LUISS

Degree Program in *Corporate Finance*

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The financial burden of penalties for building owners under LL97

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1. INTRODUCTION

In recent decades, increasing importance has been given to the issue of environmental sustainability as a response to the escalating environmental disasters caused by rising CO2 emissions, which seriously threaten the balance of the ecosystem in which we live.

Sustainable development has thus become central to today's economic activities. Indeed, a number of global initiatives has been implemented to encourage a change to more sustainable patterns of production and consumption.
However, several sectors have a responsibility in this system. Among them, the real estate sector contributes 30-39% for harmful gas emissions with 72% coming from the energy consumption of existing buildings. Starting from this data, which has been provided by the Environmental Protection Agency and the GRESB, it is mandatory to approve specific law and regulations to contain the emissions generated by buildings and to reduce their ecological footprint.
This is the background for the legislation that is the subject of this research: Local Law 97 of 2019 (hereafter, "LL97" or the "Law"), a New York City regulation, part of the Climate Mobilization Act, which aims to reduce gas emissions and energy consumption for buildings in New York City by 40% by 2030 and 80% by 2050.

In particular, the above mentioned law imposes progressively harsher fines for the buildings that exceed the emission limits provided by LL97, which are set in relation to both the type of building and its size, which indirectly defines the energy consumption. The law envisages five time horizons in which penalties are disbursed. Specifically, there is an initial period of adaptation to the regulation, from 2024 to 2029, in which the sanctions provided for are practically nil. This is followed by four further time periods (2030-2034, 2035-2040, 2040-2049, and 2050 onwards) in which the sanctions become progressively more stringent.

The objective of this thesis is twofold: on the one hand to analyze, by means of two key financial variables - Net Operating Income (NOI) and Capital Expenditure (CAPEX) - the likelihood of a building being subject to a penalty according to LL97; on the other hand, for the buildings actually penalized, to investigate the extent to which these variables influence the size of the penalty.

To answer these two research questions, a two-stage regression study was carried out:

(i) the first stage involves logistic regression to estimate the probability of a building being penalized, using a binary dependent variable -penalties- which takes a value of one if the building is penalized and zero otherwise;

(ii) the second stage involves OLS regression, conducted on the subsample of buildings effectively penalized to assess the impact of NOI and CAPEX on the amount of penalties.

The thesis is structured as follows: section 2- Conceptual Framework & Literature Review - aims to provide the theoretical and regulatory context for the research. In this section, the importance of the research is underlined on the one hand by highlighting the amount of harmful gases produced by the real estate sector, which therefore made the introduction of LL97 necessary, and on the other hand the lack in the existing literature of a specific study on the direct financial impact of the sanctions provided for by the aforementioned legislation. Section 3- Data and Methodology - describes the data collection method and the statistical method implemented for the research. Section 4 - Descriptive Statistics and Results - presents the results that emerged from the study. Finally, section 5 - Limitations and Recommendations - describes some of the main shortcomings of this study and provides recommendations for further research.

2. CONCEPTUAL FRAMEWORK & LITERATURE REVIEW

The objective of this research is to analyze the financial burden of penalties imposed by the New York Local Law 97 – a law on sustainability in real estate sector that aims to reduce CO2 emissions from buildings. To provide a comprehensive understanding, it is necessary to contextualize the topic beginning with the analysis of the regulatory and environmental context that led to its introduction. Next, the literature review underscores the importance of the study: although numerous studies have examined the impact of environmental penalties in different contexts, none of these have specifically examined the direct impact of penalties under LL97 for building owners. Therefore, address this gap in the literature is the goal of this analysis.

2.1 What is sustainability?

The term sustainability derives from the Latin *"sustinere"* – that means to support, defend, foster, preserve and/or take care for -.

Sustainability has long been discussed as a complex concept that considers the interconnection between respect for the environment, social wellbeing and economic development. Keeping in balance the relationship between these three components - environment, economy and society - is the goal of sustainable development, in order to ensure present and future needs and better living conditions for the whole community.

Although a unique definition of sustainable development does not exists, this notion first appeared in 1987, in the Brundtland Report of the World Commission on Environment and Development, which defined it as: *"the satisfaction of the needs of the present generation without compromising the ability of future generations to realize their own"* (WCED, 1987), thus highlighting the goal of ensuring long-term well-being by balancing the need for economic development with human and social evolution.

Having recognized that the transaction toward sustainable development is urgent as the deterioration of environmental ecosystems imposes time limits, from that moment after there have been numerous initiatives by the international community through which an attempt has been made to define a strategy capable of integrating development needs with those of the environment. Among the most recent, in 2015, the United Nations 2030 Agenda for Sustainable Development (hereafter "Agenda 2030") and the accession of 195 countries to the Paris Agreement on Climate Change (hereafter "Paris Agreement").

More in detail, the 2030 Agenda is an action plan that aims to reach sustainable development along economic, social and environmental pillars, identifying 17 goals and 169 targets to be achieved by 2030 (the so called “Sustainable Development Goals”, in brief SDGs[1]). The Paris Agreement, on the other hand, is a binding international treaty whose main purposes are to contrast climate change and to contain the increase in the average global temperature below 2°C compared to preindustrial levels (the average of 1850-1900 period).

Rising temperatures – caused mainly by increased levels of CO2 emissions produced by industrial and real estate activities - are becoming an increasingly important topic nowadays, as they can have devastating consequences for the environment, and consequently, for the people who live in it, affecting food and water suppliers, whether pattern and sea levels.

However, to ensure a rapid and efficient process toward sustainable development, it is necessary to preliminarily identify economic activities capable in practice of making a substantial contribution to the ecosustainable transaction.

2.2 The role of the Real Estate sector

According to the Intergovernmental Panel on Climate Change (IPCC) to prevent the worst climate damages and meet the goals of the Paris Agreement, global carbon dioxide emissions (CO2), need to be reduced by around the 50% by 2030 from 2010 levels, and reach net zero emissions by 2050.

Every year the real estate and building sector consumes around one third of the world’s energy and contribute similarly to greenhouse gas emissions (hereafter “GHG”) (Coulson, Palacios, Zheng, 2024). According to the Environmental Protection Agency (EPA 2022) and GRESB (2024), the real estate sector is responsible for 30% - 39% of greenhouse gas emissions with the 72% arising from the existing properties and their associated energy consumption (Van der Kroft, Palacios, Rigobon, Zheng, 2024).

However, the emission of harmful gases from buildings depends not only on the use of unsustainable energy sources to operate and ensure high quality of life for those who live in them (i.e. lightening, heating, coaling and water) but starts from the production phase and continues in the later stages of construction, use, and demolition. These emissions, commonly referred to as embodied carbon, contribute around 11% of all global carbon emissions (WorldGBC, 2019).

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[1] The real estate sector can play a key role in advancing some of the several SDG targets, such as:

- SDG 7 (affordable clean energy): in the real estate industry this goal manifest through sustainable construction practices and the integration of energy-efficient technologies in buildings.
- SDG 9 (industry, innovation and infrastructure): the real estate sector can drive sustainable infrastructure trough innovations, including IoT sensors and AI-based energy management.
- SDG 13 (climate action): the real estate sector can reduce the CO2 emissions by prioritizing energy efficiency designs, low emission materials and retrofitting existing properties to meet modern standards.

Hence, the construction of a building emits CO2, both directly and indirectly: direct emissions originate from the burning of natural gas, diesel, light fuel oil and other oil-based commodities, while indirect emissions come from the application of electricity (Ali Ahmad & Yusup, 2020).

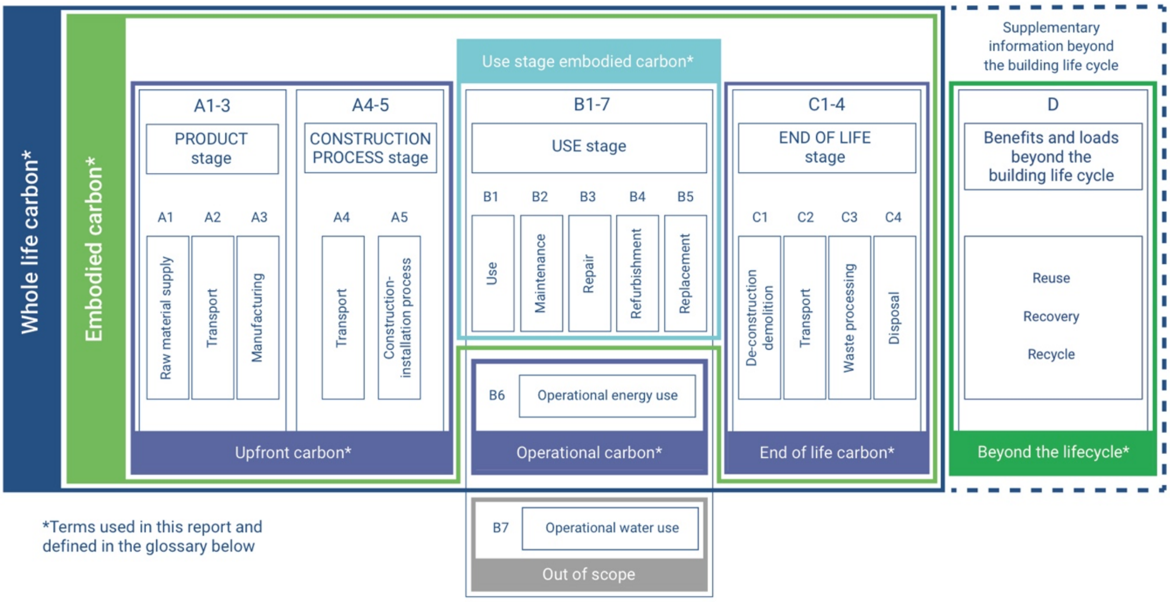

Figure 1. Source: WorldGBC, 2019

Nowadays, the focus has been on measuring and mitigating emissions related to operational carbon (step B1-7, related to energy use). Nevertheless, efforts to reduce embodied carbon emissions need to be strengthened. For this purpose, in 2023 GRESB generated an indicator to monitor embodied carbon emissions from new construction and renovation projects.

What emerged was that embodied carbon emissions increased from 24% to 31% globally from 2023 to 2024. Specifically: (i) for new construction from 20% in 2023 to 26% in 2024, (ii) for renovation projects from 6% to 7% (GRESB, 2024).

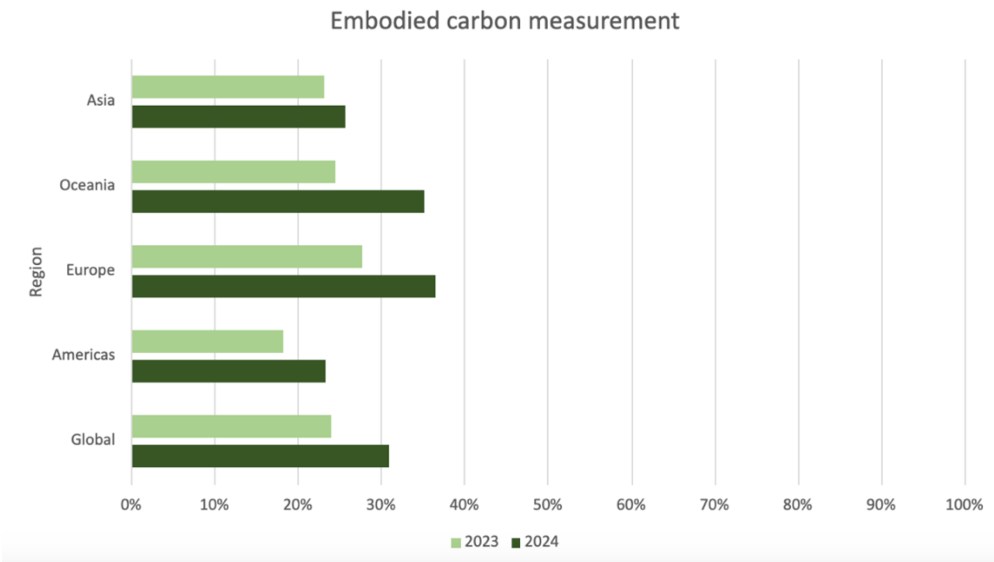

Figure 2: Source: GRESB, 2024

According to the Global Alliance of Buildings and Construction (GlobalABC, 2024), the building stock is expected to growth by 2050 by 60%, which could lead to an increase in emissions if they are not controlled.

Therefore, based on the data provided until now, that show that the real estate sector is one of the major contributors to current levels of pollution, according to the World Green Building council (2024) to reach the net zero emission target in 2050 it is necessary to:

- reduce the energy intensity of buildings by 35%;
- secure regenerative, resource – efficient and waste – free infrastructure;
- address the whole life carbon emissions of existing and new buildings. Specifically, reduce operational emissions by 50% and reduce the embodied carbon emissions by 40%;
- shift to buildings powered by electricity which is from renewable sources.

Thus, the construction sector has a huge opportunity to help fulfill the SDGs set by the United Nations. Indeed, it can:

- reduce its environmental impact by reducing its carbon footprint. In this regard, the World Bank (2019) highlighted that investing in more resilient infrastructure could also save humanity 4.2 trillion dollars from damages of climate change.
- have a positive economic impact as a result of:
  1. long term cost savings through lower maintenance and energy costs
  2. increase the value of properties making them more appealing to investors
- have a positive social impact due to the promotion of healthier living environments.

In this context, the development of new legislation to guide the transaction is essential.
However, although the number of international building codes has increased since 2023, 30% of these codes have not been updated since 2015 and may not meet high standards (UNEP & GlobalABC, 2024).
The transition towards zero-impact buildings requires the strategic use of political and financial tools. Indeed, the coordinate use of policy tools – such as capacity building, mandates and incentives – with specific financial instruments – such as grants, risk mitigation tools, contracts, financing models - can eliminate or otherwise reduce barriers to more energy efficient investments and low carbon technologies (GlobalABC, 2024).
Regulations to facilitate the transaction have been developed mainly by the United States and Europe. However, although the ultimate goal is identical, the methods used by different countries to achieve it vary.

2.3 The New York City Local Law 97

In New York City over two thirds of greenhouse gas emissions come from buildings (City of New York, n.d.[2]).
It was only in 2005, under Mayor Michel Bloomberg's administration, that the issue of emissions gained importance and began to be addressed. However, it was only after Hurricane Sandy in 2012 that companies started to take the issue of sustainability seriously (Spitzer, 2021).
In particular, the real estate sector slowly adapted to sustainability, and associations such as BOMA (Building Owners and Managers Association) played an important role in promoting energy efficiency.
Over the years a huge number of laws have been implemented to lower emissions from edifices, the most recent among them is the New York Local Law 97, enacted as part of the City's broader 2019 Climate Mobilization Act. Specifically, the goal of the Law is to cut emissions produced by the City's largest buildings by 40% by 2030 and 80% by 2050.
New York Local Law 97 primarily covers larger buildings, since those contribute significantly to the city's greenhouse gas emissions. The specific categories of budling covered under LL97 are:

- buildings over 25,000 square feet
- buildings on the same tax lot that together exceed 50,000 gross square feet
- condominium buildings, governed by the same condominium board, that together exceed 50,000 gross square feet.

[2] Available at: https://www.nyc.gov/site/buildings/codes/ll97-greenhouse-gas-emissions-reductions.page

Starting from 2024, the above-mentioned buildings must be compliant with the specific greenhouse gas (GHG) emissions limits, which vary based on the building's intended use (e.g. residential, commercial, etc.), become more stringent in 2030 and will continue to tighten through 2050.

For building owners who fail to comply with LL97, the Law provides three kinds of fines:

(i) for building owners who exceed the emissions limit, the maximum annual penalty is the difference between the building's annual emissions limits and its actual emissions, multiplied by $268

(ii) for building owner who fail to file the annual report of their GHG emissions to the New York City Department of Buildings (DOB), the fine is $0,5 per building square foot, per month report

(iii) for building owners who provide false statements on their report, there is a fine of $500,000. In addition to fines and penalties, buildings that are not compliant may face reputational damage and decreased property values.

2.4 Gap in literature

So far, various aspects of sustainability have been discussed in the real estate literature. For example, the Salimifrad study (2022) focuses on three specific aspects: (1) energy consumption, (2) CO2 emission levels and (3) health. This study was one of the first to link the level of carbon dioxide emissions from buildings to the health of New York residents, discovering that these emissions also result in early mortality.

Other studies have also examined the financial effects that investments in sustainable buildings can have for the building owners. Such sustainable buildings are also known as "green buildings" and are defined as any structure whose design, construction and operation are intended to improve the well-being of its residents and the community at large while minimizing adverse environmental effects (Baeroom, Hossen, Abid, Shahzard, 2025). In particular, it has been shown that green buildings have a higher sales price and rent than brown buildings (the no sustainable buildings), according to the study by Eichholtz, Kok and Quigley (2010). This has also been confirmed by subsequent studies, such as that of Jayakody and Vaz (2023) who found that Leadership in Energy and Environmental Design (LEED)-certified[3] office structures in the United States have a premium rental of 6% and a premium price of up to 16%.

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[3] LEED is a certification aimed to promote sustainable home building designs. It is based on 110-point system that assesses and assigns points based on different sustainability criteria in various categories to ultimately arrive at either certified silver, gold or platinum level.

In the past literature, importance was also given to studying the effect of penalties in ensuring compliance with different environmental laws. In this regard, reference can be made to several studies, including that of Harrington (1988), who analyzed the conditions under which it is advantageous for companies to maintain compliance with the regulators and when it may be advantageous for them to opt to pay penalties. In particular, the study found that adapting to the demands of regulators is only beneficial if the costs involved in ensuring compliance are low. Otherwise, it is more cost effective to opt for the payment of penalties.

The following year the study of Kambhu (1989) examined the two main tactics that companies can use to deal with environmental compliance. The first option is to invest in programs that effectively aim to reduce the pollution produced by the company itself. The second option is to invest in approaches that aim to reduce the amount of fines. The interesting conclusion of the paper is that companies are more induced to invest in these penalty erosion activities when environmental standards are promoted. This has the opposite effect to that intended by these laws.

A further study is that of Kadambe and Segerson (1998), which analyses the relationship between penalties imposed by regulators and companies. In particular, the analysis considers two main effects: (i) the direct effect, which consists in the increase of the fine compared to the presumed cost of a violation while assuming that enforcement probabilities remain unchanged, and (ii) the indirect effect, defined as the effect of the fine on the probability of the violation through its effect on the probability of application of enforcement action by the Authorities. What emerged from the study of Kadambe and Segerson is that, while the direct effect is always positive - as the fine increases, it becomes more expensive to violate environmental laws – the indirect effect is ambiguous. This implies that there is no clear correlation on how these sanctions affect how the company decides to act.

A more recent study (Adrison, 2008), instead, examined and compared, among other things, the impact of sanctions and the impact of intermediate enforcement actions (IEAs) in preventing violations. The results of the study show that the former have an effect of compliance less than one year after the penalty is applied and continue to have an effect up to two years later, in contrast the latter do no improve compliance within one year of being applied but do have an effect five to eight quarters later (Adrison, 2008).

Finally, I would like to mention one last study that indirectly analyzed the effect of environmental penalties. Specifically, the study by Echeverria, Palacios, Davila & Zheng (2023), analyzes how increasingly stringent climate regulations – such as the recent LL97 – influence building owners' decisions regarding the implementation of decarbonization technologies. In the research the net present values of three distinct building designs are considered: (i) a building with natural gas-powered water and space heating, (ii) a fully electrified building, (iii) a flexible building with a natural

– gas powered space and water heating, but with the option to replace the natural gas system with fully electric air source heat pump system. The results of the study showed that the optimal choice for owners, both in terms of initial investment costs efficiency and possible penalties to be incurred, appears to be the flexible one. This option, indeed, allows switching to the electricity system in the event that, in an uncertain environment, natural gas prices rise, or emissions regulations become stricter and penalties for no compliant higher.

Although all the studies cited so far have examined the impact of penalties on climate regulations in different contexts, however, none have analyzed the direct impact of the financial burden for building owners resulting from LL97's penalties. Therefore, the double role of my research is the following:

(1) first, investigate what predicts LL97's penalties, and

(2) second, identify the role of some financial variables in predicting the magnitude of the LL97's penalties for the building effectively penalized.

3. DATA AND METHODOLOGY

This section illustrates the data and the analytical methods used in the thesis. More specifically, this section outlines the data collection process, the construction of the dataset, and the analytical methods and variables employed to answer the two research questions indicated on the previous page.

3.1 Data

The National Council of Real Estate Investment Fiduciaries (NCREIF) database and the official Building Energy Exchange platform were the two primary sources of the data used in the analysis.
Specifically, from the NCREIF database were extracted the principal information on the buildings in the sample, creating a final data set containing 437 observations.
The observations refer to several buildings located in New York City, mainly in the borough of Manhattan, as illustrated in Figure 3, which shows a map of the city with the buildings included in the sample.

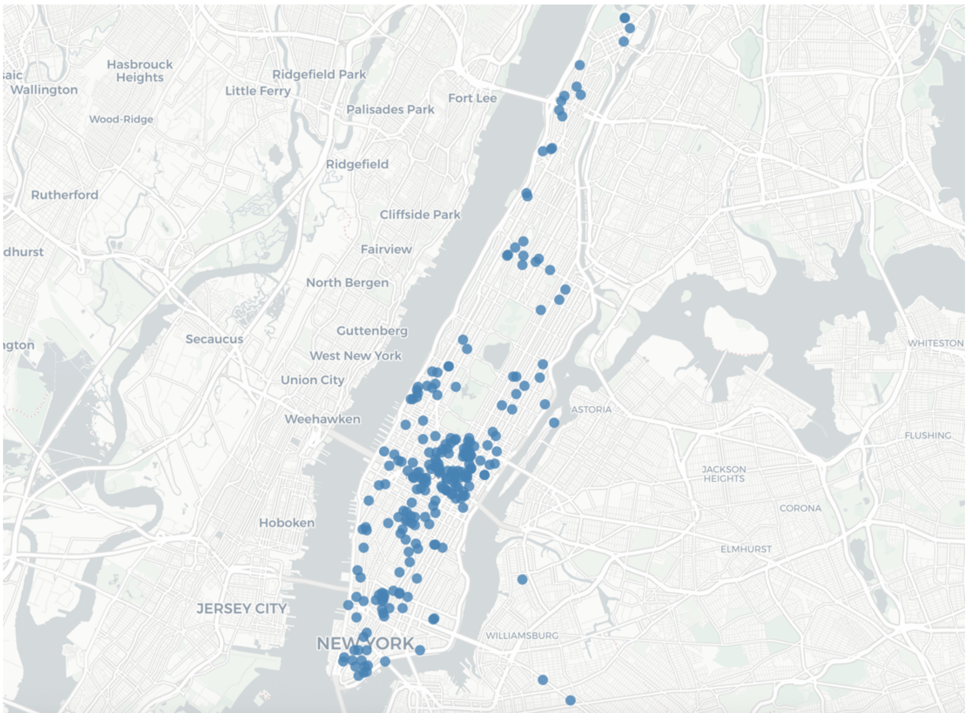

Figure 3: Map of sample buildings

Numerous descriptive variables were available for each building, belonging to various categories such as:

(i) financial variables, including Net Operating Income (hereinafter, also “NOI”), Market Value (MV), expenditures in investments for retrofits and energy efficiency upgrades (hereinafter also “CAPEX”), and different types of operating costs and incidental expenses;
(ii) geographic variables, such as latitude, longitude, and zip code;
(iii) other structural and managerial information, such as construction year of the building and landlord fund owned.

Since the financial variables were available over multiple years with varying temporal coverage across buildings, it was necessary to construct a dataset with a consistent structure—namely, one row per observation (i.e., one row per building). To achieve this aim, the average of the available values was computed for each financial variable at the building level.
A fixed time horizon (e.g., 10 years) was deliberately not imposed, in order to maximize the sample size and avoid excluding buildings with incomplete or shorter financial time series. This approach ensured a more balanced and inclusive dataset while maintaining comparability across observations.

On the other hand, as for the values of the penalties under LL97 (hereinafter “penalties” or “LL97 penalties”), they were collected manually through the official Building Energy Exchange platform.
By entering the address of each building in the above mentioned platform, in fact, it was possible to view projections of the future penalties to which the building would be subjected in the event of noncompliance with the emission limits stipulated in the regulation.
The penalties were divided into different time clusters, corresponding to the progressive implementation stages of LL97, specifically: 2024-2029, 2030-2034, 2035-2039, 2040-2049 and 2050 onwards.
As the penalty regime under LL97 becomes progressively more stringent over time, the penalties are found to be increasing in the different intervals. However, because not all buildings in the sample had complete estimates of expected penalties, observations lacking this information were excluded from the regressions.
Finally, to obtain a complete and consistently structured dataset, the two data sources—the one derived from the NCREIF database and the one containing the manually collected penalty values—were merged using the R statistical software. The resulting dataset was organized so that each row corresponded to a single building, with one consolidated observation for each relevant variable.

3.2 Methodology

As anticipated in the introduction and in section 2.4, the analysis of this thesis has a twofold objective: (i) to analyze whether the financial variables under study - i.e. the key independent variables – influence the likelihood of a building being penalized and, (ii) for those buildings that are effectively penalized, to investigate the extent to which these financial variables influence the amount of penalties incurred under Local Law 97.

Specifically, for both stages of the analysis, the work focuses on two following key indicators:

a. the Net Operating Income (hereafter, as already said, also “NOI”), and
b. the CAPEX, meaning the capital expenditures.

More in details, NOI measures the net operating profitability of a building, i.e., rental income after considering the operating expenses. This variable, not only reflects the economic performance and financial capacity of a building, but can also provide indications on structural characteristics of the building itself, these are all important elements for both stages of the analysis.

CAPEX represents investments in all those technologies aimed at improving the energy efficiency of buildings, such as HVAC systems and thermal insulation systems.

The inclusion of the CAPEX in the analysis is indeed essential since, such investments are often necessary to reduce emissions and, consequently, avoid or decrease the penalties under LL97.

Therefore, the CAPEX analysis provides insight into the reaction of building owners to the regulation by assessing whether investments to comply with the standards set by LL97 actually translate into future benefits.

In order to assess empirically the role of the NOI and the CAPEX in the penalty mechanisms established by LL97, a two-stage analysis methodology was adopted, articulated as illustrated by Figure 4.

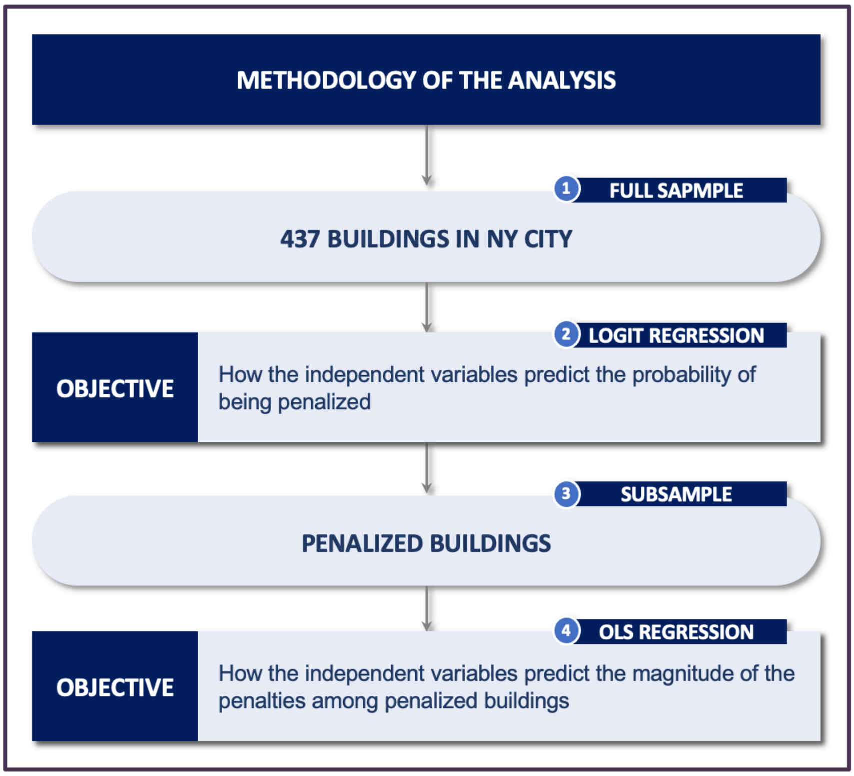

Figure 4: Methodology of the analysis

Notably, the first stage of analysis, conducted on the full sample, uses a logistic regression in line with the objective of determining how NOI and CAPEX, respectively, influence the probability of buildings being penalized.

The dependent variable, i.e. penalties, is a dummy variable defined as:

$$Penalties_i = \begin{cases} 1 & \text{If building } i \text{ is penalized under LL97} \\ 0 & \text{If building } i \text{ is not penalized under LL97} \end{cases}$$

The two regressions adopted are structured according to the following mathematical specifications:

$$\Pr(Penalties_i = 1) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 \log(NOI_i) + X_i'\gamma}}$$

$$\Pr(Penalties_i = 1) = \frac{1}{1+e^{-(\beta_0+\beta_1 \log(CAPEX_i)+X_i'\gamma}}$$

Where:

- $\Pr(\text{Penalties}_\text{i} = 1)$ is the probability for the building *i* of incurring in some penalties
- $\log(\text{NOI}_\text{i})$ and $\log(\text{CAPEX}_\text{i})$ are the logarithmic form of the key explanatory variables

- X_i' is the vector of control variables
- γ is the vector of the coefficients associated with the control variables

Then, starting from the subsample of buildings penalized in the logit regression, i.e. those for which the dependent variable assumes a value equal to 1, a second phase of the analysis was conducted to assess the impact of the independent variables on the magnitude of penalties. This analysis involves two separate OLS regressions, for NOI and CAPEX respectively, whose mathematical specifications are as follows:

$$\log\left(\frac{Penalties_i}{Sqft_i}\right) = \beta_0 + \beta_1 \log(NOI_i) + \sum \beta_k (Control\ variables_i) + \epsilon_i$$

$$\log\left(\frac{Penalties_i}{Sqft_i}\right) = \beta_0 + \beta_1 \log(CAPEX_i) + \sum \beta_k (Control\ variables_i) + \epsilon_i$$

As for the dependent variable is important to emphasize the fact that penalties in absolute value were not used, but rather $\frac{Penalties}{sqft}$ ratios. This choice is justified by the need to normalize the data. Indeed, the dataset contains extremely heterogeneous buildings, presenting very different structural and economic characteristics. Using absolute value penalties would not have allowed a fair comparison; larger buildings tend to generate higher penalties, without necessarily implying lower environmental efficiency. Instead, using a ratio of penalties over the square feet allows for a normalization by size in order to get a better comparison of penalty intensity across buildings penalized.
In sum, the use of penalties over square feet ratio ensures a more robust, comparable, and interpretable analysis by allowing a thorough understanding of the regulatory burden across buildings of different sizes, and by isolating the effect of financial and structural variables on the intensity of penalties, rather than on their absolute magnitude.

A further clarification regarding the dependent variable should be provided.
The value of the penalties resulting from LL97 is available on the 'Building Energy Exchange' website broken down by time clusters between 2024 and 2050. However, in order to analyze the overall effect of the legislation on the building, in terms of the total expected penalty burden, an aggregate variable was constructed as the sum of the expected penalties in the different time intervals.

However, in order to verify the robustness of the results, in untabulated results the analysis was replicated by calculating the aggregate penalties as the present value of the expected future cash flows. For this purpose, a rate of 7.5% was used as the discount rate, which is the median value of the uniform distribution used in the reference literature (Valdez Echeverria et al., 2023). The choice of the 7.5% discount rate makes it possible to keep the analysis representative of a base scenario, avoiding optimistic or pessimistic extremes. The results obtained from this alternative methodology are substantially unchanged from those derived from the raw sum of the penalties divided into the different time clusters.
For this reason, and considering that the assumption of a constant discount rate over a long-time horizon would have been an overly rigid and unrealistic assumption in reflecting future uncertainty, in this analysis it was preferred to adopt the raw sum of the expected penalties in the different time clusters.

A final specification concerns the logarithmic transformation of penalties, NOI and CAPEX variables. This decision was dictated by the fact that the variables showed strongly skewed distributions and the presence of outliers. To ensure greater adherence to the assumptions of the OLS regression model, the use of the logarithm allowed to reduce bias, stabilize variance, and increase the robustness of the estimates.

Control variables were also included in the regressions in order to optimize the precision of the estimates and reduce potential noise in the data. These variables reflect structural and management characteristics of the buildings, specifically:

- the year of construction, to consider the technological and regulatory context in which the building was developed;
- the building type, meaning the classification into three macro categories: residential, medical use and industrial use. This choice was motivated by some main reasons such as the fact that some original categories were poorly represented, which could have compromised the statistical significance of the estimates and generated convergence problems in the regression models. However, even after aggregation, as better explained in the results section, some categories remain underrepresented.

  Moreover, the grouping into the three identified macro-categories reflects homogeneous energy and operational use functions, which may result in different patterns of exposure and response to LL97;

- the nature of the owner's fund, in order to capture heterogeneity related to ownership structure. The inclusion of this variable is important as it reflects different sanction risk mitigation strategies.

4. DESCRIPTIVE STATISTICS & RESULTS

4.1 Descriptive statistics

Before proceeding by presenting the results of the regressions, Table 1 below reports the descriptive statistics of some important variables. Specifically, it shows the minimum, the first quartile, the median, the mean, the third quartile the maximum and the standard deviation for the following variables: Net Operating Income (NOI), Capital Expenditures (CAPEX), building size (square feet), geographical coordinates (latitude & longitude) and penalties divided for different time periods.

Table 1: Descriptive Statistics

Variable	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Standard Deviation
NOI	-765.806	194.644	948.584	2.277.813	2.455.014	29.318.049	3.868.019,81
Capex	-12.189.971	71.224	360.777	1.864.057	1.524.922	811.569.03	5.802.651,25
sqft	0	43.266	127.947	311.837	377.774	2.806.503	452.028,47
Latitude	407.042	40.756.681	407.260.946	264.542.574	407.569.027	408.686.555	183.606.724,64
Longitude	-740.161.343	-739.863.448	-739.677.651	-468.755.011	-73.982.315	-739.521	33.637.736,29
Penalties 2024-2029	0	0	0	4.375	0	245.657	23.913,75
Penalties 2030-2034	0	0	0	46.792	41.557	573.240	100.270,84
Penalties 2035-2039	0	14.059	48.266	124.728	148.954	1.106.981	201.762,05
Penalties 2040-2049	0	43.966	117.316	226.963	254.130	1.830.875	315.921,29
Penalties 2050	134	90.318	207.679	351.897	443.734	2.369.666	429.054,23

To further contextualize the descriptive statistics presented in Table 1, figure 5 provides a visual representation of the number of buildings in the dataset that are subject to penalties under the LL97 regulatory framework.

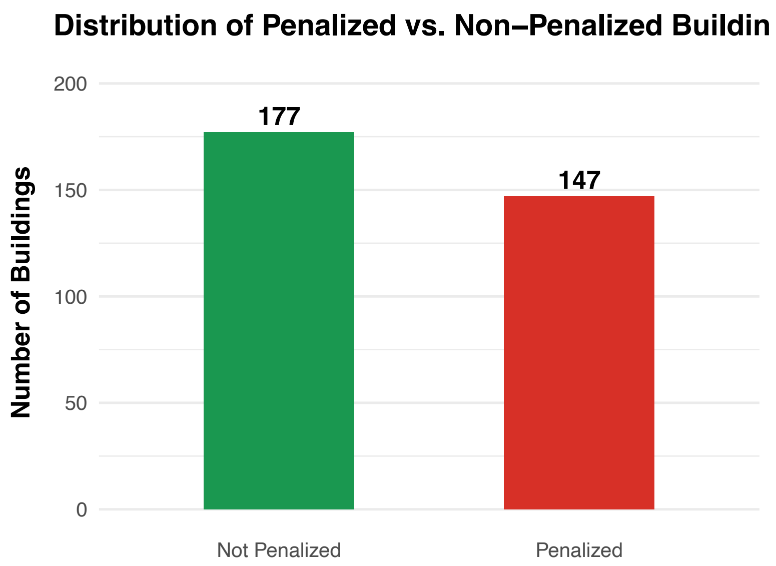

Figure 5: Distribution of penalized VS non penalized buildings

As can be seen from the bar chart, the number of penalized buildings in the sample is slightly lower than the number of those not subject to any penalties, meaning that some properties already meet emission criteria.

Subsequentially, the distributions of the main variables under analysis - namely the two primary independent variables (NOI and CAPEX) and the dependent variables related to penalties – were examined. It should be premised that due to the high heterogeneity of the data set, data manipulation was required to make the distributions more robust and comparable. Specifically, the CAPEX, NOI and penalties variables were first normalized with respect to the building size and then transform by natural logarithm due to their high skewed distribution.
By enabling a more informative depiction of the distributions, these two steps enhanced the quality of the statistical analysis and the comparability of the observations.

The first distribution presented refers to the normalized and log-transformed penalty variables.

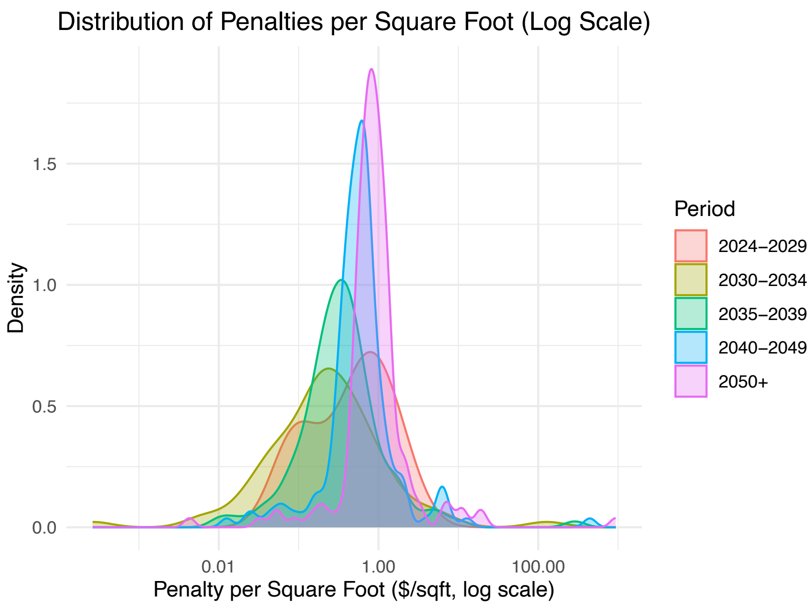

Figure 6: Penalties' distribution

Figure 6 displays the comparative distribution of penalties per square foot across the five regulatory time periods: 2024-2029, 2030-2034, 2035-2039, 2040-2049 and 2050 onwards.
The density functions show a marked asymmetry to the right, which tends to intensify over time, particularly from the period 2035-2039. This trend suggests a general increase in penalties as the years go by, in line with the regulatory tightening under LL97. Interestingly, the density curves are more pronounced in the final time clusters of the law (i.e., 2040-2049 and 2050 onwards), indicating

a greater concentration of penalties' distributions. In other words, a substantial number of buildings record similar normalized penalty values in these periods.
However, the distributions remain broad and characterized by long tails to the right, signaling the presence of buildings subject to exceptionally high penalties per square feet.

Figure 7 represents the distribution of the variable Net Operating Income per square foot across all buildings in the sample.

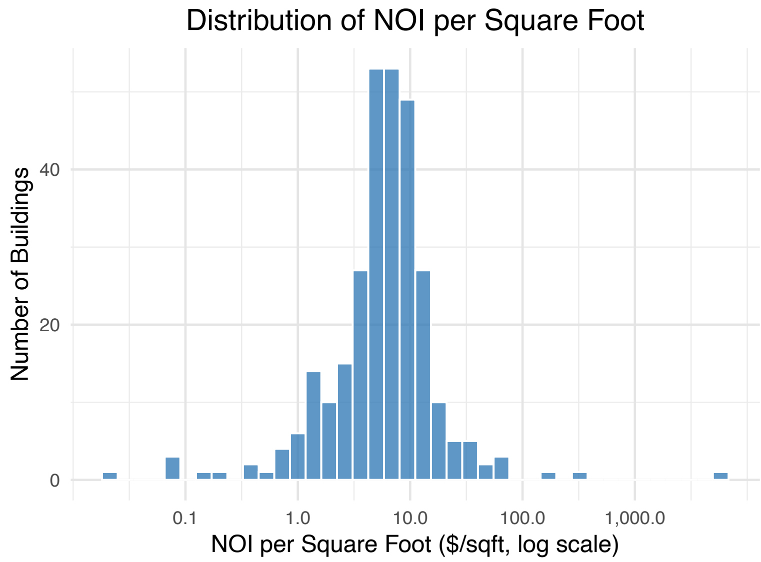

Figure 7: NOI distribution

The distribution shows a marked positive skewness, with most buildings recording a Net Operating Income per square foot (NOI/sqft) between about $5 and $15/sqft. The presence of outliers in both tails of the distribution -both buildings with extremely low values and others with exceptionally high values- shows the high structural and economic heterogeneity of the analyzed sample. This further reinforces the need to use normalized variables in order to ensure greater robustness and comparability between buildings.

Finally, the distribution of the CAPEX was also examined.

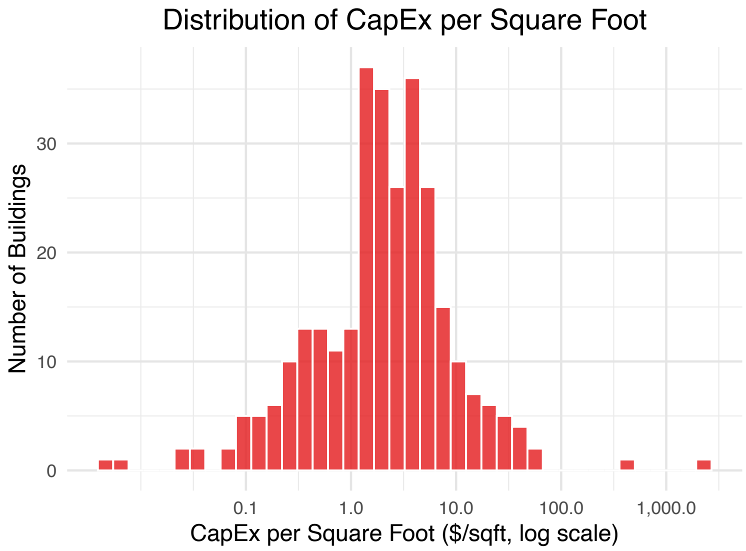

Figure 8: Capex distribution

The distribution shows a pronounced right skewed, with most observations concentrated between about $1 and $10/square foot. This clustering shows that most buildings do relatively little investments per unit area. Also in this case, the presence of long tails on both sides' points to significant heterogeneity in capital investment intensity within the sample.

4.2 Results

This section examines the results of an empirical analysis conducted in order to assess the impact of the economic and structural characteristics of buildings on the likelihood and magnitude of LL97 penalties. To achieve this aim, as anticipated in Section 3.2, a two-stage regression strategy was implemented. In the first stage, a logistic regression model (LOGIT) is estimated on the full sample, using a binary dummy as the dependent variable to determine whether or not the building is subject to penalties. In the second stage, limited to the subsample of penalized buildings only, a linear regression (OLS) is estimated to explain the amount of penalties as a function of the same explanatory variables.

The main results of the empirical analysis are presented in Tables 2 to 5 below. Each table is structured in five columns, labelled (1) to (5), corresponding to progressively more complete model specifications. In particular, each column progressively adds a different set of control variables to assess the robustness of the relationship between the key explanatory independent variables - the Net Operating Income (NOI) and the Capital Expenditures (CAPEX)- and the dependent variable of interest, maintaining the same functional form and estimation technique at each stage.

Specifically, column (1) presents the results for the baseline model, where the only key independent variable is considered. Column (2) extends the model by adding fund type as a categorical control variable, in order to capture heterogeneity related to ownership structure. Column (3) incorporates the building type divided into three main categories as anticipated in the section 3.2. Column (4) includes the year of construction to take into account the technological and regulatory context in which the building was developed. Finally, column (5) simultaneously controls both the fund type that owns the building and the year of construction, thus providing a more complete specification of the model.

It is also important to note that the control variable "building type", which was initially included in exploratory specification (column (3) Table 2 to 5) to assess its marginal effect on both the probability of incurring penalties and the intensity of penalties, was, however, excluded from the final aggregate specification (column (5)). This was done for the following two main reasons:

1. firstly, the division of the buildings into homogeneous groups according to their use (e.g. commercial, residential and medical use) resulted in some poorly represented categories, with too few observations to guarantee the stability of the estimates. The reliability of the coefficients would have been compromised by this deficiency, leading to convergence problems in the regression models, separation errors, and estimates affected by high statistical uncertainty;

2. secondly, some variables included in the model (such as the year of construction) are strongly correlated with the building type variable.

In order to ensure greater robustness, interpretative clarity and reliability in the estimates, it was decided to exclude the building type from the final version of the model, in line with the principle of modelling parsimony.

The interpretation and implications of each model will be discussed in detail in the following sections.

4.2.1 Logistic panel regression results- NOI

The model (from 1 to 5) aims to estimate the probability of a building incurring penalties using the logarithm of Net Operating Income (NOI) as the main independent variable, together with a set of control variables.

The main results of the Logistic regression are reported in Table 2 below.

Table 2: Logit regression results for Net Operating Income

Depedent variable: Penalties					
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Ln (Net Operating Income (NOI))	0.25168	0.2199	0.23710	0.24738	0.2567
	(<0.001)***	(<0.05)*	(<0.01)**	(<0.05)*	(0.05)*
Control variables					
Fund type					
Fund Type D		-19.814			-2.2694
		(<0.001)*			(<0.001)***
Fund Type N		-1.3115			-0.8886
		(0.088)			(0.320)
Fund Type O		-1.6253			-1.6481
		(<0.01)**			(<0.05)*
Fund Type R		-1.8151			-2.2036
		(0.061)			(<0.05)*
Fund Type S		-0.7203			-0.8257
		(0.138)			(0.136)
Building Type					
Health/ Medical			0.73419		
			(0.999)		
Industrial			0.57081		
			(0.999)		
Residential			0.68015		
			(0.999)		
Construction Year				0.0045	0.0073
				(0.327)	(0.146)

Note. Penalties= Dummy variable (0,1)
Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

In all five models, the log (NOI) is statistically significant and positive. This result remains robust to the introduction of the different control variables, suggesting that as net operating income increases, the probability of a building being penalized increases as well.

The finding can be explained by the fact that the most profitable buildings are generally larger, energy-intensive, or intensively used. High operating income can be the result of many occupied units, high rental flows, or continuous, high-intensity use of the building. This leads, all other things being equal, to higher absolute energy consumption and, consequently, to a greater likelihood of exceeding the emission thresholds imposed by LL97.
Specifically, the study by Eichholtz, Kok and Quigley (2010) showed that non green certified buildings consume much more energy per square foot than certified buildings, despite having high levels of profitability due to rental and sales times. Consequently, economic performance and energy performance are not necessarily aligned. A profitable building may be environmentally inefficient and therefore it is more probable that it will exceed the emission thresholds set by the Local Law 97.
Another explanation for this phenomenon may be related to the fact that a building with high revenue streams can afford not to invest in energy retrofits immediately, assuming that the penalties are a sustainable cost.
Again, the academic literature supports this observation. Kontokosta's (2016) study of energy retrofit decisions in commercial buildings points out that more profitable properties are not automatically more inclined to invest in energy efficiency improvements. This is especially true when such interventions have a high opportunity cost. In other words, highly profitable buildings may find it more cost-effective to absorb the cost of a potential penalty than to anticipate large expenses for retrofitting, at least in the short term.

Analyzing in detail the results of Model (2) in detail, a significant heterogeneity in the coefficients associated with the different fund type categories emerges. This suggests that the type of ownership and management of the building have a significant impact on the likelihood of incurring penalties. In particular, fund type D and fund type O show significantly negative coefficients (-19.814 and -1,6253 respectively), indicating a lower probability of receiving penalties. In contrast, the other fund types, although they show negative coefficients, are not statistically significant, meaning that they have no impact on the reduction of the penalty.
These results can be interpreted by observing how different funds differ in their management strategies, incentives and investment capacity. Specifically, in their study, Bauer, Eichholtz & Kok (2013), show that institutional funds are more inclined to invest in sustainable real estate and adopt environmental sustainable strategies in order to meet fiduciary constraints and investors' long-term

expectations. Similarly, Kok, McGraw and Quigley (2012) show that the governance structure and internal diffusion capacity of efficient technologies differ significantly across real estate managers, which has an impact on the likelihood of taking corrective action in response to regulatory constraints. Therefore this evidence, also supported by existing literature, highlights how in the context of LL97, certain types of funds can implement more effective preventive strategies through investments in energy retrofits or compliance-oriented management practices by reducing the likelihood of paying penalties.

The explanatory power of Model (3) is not significantly improved by the addition of the "building type" variable since the coefficients associated with the various building categories are not statistically significant. This result shows that building type, whether residential, medical or industrial, is not a significant predictor in terms of the likelihood of incurring penalties.

A plausible interpretation of the result is that, in the context of Local Law 97, the emission thresholds are calibrated per use category, and thus intra-category variability tends to prevail over inter-category variability. In other words, the penalty risk is not determined by the use per se, but by the energy efficiency of the building in relation to the benchmark for its category.

Indeed, even according to existing academic literature, the functional use of a building is not always a good predictor of energy efficiency or the propensity to incur environmental penalties if it is not accompanied by more specific technical indicators.
For example, Papineau (2013) points out that energy regulation policies have uneven effects even within the same building type, as the impact depends mostly on plant technology and management behavior. Similarly, Kontokosta (2016) shows that, in regulated urban settings, economic and physical building characteristics are often more decisive than the nominal use in explaining energy behavior and regulatory response.

In Model 4, the year of construction is not significant. An interpretation related to this result is that the year of construction does not necessarily indicate the buildings' current energy performance, especially in an urban context - such as New York City - where many historic buildings have undergone significant energy retrofits and upgrades. Consequently, the time variable may be uninformative if not accompanied by more direct indicators of actual energy behavior, such as consumption per square foot or the presence of environmental certifications. This observation is consistent with the study by Kontokosta (2016), who points out that the age of a building is not always

a good indicator of its energy efficiency as many older buildings may have undergone retrofitting and newer buildings are not necessarily designed to maximize environmental performance.
Moreover, Papineau in his 2013 study notes that energy regulation policies have a different impact and that the time variable alone is not sufficient to explain how buildings comply with environmental standards because there are also behavioral, economic and technological aspects.

Model 5, in which the year of construction is analyzed together with the fund type, confirms the evidence of the previous models: here again, the variables relating to the fund types of property owners retain their statistical significance, in contrast to the variable relating to the year of construction of the property, which is not a statistically significant predictor of penalties under LL97.

Overall, the logit regression results show that the likelihood of incurring Local Law 97 penalties is significantly influenced by economic and structural characteristics of buildings. Specifically, the NOI is a reliable predictor of penalties, consistent with the hypothesis that more profitable, often larger and more frequently used buildings tend to produce higher levels of emissions. On the other hand, fund type is also a significant predictor of penalties suggesting that proprietary strategies in regulatory risk management are key to avoiding penalties.
Finally, structural variables such as year of construction and building type were not statistically significant in a consistent manner, suggesting that the physical characteristics of the building, when considered in isolation, are not sufficient to explain the propensity to incur penalties.

4.2.2 OLS Regression - NOI

The results of the second stage regression, based on the sub-sample of penalized buildings, are shown in Table 3.

Table 3: OLS regression results for Net Operating Income

Depedent variable: Ln (Penalties/sqft)					
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Ln (Net Operating Income (NOI))	-0.01493	-0.01233	0.00319	0.02443	0.02111
	(0.822)	(0.913)	(0.963)	(0.831)	(0.860)
Control variables					
Fund type					
Fund Type D		0.21666			0.279275
		(0.721)			(0.654)
Fund Type N		-0.56636			-0.577125
		(0.473)			(0.470)
Fund Type O		-0.58909			-0.563354
		(0.337)			(0.360)
Fund Type R		-0.27670			-0.411968
		(0.795)			(0.705)
Fund Type S		0.12818			0.189718
		(0.754)			(0.663)
Building Type					
Health/ Medical			0.76537		
			(0.603)		
Industrial			0.30707		
			(0.798)		
Residential			1.35486		
			(0.199)		
Contruction Year				0.00291	0.003464
				(0.575)	(0.529)
R^2	0.0036	0.03504	0.01546	0.006097	0.04952

Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Recalling that the objective of the OLS regression is to analyze the extent to which some economic and structural factors influence the magnitude of the penalty - expressed as ln (penalties/sqft) - it is possible to see how the results shown in Table 3 paint a different picture to that which emerged in the logit regression. In the first stage of the analysis, indeed, the focus was on the probability of incurring a penalty, whereas in the second stage of the analysis, the focus shifts to the size of the penalty among buildings that have already been penalized.

The results of the analysis are detailed in this section.

A particularly interesting result that concerns the behavior of Net Operating Income (NOI). At this stage, unlike the first stage, the coefficient associated with NOI is never statistically significant. This suggests that once a building is penalized, the level of profit generated does not systematically influence the intensity of the penalty.

This result is primarily supported by the legislative structure of Local Law 97.

In fact, it is crucial to emphasize that the structure of LL97 imposes penalties based on exceeding predetermined thresholds of carbon emissions per square foot, without considering the profitability of the building. According to the Local Law 97, the penalty is determined by the following formula:

$$Annual\ Penalty = (Annual\ emissions - emission\ limit) \times 268\$ per\ metre\ tonne\ of\ CO_2$$

where:

- the annual emissions are calculated as:

$$Annual\ GHG\ emissions = \sum Annual\ fuel\ use \times emission\ coefficient\ of\ fuel\ type$$

- and the emission limit is calculated as:

$$Emission\ limit = Gross\ floor\ area \times emission\ factor$$

Therefore, as the formulas show, once a building is classified as penalized, the finding that the NOI is not a significant predictor of the amount of penalty among penalized buildings is fully consistent with the regulatory logic of LL97. Indeed, the amount of the penalty potentially applicable to a building is linked solely to the degree to which the threshold is exceeded, and not to its operational viability.

Control variables, such as fund type categories, building type and construction year, also do not have a significant impact on the amount of the penalty.
In fact, none of the coefficients reach the thresholds of statistical significance although some retain the same sign observed in the first stage.
This absence of robust results suggests that the determination of the amount of the penalty is probably driven by parameters more directly related to actual energy performance, such as plant efficiency, the level of actual emissions, or the adoption of environmental certifications (Kok, Miller and Morris, 2012), rather than by structural and economic variables.

4.2.3 Logit regression – CAPEX

The study conducted using the NOI as the main independent variable was replicated by employing, as the main independent variable, the CAPEX. Again, the analysis conducted consists of a two-stage regression: a first logistic regression (logit) aimed at estimating the probability of a building being penalized as a function of the investments in retrofits made and additional control variables; and a second linear regression (OLS), conducted on the subsample of buildings actually penalized, aimed at analyzing whether the CAPEX represents a significant predictor of the amount of penalties received.

The results of the first stage regression (logit) are illustrated in Table 4.

Table 4: Logit regression results for Capex

Depedent variable: Penalties					
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Ln (Capex)	0.13159	0.2052	0.14360	0.12911	0.21239
	(<0.01)**	(<0.01)**	(0.01)**	(<0.01)**	(<0.01)**
Control variables					
Fund type					
Fund Type D		-2.0819			-1.98113
		(<0.001)***			(<0.001)***
Fund Type N		-0.8853			-0.24534
		(0.271)			(0.780)
Fund Type O		-1.7622			-1.4775
		(<0.01)**			(<0.05)*
Fund Type R		-1.9404			-2.07853
		(<0.05)*			(<0.05)*
Fund Type S		-0.8759			-0.69789
		(0.0625).			(0.148)
Building Type					
Health/ Medical			-16.830		
			(0.992)		
Industrial			0.23237		
			(0.999)		
Residential			0.07113		
			(0.999)		
Construction Year				0.00029	0.0090
				(0.681)	(0.520).

Note. Penalties= Dummy variable (0,1)
Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

In the logit regression, the variable CAPEX turns out to be positively and statistically significant in all five models, suggesting that higher CAPEX increases the likelihood for the building to suffer a penalty from LL97.

Some findings in the literature support these conclusions. In particular, many studies emphasize that capital investments may act as a reactive response to initially critical structural conditions rather than

a preventive strategy. Pivo and Fisher (2011), for example, point out that buildings that require more modernization are often characterized by lower quality or a higher degree of obsolescence, making them more vulnerable to regulatory penalties. Similarly, Kontokosta in his 2016 study '*modelling the energy retrofit decision in commercial office buildings*', shows how in regulated cities such as New York City, energy retrofit decisions are often motivated by the urgency to comply with environmental requirements rather than by a proactive efficiency policy, and this can lead to a high penalty risk despite the investment. Eichholtz, Kok and Quigley (2010) support this interpretation by noting that, due to serious initial inefficiencies, buildings that invest in obtaining green certifications may still have similar or higher penalty levels than non-certified buildings.
Overall, the investment itself is not enough to reduce the risk of incurring penalties, especially if driven by corrective needs rather than a preventive strategy.

In Model (2), proprietary fund types were introduced as control variables. The coefficient associated with the CAPEX increases slightly (0.2052) and remains significant at the 1% level.
Specifically, owner fund types D, O and R show negative and statistically significant coefficients. This suggests better governance for real estate asset management that improves regulatory compliance and makes buildings more resilient to penalties.
The N and S funds, on the other hand, although associated with negative coefficients, do not show statistical significance.
These findings are supported by the study of Eichholtz, Kok and Yonder (2012) who show that funds with more robust and environmentally oriented management structures perform better in terms of environmental performance and reduced regulatory risk. Similarly, Andonov, Eichholtz and Kok (2015) point out that the ability to meet increasingly stringent environmental regulations is strongly influenced by the governance structure of real estate funds, which includes internal control mechanisms, management expertise and proactive investment strategies. Furthermore, Krüger (2015) emphasizes that governance geared towards sustainability and regulatory transparency is an important factor in mitigating sanction risk, reinforcing the idea that fund type is a relevant determinant of the regulatory performance of the real estate held.

In Model (3), the analysis was extended by including, control variables relating to the building type, i.e. the intended use of the buildings (Health/Medical, Industrial, Residential).
The coefficients relating to building type do not show statistical significance, indicating the absence of a systematic relationship between the function of use of the buildings and the probability of receiving penalties in the sample considered. As discussed in section 4.1, this absence of significance

may be related to the fact that in the context of Local Law 97, the emission thresholds are calibrated per use category, and thus intra-category variability tends to prevail over inter-category variability. Overall, the inclusion of building types does not change the observed relationship between CAPEX and penalty probability.

Model (4) includes the control variable relating to the year of construction of the building.
The coefficient associated with it is 0.0090, but it doesn't show statistical significance. This advocates that, in the sample analyzed, the age of the building is not a relevant predictor of the probability of incurring penalties. In fact, as already anticipated, and as also confirmed by the study of Kontokosta et al. (2020) studying the NYC regulatory environment, the likelihood of non-compliance with environmental standards is more strongly correlated with factors such as specific energy efficiency, floor area, occupancy level and intensity of use, rather than with the age of the building per se. Furthermore, the official reports of the NYC Mayor's Office of Sustainability (2021) point out that the standards set by Local Law 97 are mostly based on emission thresholds per square foot, applied uniformly to all buildings above a certain size, without explicit distinctions related to the year of construction. Finally, Fuerst and McAllister (2011) also point out that, if subjected to significant retrofits, older buildings can sometimes show better environmental performance than newer ones.

The results obtained in the previous models are also confirmed in Model (5), which includes among the control variables both the types of property ownership and the year of construction of the building.

Overall, the analysis revealed a significant positive relationship between the level of investment made and the likelihood of receiving a penalty from LL97.
This result suggests that the investment itself is not necessarily indicative of increased regulatory compliance but may be a reactive response to pre-existing conditions of structural inefficiency.

4.2.4 OLS regression – CAPEX

The sub-sample of penalized buildings resulting from the first regression was then subjected to an OLS regression in order to investigate the relationship between energy efficiency investments and the magnitude of the penalties under LL97. The dependent variable is the natural logarithm of the amount of expected penalties per square foot, which reflects the intensity of the penalty burden under LL97. On the other hand, the independent variable of main interest is the natural logarithm of capital expenditure which, as stated in section 3.2, in this context represents investments made to improve the energy performance of buildings, such as replacing obsolete HVAC systems, insulating the building envelope, installing low-energy lighting systems, etc.

The results are shown in Table 5.

Table 5: OLS regression results for Capex

Depedent variable: Ln (Penalties/sqft)					
Variable	(1)	(2)	(3)	(4)	(5)
Ln (Capex)	-0.04234	-0.09249	-0.04315	-0.0432	-0.09077
	(0.0843).	(<0.05)*	(0.0834).	(0.096).	(<0.05)*
Control variables					
Fund type					
Fund Type D		0.27275			0.26971
		(0.500)			(0.528)
Fund Type N		-0.45495			-0.48728
		(0.395)			(0.386)
Fund Type O		-0.08619			-0.11969
		(0.830)			(0.776)
Fund Type R		-0.0426			-0.13327
		(0.951)			(0.857)
Fund Type S		0.26891			0.23842
		(0.316)			(0.412)
Building Type					
Health/ Medical			0.20131		
			(0.7341)		
Industrial			-0.27070		
			(0.745)		
Residential			0.41863		
			(0.5617)		
Contruction Year				8,41E-02	0.00170
				(0.843)	(0.631)
R^2	0.02	0.09356	0.02694	0.02036	0.0943

Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The coefficient associated with the CAPEX turns out to be negative in all models (Model (1) - (5)), suggesting an inverse relationship between the amount of investment made and regulatory penalties. However, this relationship is statistically significant at the 5% level only in Models (2) and (5), which include controls for fund type and year of construction, respectively. The economic interpretation of these results is that, all other things being equal, a 1% increase in capex is associated with an approximately 0.09% reduction in penalties per square foot.

The observed results, consistent with the theoretical intuition, suggests that although buildings with high CAPEX are more frequently penalized (probably, as anticipated, because of the initial structural characteristics), the investments made are effective in containing the financial burden of penalties.

Corroborating this empirical evidence, in the report *“What's in the December 2023 Rules for LL97?”* (Urban Green Council 2024) emerges the notion of “good faith effort”, which represents one of the main innovations introduced by the December 2023 regulation.
According to this notion, buildings that demonstrate that they have taken concrete actions towards decarbonization such as starting energy retrofit investments or submitting a decarbonization plan that complies with the DOB guidelines, can obtain reductions, suspensions or postponements of economic penalties, even if at the time of the verification they are not yet fully compliant with the limits imposed by the Local Law 97.

To conclude, to assess the robustness of the main result, as in the other models, several control variables were included, but none of them were significant in determining the intensity of the penalties. However, their introduction increases the significance of the main independent variable. This is because their inclusion in the model allows a reduction in the variance of the residual error, improving the efficiency of the estimates and reducing the standard error associated with the coefficient of interest.

5. LIMITATIONS AND RECOMMENDATIONS

However, the study conducted so far has some limitations. The aim of this last section is to highlight the limitations of the analysis in order to provide insights and recommendations for further research.

The sample analyzed consists of 437 buildings located in the Manhattan district of New York City. However, many buildings, due to unavailable penalty estimates, were automatically excluded by the R studio software when conducting the regressions. To increase the robustness and significance of the results, it may therefore be appropriate to conduct the research again by expanding the sample to include a larger number of buildings.

A second limitation concerns the construction of the dependent variable, specifically the choice to use as the dependent variable the raw sum of the penalties divided into the different time clusters. This approach does not take into account future uncertainty related to both possible regulatory changes and technological developments in the sector. Although, as also previously specified in section 3.2, an alternative analysis was also conducted using a fixed median rate of 7.5% to discount the expected cash flows from future penalties, the use of a constant rate does not allow for the dynamic evolution of the business environment to be captured. Therefore, it might be appropriate to conduct future research using a method of analysis that allows the interest rate to vary over time - from lower to higher values - in order to simulate more realistic and flexible scenarios.

A third limitation concerns the way in which the key financial variables NOI and CAPEX were calculated. As mentioned in section 3.1, since these data were available for different time horizons between buildings, an average of the available values for each observation was adopted in order not to excessively reduce the available observations on which to conduct the analysis. As a result of this approach, for some observations data available from distant periods of time were also included in the average calculation. Therefore, in order to make the values more representative of the building's current economic-financial situation, a new analysis could be carried out by including in the sample only those observations with more recent data, e.g. relating to the last ten years, thus increasing the representativeness of the values used.

To conclude, since the analysis only focused on two financial indicators, other explanatory variables can be taken into account by future research to enrich the models.

6. CONCLUSION

The study analyzed the financial impact of Local Law 97 penalties on building owners. By means of a statistical analysis conducted on a sample of 437 buildings located in the borough of Manhattan, the study assessed the extent to which two key financial variables, NOI and CAPEX, influence the likelihood of incurring penalties, on the one hand, and the amount of these penalties for buildings actually sanctioned, on the other.

The results of the study are presented in Section 4.

Specifically, regarding the NOI, in the first stage of the analysis - conducted via logistic regression - the variable turns out to be a statistically significant predictor of penalties. Specifically, all the coefficients associated with it are positive, suggesting that as the Net Operating Income generated by the building increases, so does the probability of exceeding the limits imposed by LL97 and thus of being penalized. This can be explained by the fact that the most profitable buildings are those with more occupied units and thus higher energy consumption. However, in the second stage of analysis, no coefficient of the Net Operating income is statistically significant, indicating that it does not affect the amount of penalties. This explanation is based on the structure of LL97, which penalizes buildings solely according to the level of emissions produced, not the amount of operating income generated.

As far as CAPEX is concerned, again in the first stage of analysis all coefficients are positive and statistically significant, indicating that as capital expenditure in energy improvement measures increases, the probability of incurring penalties also increases. This relationship can be interpreted as a reactive effect, whereby efficiency measures are implemented in response to initially critical structural conditions. In the second stage of the analysis, however, the CAPEX coefficients are negative and statistically significant in models 2 and 5. This suggests that, among the penalized buildings, those that have incurred larger investments in energy efficiency tend to incur smaller penalties, showing a mitigating effect of retrofit expenditure with respect to the regulatory penalty burden.

The study, albeit with its limitations, offers a first quantitative contribution that is useful both for the academic literature and for public decision-makers and institutional investors. On the one hand, it highlights the need to integrate economic criteria into the assessment of environmental policy impacts; on the other, it highlights how investment decisions in sustainability may represent not only a regulatory obligation, but also a rational financial strategy in the medium to long term.

REFERENCES

Adrison, V. (2008). Estimating the effect of penalties on regulatory compliance. Dissertation, Georgia State University.

Ahmed Ali, M., Ahmad, M., & Yusup, S. (2020). Issues, impacts, and mitigations of carbon dioxide emissions in the building sector. *Sustainability, 12*(3), 1–15. https://mdpi-res.com/d_attachment/sustainability/sustainability-12-07427/article_deploy/sustainability-12-07427.pdf?version=1599701781

Alves, F., Filho, W. L., Casaleiro, P., Nagy, G. J., Diaz, H. P., Al-Amin, A. Q., Osório de Andrade Guerra, J. B. S., Hurlbert, M., Farooq, M. U., Klavins, M., Saroar, M., Lorencova, E., Jain, M., Soares, J., Morgado, F., O'Hare, P., Wolf, F., & Azeiteiro, U. M. (2020). Climate change policies and agendas: Facing implementation challenges and guiding responses. *Environmental Science & Policy, 114*, 219–229. https://www.sciencedirect.com/science/article/abs/pii/S146290111931322X

Andonov, A., Eichholtz, P., & Kok, N. (2015). A global perspective on pension fund investments in real estate. *The Journal of Portfolio Management, 41*(5), 32–42. https://www.researchgate.net/publication/275906521_A_Global_Perspective_on_Pension_Fund_Investmentsin_Real_Estate/link/5c258985458515a4c7fcca5c/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19

Arnold, S. (2024). *Local carbon policies reduce emissions: Evidence from New York City*. SSRN. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5051466

Baeroom, A. A., Hossen, M. F., Abid, M. A., & Shahzad, F. (2025). Green buildings and sustainability: A review of economic and environmental impacts. International Journal of Multidisciplinary Research and Growth Evaluation, 6(1), 1089–1094. https://www.researchgate.net/publication/388380807_Green_Buildings_and_Sustainability_A_Review_of_Economic_and_Environmental_Impacts/link/6795ec5996e7fb48b99fac37/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19

Bauer, R., Eichholtz, P., & Kok, N. (2013). How green is your property portfolio? The Global Real Estate Sustainability Benchmark. *Rotman International Journal of Pension Management, 6*(1), 34–44. https://www.researchgate.net/publication/228224301_How_Green_Is_Your_Property_Portfolio_The_Global_Real_Estate_Sustainability_Benchmark/link/00b7d51c81973e8527000000/download?_tp

=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19

Blanz, M., & Gaitan, B. (2023). *Reducing residential emissions: Carbon pricing vs subsidizing retrofits* (arXiv Working Paper No. 2310.15687). arXiv. https://arxiv.org/pdf/2310.15687

Bolton, P., & Kacperczyk, M. (2023). Global pricing of carbon transition risk. *The Journal of Finance, 78*(1), 101–139. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3550233

Burhenne, S., Tsvetkova, E., Jacob, D., Henze, G. P., & Wagner, A. (2013). Uncertainty quantification for combined building performance and cost-benefit analysis. *Building and Environment, 62*, 210–221. https://www.researchgate.net/publication/257139586_Uncertainty_quantification_for_combined_building_performance_and_cost-benefit_analyses

Chegut, A., Eichholtz, P., & Kok, N. (2011). The value of green buildings: New evidence from the United Kingdom (Working Paper). Maastricht University.

Coulson, E., Palacios, J., & Zheng, S. (2024). Climate change and real estate: An introduction to the special issue. Journal of Regional Science. Advance online publication.

Devine, A., & Yonder, E. (2021). Impact of environmental investments on corporate financial performance: Decomposing valuation and cash flow effects. *The Journal of Real Estate Finance and Economics, 63*(3), 395–430. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3947873

Duer-Balkind, M., Boyce, A., Ravulpati, R., & Sharrow, D. (2024). *Lessons from the ground: Implementing building performance standards*. ACEEE Summer Study on Energy Efficiency in Buildings.https://www.aceee.org/sites/default/files/proceedings/ssb24/assets/attachments/20240722163111500_cb7d963c-92ff-4502-b5bd-853fa15a8e53.pdf

Echeverria, J., Palacios, J., Davila, M., & Zheng, Q. (2023). Quantifying the financial value of building decarbonization technology under uncertainty: Integrating energy modeling and investment analysis. *Energy and Buildings, 288*, 113031. https://www.sciencedirect.com/science/article/abs/pii/S0378778823004905

Eichholtz, P., Kok, N., & Quigley, J. M. (2010). The economics of green building. *The Review of Economics and Statistics, 92*(5), 1027–1039. https://www.researchgate.net/publication/254396180_The_Economics_of_Green_Building/link/5c2589d892851c22a34a418d/download

Eichholtz, P., Kok, N., & Quigley, J. M. (2010). Doing well by doing good? Green office buildings. *American Economic Review, 100*(5), 2492–2509. https://www.researchgate.net/publication/46438283_Doing_Well_by_Doing_Good_Green_Office_Buildings/link/5a4f7ad04585151ee284d8c9/download

Eichholtz, P., Kok, N., & Yönder, E. (2012). Portfolio greenness and the financial performance of REITs. *Journal of International Money and Finance, 31*(7), 1911–1929. https://www.researchgate.net/publication/319463395_Portfolio_greenness_and_the_financial_performance_of_REITs/link/5c258ae7458515a4c7fccaba/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19

Fuerst, F., & McAllister, P. (2011). Green noise or green value? Measuring the effects of environmental certification on office property values. *Real Estate Economics, 39*(1), 45–69 https://immobilierdurable.eu/images/2128_uploads/Fuerst_article_autoris_.pdf

Goodland, R. (1995). The concept of environmental sustainability. Annual Review of Ecology and Systematics, 26, 1–24.

GRESB. (2024). *What is embodied carbon in the real estate sector and why does it matter?* https://www.gresb.com/nl-en/what-is-embodied-carbon-in-the-real-estate-sector-and-why-does-it-matter/

Harrington, W. (1988). *Enforcement leverage when penalties are restricted. Journal of Public Economics, 37*, 29–53.

Hoffman, J., & Kim, S. (2024). *Local Law 97: Calculating building emissions & emission limits*. New York City Department of Buildings. https://www.nyc.gov/assets/buildings/pdf/ll97_emissions.pdf

Jackson, C., & Orr, A. (2021). The embeddedness of sustainability in real estate investment decision-making. Journal of European Real Estate Research, 14(3), 362–380.

Jayakody, T. A. C. H., & Vaz, A. (2023). Impact of green building certification on the rent of commercial properties: A review. Journal of Informatics and Web Engineering, 2(2), 1–21. https://www.researchgate.net/publication/373895611_Impact_of_green_building_certification_on_the_rent_of_commercial_properties_A_review/link/6501eae68d6da36cc877d25b/download

Kadambe, S., & Segerson, K. (1998). On the role of fines as an environmental enforcement tool. *Journal of Environmental Planning and Management, 41*(2), 217–226.

Kambhu, J. (1989). Regulatory standards, non-compliance and enforcement. *Journal of Regulatory Economics, 1*(2), 103–114.

Kok, N., McGraw, M., & Quigley, J. M. (2011). The diffusion of energy efficiency in building. *American Economic Review, 101*(3), 77–82. https://www.researchgate.net/publication/226641256_The_Diffusion_of_Energy_Efficiency_in_Building/link/5a4e31d0a6fdcc3e99d47d11/download

Kok, N., Miller, N. G., & Morris, P. (2012). The economics of green retrofits. *Journal of Sustainable Real Estate, 4*(1), 4–22. https://www.researchgate.net/publication/349727519_The_Economics_of_Green_Retrofits

Kontokosta, C. E. (2016). Modeling the energy retrofit decision in commercial office buildings. *Energy and Buildings, 131*, 1–20.

Krüger, P. (2015). Corporate goodness and shareholder wealth. *Journal of Financial Economics, 115*(2), 304–329. https://www.sciencedirect.com/science/article/abs/pii/S0304405X14001925

New York State Energy Research and Development Authority. (n.d.). *Greenhouse gas emissions reduction.* *https://www.nyserda.ny.gov/Impact-Greenhouse-Gas-Emissions-Reduction?gad_source=1&gbraid=0AAAAADlA_kCrjXFglU3gYoERyxQSXFvh1&gclid=CjwKCAiAwaG9BhAREiwAdhv6Y6Oq2DGfNQDaUgSnu6qApjXw6BO804aDr23NTBK8rDDlC9rn_uY4xRoCRKQQAvD_BwE*

New York City Department of Buildings. (n.d.). *LL97: Greenhouse gas emissions reductions.* https://www.nyc.gov/site/buildings/codes/ll97-greenhouse-gas-emissions-reductions.page

Office of Building Energy and Emissions Performance. (2023). *Energy Star Portfolio Manager: Property types & LL97/19*. New York City Department of Buildings.

Palacios, J., Eichholtz, P., & Kok, N. (2020). Moving to productivity: The benefits of healthy buildings. *PLOS ONE, 15*(4), e0231931. https://www.researchgate.net/publication/343487041_Moving_to_productivity_The_benefits_of_healthy_buildings/link/66ccadad75613475fe7f35ed/download

Papineau, M. (2013). *Energy codes and the landlord-tenant problem* (Carleton Economic Papers No. 13-03). Department of Economics, Carleton University. https://escholarship.org/content/qt2bq3x1t6/qt2bq3x1t6.pdf

Pivo, G., & Fisher, J. D. (2011). Income, value, and returns in socially responsible office properties. *Journal of Real Estate Research, 33*(3), 435–468. https://www.researchgate.net/publication/227450838_Income_Value_and_Returns_in_Socially_Responsible_Office_Properties/link/5cdf1758a6fdccc9ddb93db7/download

Salimifard, P., Buonocore, J. J., Konschnik, K. E., Azimi, P., VanRy, M., Laurent, J. G. C., Hernandez, D., & Allen, J. G. (2022). Climate policy impacts on building energy use, emissions, and health: New York City Local Law 97. *Energy, 238*, 121652.

Spitzer, P. (2021). Carbon reduction standards emissions in New York City's buildings: Climate cultures in sociological research. Sociology Insights, 4(1), 1–13.

The Office of the Mayor's Office of Climate and Environmental Justice. (2021). *Local Law 97 implementation action plan*. New York City. https://www.nyc.gov/assets/dcas/downloads/pdf/energy/reportsandpublication/local_law_97_implementation_action_plan_2021_report.pdf

United Nations Environment Programme. (2024). Global status report for buildings and construction: Beyond foundations: Mainstreaming sustainable solutions to cut emissions from the buildings sector.

Urban Green Council. (2024, January). *What's in the December 2023 rules for LL97?* Retrieved from https://www.urbangreencouncil.org/whats-in-the-2023-proposed-rules-for-ll97/

U.S. Global Change Research Program. (2023). *Fifth National Climate Assessment*. https://nca2023.globalchange.gov

U.S. Green Building Council. (n.d.). *Public policies.* https://public-policies.usgbc.org/policies

U.S. Environmental Protection Agency. (2024). *Commercial and residential sector emissions (2022 data).* Retrieved from U.S. EPA website.

van der Kroft, B., Palacios, J., Rigobon, R., & Zheng, S. (2024). Timing sustainable engagement in real asset investments (NBER Working Paper No. 32646). National Bureau of Economic Research.

de Wit, S., & Augenbroe, G. (2002). Analysis of uncertainty in building design evaluations and its implications. *Energy and Buildings, 34*(9), 951–958.

World Green Building Council. (2019). Bringing embodied carbon upfront: Coordinated action for the building and construction sector to tackle embodied carbon. https://worldgbc.s3.eu-west-2.amazonaws.com/wp-content/uploads/2022/09/22123951/WorldGBC_Bringing_Embodied_Carbon_Upfront.pdf

World Green Building Council. (2024, October). Be bold on buildings at COP29: Briefing paper outlining successful outcomes for COP29 negotiations from a building sector perspective. https://worldgbc.org/wp-content/uploads/2024/10/WorldGBC-COP29-Briefing-Paper-1.pdf

APPENDIX

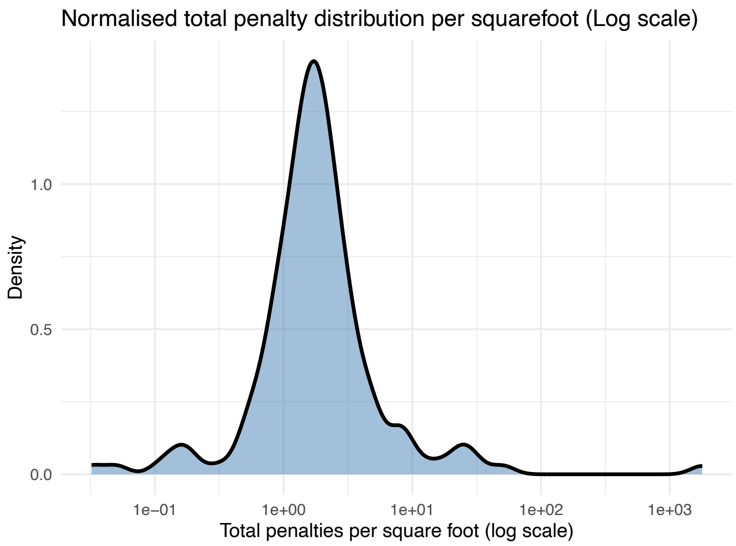

Figure 9: Total penalties' distribution

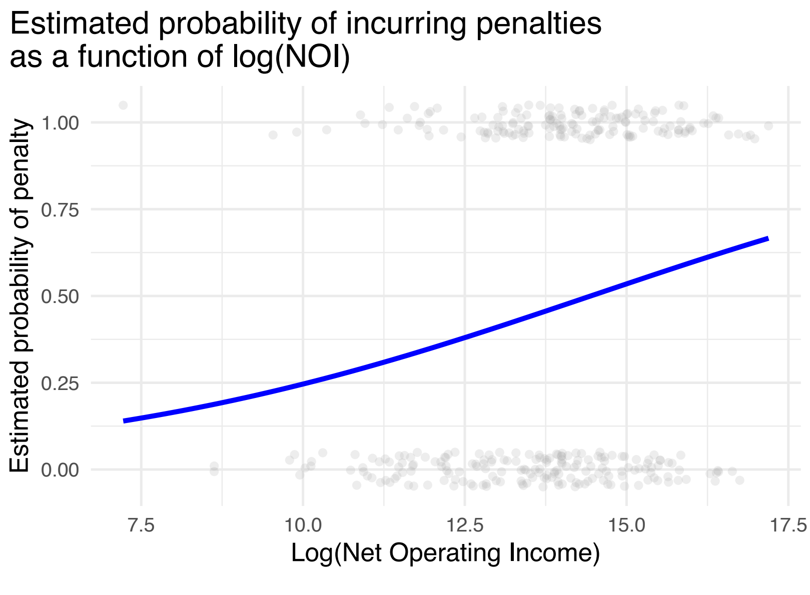

Figure 10: Logistic regression - Estimated probability of incurring penalties as a function of logarithmic NOI

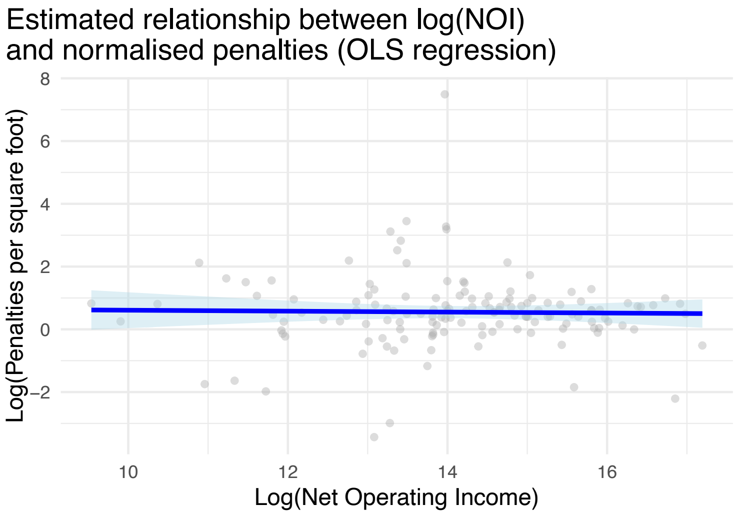

Figure 11: OLS regression – estimated relationship between Net Operating Income and Penalties normalized by square footage

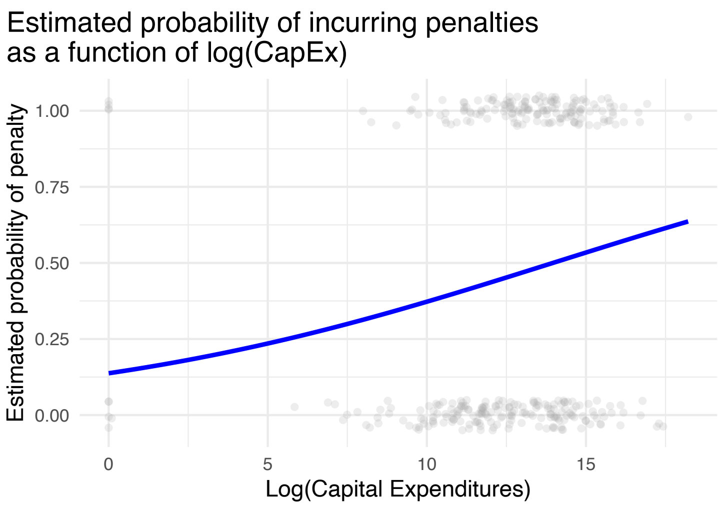

Figure 12: Logistic regression - Estimated probability of incurring penalties as a function of logarithmic CAPEX

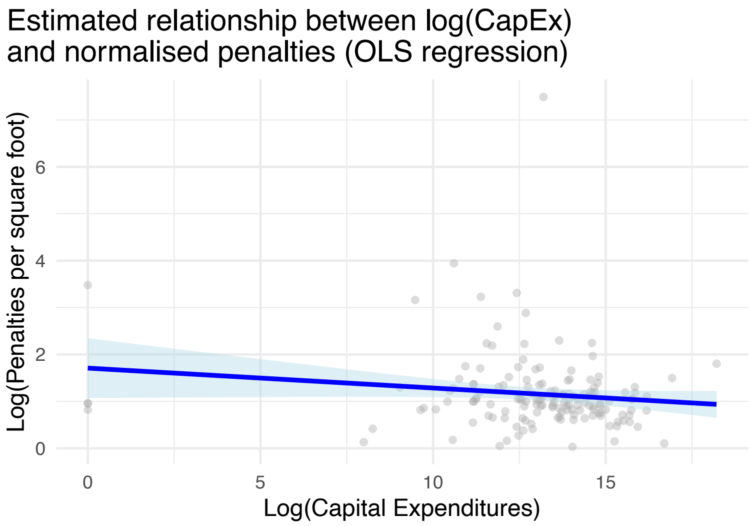

Figure 13: OLS regression – estimated relationship between CAPEX and Penalties normalized by square footage