkole, 2019).

Specifically, in 2023, of around 700 schools in Paris, including nursery schools, primary schools and colleges[3], 120 are part of the green schools programme. The selection of schools to be modified as a priority was primarily based on their cooling potential. In fact, a preliminary study (Karam et al., 2019) aimed to identify the highest priority school playgrounds among the 670 schools belonging to the City of Paris. In their article, Karam et al. (2019) developed a cooling indicator based on the ratio of the area of the schoolyard exposed to strong sunlight to the total area of the schoolyard. Out of the 670 schools surveyed, they identified 38 with high cooling potential, 157 with medium potential, and 286 with moderate potential.

Despite these objective criteria, political factors may have influenced the number of green schoolyards implemented across Paris. The city is divided into 20 arrondissements, each governed by its own mayor, in addition to the overall mayor of Paris. Depending on the arrondissement, the local mayor's level of support for the project may have either facilitated or hindered its implementation. For instance, some eastern arrondissements appear to have been particularly proactive in adopting the program[4], while some western arrondissements seem less involved[5].

Table A1 in the Appendix shows that between 2018 and 2023, about 20 schoolyards were renovated each year, except in 2018 when only 4 were included in the programme. The others will be renovated gradually, at a rate of about 40 schools per year. The renovation has several objectives: the ground is landscaped in order to better manage rainwater and to avoid heat storage if it is not shaded, the vegetated areas are increased (tree planting, green roofs and walls, educational gardens, orchards, plant huts, etc.), the furniture is designed to meet the needs of a better sharing of space, shade and water are also more present in the schoolyards.

Figure A1 in the Appendix shows photographs of the same school in Paris's 11th arrondissement before and after the greening initiative. Nearly half of the courtyard was depaved to allow rainwater to seep directly into the wood chip surface. Two mounds were added for topographical relief and to support vegetation, and recreational facilities were

[2]By 2023, 10% of schools will be open to the public at weekends.

[3]High schools are not part of the OASIS project as they are not managed by the City of Paris.

[4]The 12th arrondissement of Paris has publicly emphasized its involvement, stating that it is one of its priorities.

[5]In our dataset, only one green schools is located in the 16th arrondissement of Paris.

installed. Before the renovation, the entire 1,930-square-meter area accessible to children was fully impermeable. After the work was completed, 600 square metres were made permeable, and 114 square metres were planted.[6]

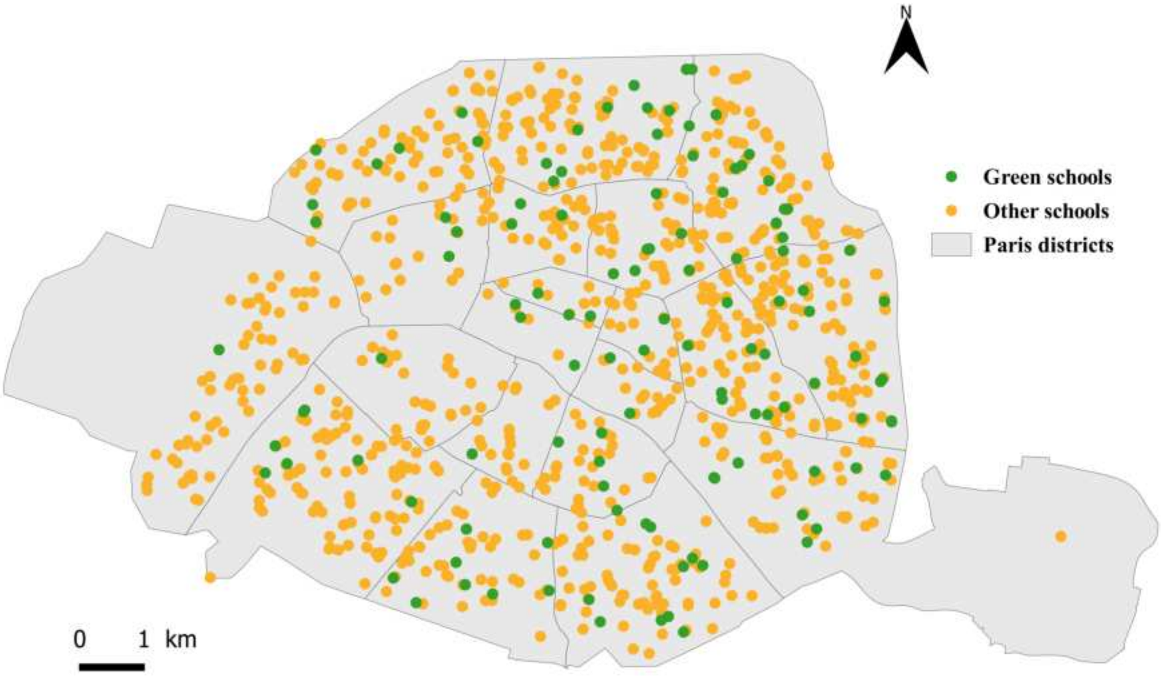

Figure 1: Green and non-green schools in Paris in 2023

Sources : OASIS programme and RAMSESE, 2024

Figure 1 shows the spatial distribution of green and non-green schoolyards in Paris in 2023. The spatial distribution of green and non-green schools appears to be relatively similar across Paris. The proportion of green schools is slightly lower in the western part of the city, as is the case for non-green schools. An exception is the 16th arrondissement, which had only one green school in 2023. Several schools in the 16th arrondissement will join the OASIS program in 2024.

3 Empirical Strategy

We use a DiD strategy to identify the effect of green schools on transaction prices. We compare the price changes of transactions close to a renovated school with those close

[6]This example is not one of the most green-covered schools in the Oasis project. According to the Oasis Project Observatory, one limitation of this school is that it could be even more vegetated: https://www.observatoire-oasis.fr/ecole-elementaire-keller/.

to a non-green school or a school not yet included in the programme. The approach is based on the fact that whether or not a school is renovated to become a green school is essentially exogenous to variations in the price of dwellings sold near the school. Although the choice of which schools to renovate is not random—being primarily based on cooling potential and possibly other factors such as the political orientation of the boroughs—this selection does not appear to be driven by specific local dynamics. Therefore, it is likely that the price trends in the two groups would have been similar in the absence of the program.

The two-way fixed effect model would be:

$$log(P_{ict}) = \alpha + \lambda T_i \times Post_t + \theta X_{it} + \phi_t + \mu_c + \epsilon_{ict} \tag{1}$$

Where P_{ict} is the price per square metre of dwelling i near school c at time t. T_i takes 1 for a dwelling near a green school and 0 for a dwelling near a non-green school. $Post_t$ takes 1 after the date when the nearest green school was renovated and 0 before. School renovations took place in the summers between 2018 and 2023. For example, $Post_t$ for a dwelling near a school renovated in July 2018 takes the value 1 if the transaction occurred after July 2018. Therefore, the interaction $T_i \times Post_t$ takes the value 1 for sales of dwellings close to a renovated school after the renovation date and 0 for sales of dwellings close to a non-green school at any date or close to a green school before the renovation date. We use alternative buffers to define the proximity of a dwelling to a school (i.e. 20m, 40m, 60m, 80m, 100m). The control group therefore also consists of dwellings located near a school. Time fixed effects (month × year) capture common shocks affecting transactions in the treatment and control groups. μ_c controls for unobserved time-invariant differences in school zone location characteristics.

As a result, λ captures the average effect of the renovation in the years following its completion, for which we have observations. The main identifying assumptions are that the treatment and control groups would have followed the same trends in the absence of the intervention and that there is no anticipation of the policy's effects.

We do not include any control variables in our main specification, following the recommendation of De Chaisemartin and d'Haultfoeuille (2023). They indeed argue that "if the pre-trend coefficients in the TWFE regression without controls [...] are precisely estimated and not significantly different from zero, there may not be a compelling reason to include controls in the estimation". Nevertheless, as a robustness check, we include a set

X_{it} of hedonic characteristics of dwelling i (i.e., size in square metres, year of construction and dwelling floor).[7]

As pointed out in several studies, such as the one by Goodman-Bacon (2021), one problem with estimating a staggered treatment using two-way fixed effects is that already treated transactions are included in the control group, which may introduce bias under certain conditions (i.e. heterogeneity in the treatment effect across groups and over time). Several methods have been proposed to deal with this bias (de Chaisemartin and D'Haultfœuille, 2020; Callaway and Sant'Anna, 2021; Sun and Abraham, 2021; Borusyak et al., 2024). They have in common to modify the units that can act as effective comparison units to avoid comparing treatment units to inappropriate controls (Baker et al., 2022). We therefore use the Borusyak et al. (2024) method in order to estimate the average treatment effect as well as dynamic effects. This method corresponds to regressing the log of housing prices on group and time fixed effects in the sample of untreated observations, and using that regression to predict the counterfactual price of treated observations. Estimates of the treatment effect of those observations are then obtained by substracting the counterfactual to the actual price. This method has the advantage to be more efficient than the ones of Callaway and Sant'Anna (2021) and Sun and Abraham (2021) under the assumptions of the Gauss-Markov theorem and parallel trends (de Chaisemartin and D'Haultfœuille, 2022).

Estimating the dynamic effects of greening would allow us to assess the plausibility of the parallel trends assumption and to test for the presence of anticipation of the policy's effects. Because the City of Paris implements consultation and communication phases to inform stakeholders—including schools, local residents, and parents—about greening projects, the greening of a school is generally announced some months before the start of the works. Anticipation is therefore possible, but it could be tested by examining the differential evolution of prices between the groups before the implementation of the program.

[7]We do not control for the type of housing (apartment/house), as all the dwellings are flats.

4 Data and Summary Statistics

4.1 Data

We use the DV3F dataset, which contains all housing transactions, supplemented by descriptions of the dwellings from the land register. For each sale recorded, the type of dwelling (house *versus* flat), the date of the transaction, the floor level, the transaction price, the floor area, the number of rooms, the number of bathrooms and specific services such as a designated parking space and a balcony or terrace are recorded. Transactions are geolocated and cover the period 2010-2023.

We only consider sales of existing private dwellings (i.e. we exclude auctions, exchanges, expropriations, land for sale, etc.) and off-plan sales. We also exclude sales of industrial, commercial, or similar buildings and dwellings. We have also filtered out transactions in the first and last percentiles of the price per square metre distribution to eliminate extreme outliers.

Figure 2: **Dwellings and schools geolocations** The buildings are shown as darker polygons, the orange dots represent the dwellings geolocation using its GPS coordinates, while the green stars represent the school's geolocation.

We also use a geolocalised list of schools (nursery, primary and secondary) in Paris, as well as information on which schools have been renovated[8]. We can therefore determine, for each housing transaction, whether it is close to a green school or not. In practice, we

[8]The list is available on the website data.education.gouv.fr.

will use different buffers to define the proximity of a transaction to a school and observe whether the results vary with the buffer. The distance between each housing transaction and the school is accurately measured as the shortest door-to-door walking path. As illustrated in Figure 2, the distance is calculated as the crow flies between two points: the housing transaction (dots) and the school (stars).

For the sake of brevity, we present descriptive statistics using the 20m buffer as it provides a reasonable number of observations. In fact, there is a trade-off between proximity and the number of observations. The potential externality effect of renovation is expected to decrease steeply with distance, but very few dwellings transacted in the period 2010-2023 are located within 10m of a school.

4.2 Summary Statistics

Table 1: Characteristics of schools and their socio-economic environment

	Non-green schools		Green schools		Eq. test
	Mean	S.D.	Mean	S.D.	p-value
	Panel A: School characteristics				
Colleges	0.17		0.08		0.016
Primary School	0.45		0.52		0.160
Nursery	0.38		0.39		0.853
Opening year	1973.45	12.62	1971.49	10.26	0.113
	Panel B: Socio-economic environment of the school				
Prop. French nationality	0.86		0.85		0.755
Prop. 0-19 years of age	0.20		0.19		0.836
Prop. 20-64 years of age	0.64		0.65		0.329
Prop. 65 or more	0.16		0.16		0.373
Prop. Male	0.47		0.48		0.188
Socio-professional classes:					
Prop. Craftsman	0.03		0.03		0.902
Prop. Executive	0.27		0.27		0.506
Prop. Intermediate Professions	0.15		0.16		0.081
Prop. Employees	0.13		0.14		0.459
Prop. Operators	0.05		0.05		0.204
Prop. Retirees	0.18		0.18		0.662
Observations	588		119		

NOTES— The last column shows the p-value of two-sample tests of equality of mean or proportion.

SOURCE— Census 2016, RAMSESE 2024

Panel A of Table 1 shows the characteristics of green and non-green schools. Green schools are less likely than non-green schools to be secondary schools and more likely to be primary schools. However, they are comparable in terms of the proportion of nursery schools and the date of construction.

Panel B of Table 1 compares the socio-demographic characteristics of the neighbourhoods of green and non-green schools[9]. The environments of the two types of school are very similar, none of the differences are statistically significant and the differences never

[9]The information on the socio-demographic characteristics of the neighbourhoods comes from the 2016 French census. These data are merged with the school data set at the IRIS level. IRIS is an infra-communal geographical unit defined for statistical purposes as having between 1800 and 5000 inhabitants.

exceed one percentage point. This tends to support the exogeneity of the choice of green schools with respect to neighbourhood characteristics.

Table 2 describes the characteristics of dwellings located less than 20 metres from a school (including green and non-green schools) before the first renovation in 2018. Prices are on average slightly higher for dwellings close to a green school than for those close to a non-green school. These dwellings are also more recent and larger. However, they are comparable in terms of type and standard and consist solely of flats, as one would expect in the Paris region. Despite differences in baseline levels between the two groups, the difference-in-differences strategy will account for any time-invariant differences.

Table 2: Characteristics of dwelling transactions located near a school before 2018

	Non-green school<20m		Green school<20m		Eq. test
	Mean	S.D.	Mean	S.D.	p-value
Price (€)	382,050	298,859	416,244	314,758	0.027
Surface area (m^2)	49.67	33.91	52.50	37.35	0.109
Age of dwelling	1821.08	391.22	1872.66	209.69	0.007
Flat	1.00	0.05	1.00	0.07	0.339
Dwelling floor	2.42	1.42	2.33	1.43	0.267
Observations	2436		447		

Notes— The last column shows the p-value of two-sample tests of equality of mean or proportion.
Source— DV3F 2010-2023, RAMSESE 2024

Figure 3 shows the evolution of the log price per square metre between 2010 and 2023 for two transaction groups: one consisting of dwellings located less than 20 metres from a green school and the other from a non-green school. The price is slightly higher in the treated group at the beginning of the period in 2010. Both groups then show a very similar evolution until 2019, demonstrating the exogeneity of the renovation assignment. Towards the end of the period, there is a gap between the two groups, suggesting that a green school tends to increase the price of surrounding dwellings.

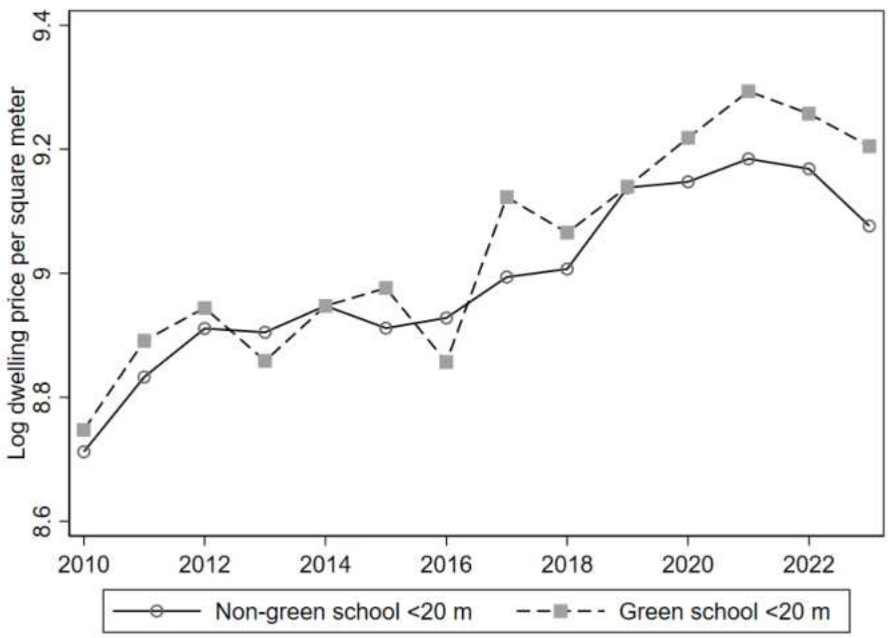

Figure 3: **Price variation in the control and treatment groups.** The dashed lines represent the price variation in the treatment group (*i.e.*, transactions of dwellings that are at less than 20m from a green school), while the solid line represents the price variation in the control group (*i.e.*, transactions of dwellings that are at less than 20m from a non-green school).

5 Results

5.1 Main results

Table 3 shows the results of the robust efficient estimator of Borusyak et al. (2024) with alternative definitions of the proximity of a dwelling to a school. We successively use buffers of 20m, 40m, 60m, 80m and 100m around the school. Only the estimated coefficient of the variable of interest is reported.

As indicated above, the sample size and therefore the precision of the estimates increases significantly with the buffer used. Nevertheless, only the estimated coefficients for the 20m buffer are significant at the 5% level. The renovation of the school increases the price of dwellings within 20m by about 8% on average in the five years following the renovation.

Table 3 shows the average effect of renovation between the date of renovation and the end of 2023. However, the effect of renovation on house prices may not be immediate and may vary over time. Therefore, we estimate the time-varying effect of renovation using the method proposed by Borusyak et al. (2024). This also allows us to test the assumption of parallel trends.

Table 3: Green School effect on housing prices

	Log of housing price per square metre				
	(1)	(2)	(3)	(4)	(5)
	20m	40m	60m	80m	100m
Average effect	0.079**	-0.023	-0.001	-0.001	-0.002
	(0.037)	(0.031)	(0.023)	(0.016)	(0.014)
School F.E.	X	X	X	X	X
Year F.E.	X	X	X	X	X
Observations	4,805	16,939	37,145	66,234	100,186

Notes: *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at the school level in parentheses.

Source— DV3F 2010-2023, RAMSESE 2024

Figures 4 show the event study plot for all the different buffers. For each buffer, the estimates are consistent with the parallel trends assumption: the estimated coefficients for the years before renovation are insignificant and show no discernible pre-trends. After the renovation, there is no discernible increase for any buffer, except for transactions less than 20 metres from a school, where the effect appears to increase over time. The estimated coefficients are very close to zero and insignificant in the two years after the renovation date. Then, three years after the renovation, the effect becomes significant at the 5% level and the estimated price increase is 22%. Five years after the renovation, the estimated coefficient is 30%. However, the precision of the estimate is reduced due to the small number of transactions for which the renovation took place five years ago and the lower bound of the 95% confidence interval is 14%.

The results therefore provide evidence of a positive externality effect of the green school on the surrounding neighbourhood. However, the externality declines sharply with distance from the school. This rapid decline is consistent with studies on housing renovation and neighbourhood renewal (Ahlfeldt et al., 2015; Rossi-Hansberg et al., 2010), although here the decline with distance is even steeper.

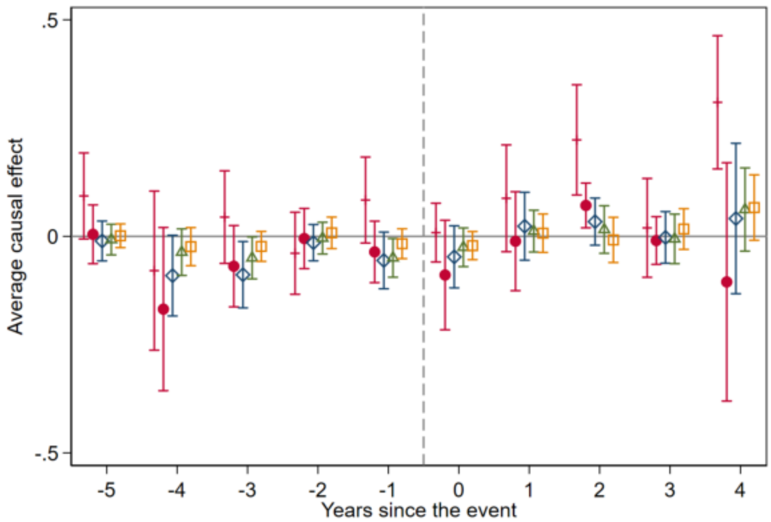

Figure 4: **Effect of proximity to a green school on house prices.** The bars represent 95% confidence intervals. The dependent variable is the logarithm of house prices per square metre. Never treated is used in the control group.

The fact that the only detectable effect concerns dwellings located less than 20 m from the school, corresponding to neighbouring buildings or buildings on the other side of the road (see Figure 2 for geolocation and distance measurement), probably gives an indication of the mechanism of the effect. It suggests that the effect could be related to the proximity of cool and shaded areas [M1: Cooling Islands and Shaded Areas],or the improvement in aesthetic and visual quality due to the greening of the schoolyards [M2 Aesthetic Quality]. The interpretation of the results cannot *a priori* be linked to an increase in the attractiveness of the school ([M3 School Attractiveness] due to environmental awareness, children's healthy development, etc.), for which there is no reason for a household to locate so close to the school. In France, school enrollment is determined by a defined catchment area surrounding each public school, within which households must reside. However, this zone is broader than the immediate surroundings of the school and does not justify moving just 20 meters closer. As such, we find no evidence to suggest that the green-schools programme has a positive economic externality in the form of increased school attractiveness.

5.2 Robustness

As mentioned in section 2, green schools are relatively evenly distributed compared to non-green schools in Paris, with the exception of the 16th arrondissement, which has few renovated schools in 2023. We check the robustness of the results by excluding this district and present the results in Table A2 in the Appendix. The results are essentially unchanged from those in Table 3.

As indicated above, in a difference-in-differences framework, if the pre-trend coefficients are precisely estimated and not significantly different from zero, it is not recommended to add controls. Nevertheless, we can check the robustness of the results by including hedonic controls. Table A3 and Figure A2 in the Appendix show the results of the static and dynamic effects with controls. Although slightly less significant, the results are similar to those without controls.

We present the results of the robust efficient estimator of Borusyak et al. (2024) as the main one, since it is more efficient under the assumptions of the Gauss-Markov theorem and parallel trends. However, if the assumption of parallel trends is not respected, the estimator may be more biased than the others, depending on the nature of the violation of parallel trends (de Chaisemartin and D'Haultfœuille, 2022). We therefore compare the results obtained using the method of Borusyak et al. (2024) with those obtained using the methods of de Chaisemartin and D'Haultfœuille (2020) , Callaway and Sant'Anna (2021), Sun and Abraham (2021) and two-way fixed effects for the 20m buffer. The results presented in Figure A3 in the Appendix are similar for the different methods. All but one show a significant effect at the 5% level without controls. When controls are included, the estimated coefficients remain similar across methods. However, the other estimates become less precise than those of Borusyak et al. (2024) and are not significant, although they are close to significance at the 10% level.

5.3 Heterogeneity

We now assess the heterogeneity of the impact of school renovations on dwellings located less than 20 metres away. This will provide insight into the underlying mechanisms (see section 2.1 for details of these mechanisms [M1, M2 and M3]).

Although the sample size is limited, we split the sample based on dwelling size (i.e., two rooms or fewer, more than two rooms, and by surface area: 45^2 or more vs. smaller units) and by floor level (first floor or lower vs. higher floors). We also investigate whether there is a difference in the effect between green primary schools and green high schools. This analysis could provide indirect evidence on the underlying mechanisms. Indeed, we can expect that if the green renovation effect is mainly due to improvements in the visual aspects of the school (e.g. more trees, grass, etc.), it would mainly affect dwellings located on higher floors with a view of the school. Conversely, if the effect is mainly driven by parents wanting to live close to their child's school, we might expect a stronger effect on larger, family-oriented dwellings.

The results are presented in Table 4. The effect is significant at the 5% level only for primary schools, and not for high schools. However, due to the smaller number of green high schools, the effect for high schools cannot be accurately estimated. Furthermore, while the effect is only significant for dwellings smaller than $45m^2$ and significant at the 1% level for dwellings on the second floor or above, the differences between subsamples are not significant. The relatively low precision of the estimates limits the ability to draw firm conclusions about the underlying mechanisms. Therefore, while the third mechanism relating to an increase in school quality is not supported due to the highly localised nature of the externality, it is difficult to determine which mechanism — cool and shaded areas proximity or aesthetics quality — prevails, or whether both contribute to explaining the positive externality.

Table 4: Heterogeneity of the effect

	Log of housing price per square metre			
	(1)	(2)	(3)	(4)
	2 rooms or less	More than 2 rooms	$45m^2$ or less	More than $45m^2$
Average effect	0.065	0.050	0.104**	0.108
	(0.055)	(0.042)	(0.044)	(0.075)
Observations	2026	2779	2737	2063
	1st floor or lower	2nd floor or higher	Primary school	High school
Average effect	0.070	0.126***	0.082**	0.287
	(0.092)	(0.040)	(0.037)	(0.506)
Observations	1278	3524	4226	579

Notes: *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at the school level in parentheses. School and year of the transaction fixed effects are included in all estimations.

SOURCE— DV3F 2010-2023, RAMSESE 2024

6 Conclusion

Due to climate change, urban areas face increasing challenges, particularly with regard to rising temperatures and the urban heat island effect. To address these issues, the city of Paris implemented the OASIS program, which aims to transform schoolyards into cooler, greener, and more climate-friendly spaces. Our study evaluates the economic externalities of this policy by examining how the greening of schools influences nearby housing prices. Using a difference-in-differences strategy, we estimate the causal effect of these renovations.

Our analysis reveals a positive impact on property values. On average, the price of dwellings within 20 meters of green schoolyards increased by approximately 8%. However, the externality effect decreases sharply with distance; no significant effect was found beyond 20 meters from the school. Our results suggest that greening schoolyards significantly improves local amenities, primarily by mitigating the urban heat island effect. This benefits not only the school itself, but also the surrounding residential area.

Despite these promising results, pinpointing the exact mechanism responsible for the increase in property values remains challenging. This increase may result from the proximity of cooling islands or the aesthetic appeal of green spaces. Furthermore, the hypothesis that enhanced school attractiveness draws families closer is not strongly supported because the externality effect diminishes rapidly with distance.

In light of these findings, urban planners should prioritize school greening initiatives, especially in dense urban areas where creating new parks is difficult. While the primary benefit appears to be reducing heat, combining greening projects with community engagement could increase participation and long-term success. Future studies could further explore the projects' impact on housing markets and their potential to promote social cohesion in urban neighborhoods.

Although our study reveals the positive externalities of the green school program on housing prices, there are still several areas of research that need to be explored. For example, the rapid attenuation of the externality effect with distance raises questions about how greening can be planned to maximize spatial impact. Investigating combinations of greening strategies, such as integrating school greening with street tree planting or neighborhood green corridors, could provide insight into more comprehensive urban cooling approaches. Additionally, the extent to which socioeconomic factors mediate the relationship between greening and housing prices warrants further investigation. More detailed data on demographic changes around green schools could clarify whether these initiatives inadvertently lead to gentrification and the displacement of low-income residents. Another promising line of research is the longitudinal evaluation of greening projects. Our study focused on the five-year period after renovation, but the long-term effects may differ, particularly as cities continue to adapt to climate change. Investigating whether positive effects on property values persist, diminish, or reverse after a decade would provide valuable insights for urban policy.

In conclusion, green schools are a promising strategy for mitigating urban heat and improving residential well-being. However, future research should address the identified gaps by focusing on mechanisms, spatial planning, socioeconomic impacts, and long-term outcomes to optimize these initiatives. Deeper understanding of these dynamics will enable urban planners to design more effective and equitable interventions.

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Appendix

Table A1: Number of new green schools per year

Year	2018	2019	2020	2021	2022	2023	Total
Number of new green schools	4	25	16	25	22	26	118

Source— OASIS Programme

((a)) Keller Primary School Before Greening

((b)) Keller Primary School Before Greening

((c)) Keller Primary School After Greening

((d)) Keller Primary School After Greening

Figure A1: **Example of Greening: A Primary School in the 11th Borough**

Source— https://www.observatoire-oasis.fr/ecole-elementaire-keller/

Table A2: Green School effect on housing prices in Paris excluding the 16th district

	Log of housing price per square metre				
	(1)	(2)	(3)	(4)	(5)
	20 m	40 m	60 m	80 m	100 m
$T_i \times Post_t$ ($\hat{\lambda}$)	0.068*	-0.022	-0.004	-0.006	-0.010
	0.039	0.026	0.023	0.016	0.015
School F.E.	X	X	X	X	X
Year F.E.	X	X	X	X	X
Observations	4,602	15,917	34,782	62,159	93,577

Notes: *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at the school level in parentheses. The control variables are: surface area and its square, date of construction, and dwelling floor. School and year of the transaction fixed effects are included in all estimations.

SOURCE— DV3F 2010-2023, RAMSESE 2024

Table A3: Green School effect on housing prices (with controls)

	Log of housing price per square metre				
	(1)	(2)	(3)	(4)	(5)
	20m	40m	60m	80m	100m
Average effect	0.069*	-0.020	-0.001	-0.004	-0.008
	(0.039)	(0.026)	(0.023)	(0.016)	(0.015)
School F.E.	X	X	X	X	X
Year F.E.	X	X	X	X	X
Observations	4,698	16,534	36,241	64,625	97,789

Notes: *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered at the school level in parentheses. The control variables are: surface area and its square, date of construction, and dwelling floor.

SOURCE— DV3F 2010-2023, RAMSESE 2024

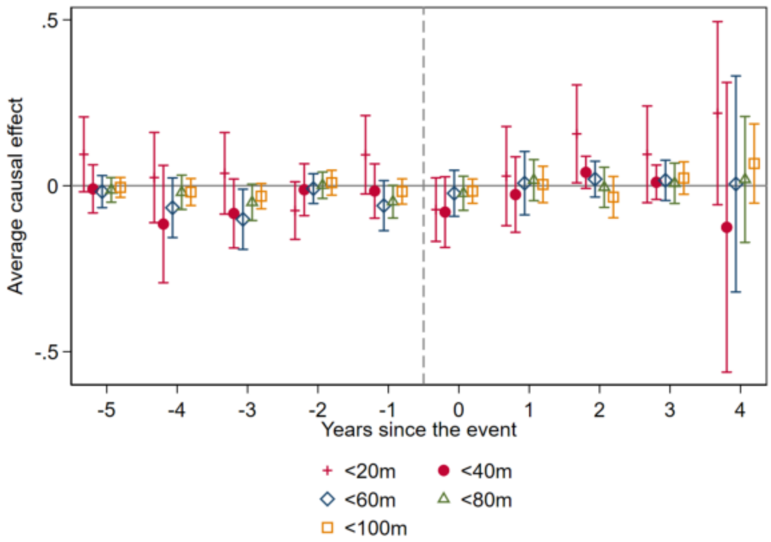
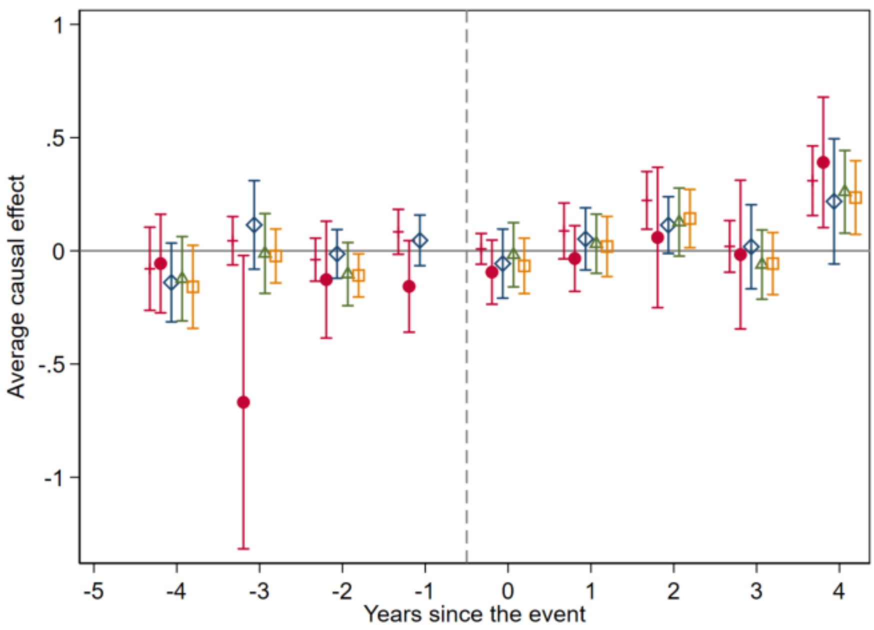
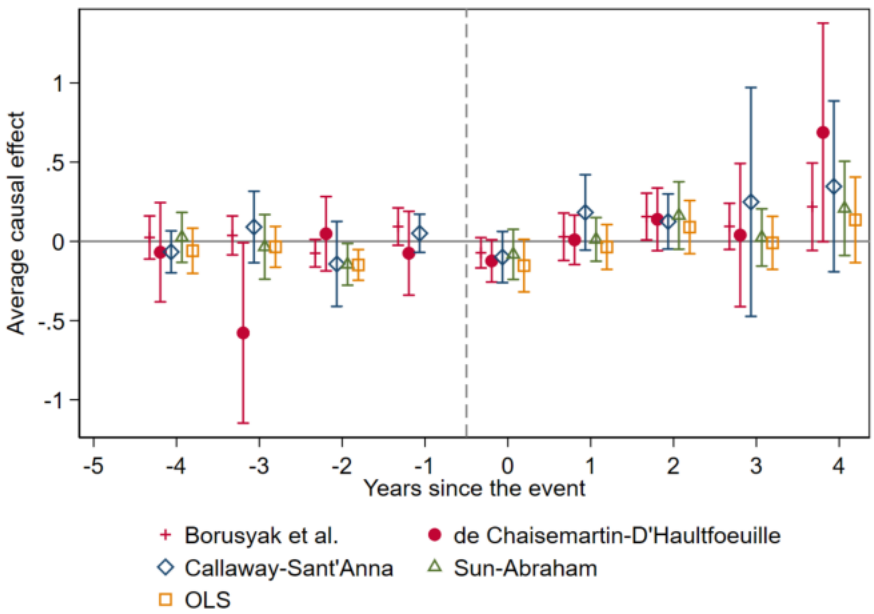


Figure A2: **Effect of proximity to a green school on house prices (with controls).** The bars represent 95% confidence intervals. The dependent variable is the logarithm of house prices per square metre. Never treated is used in the control group. The control variables are: area and its square, date of construction and floor of the dwelling.



((a)) Without control



((b)) With controls

Figure A3: **Effect of having a Green School at less than 20m on housing prices**
The bars represent 95% confidence intervals. The dependent variable is the logarithm of housing prices per square metre. Control variables are: surface area and its square, date of construction and dwelling floor.

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