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The Value of Design in Real Estate Asset Pricing

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Received: 21 September 2020; Accepted: 5 October 2020; Published: 9 October 2020

Abstract: Does design contribute to real estate value? Practicing architects require evidence to justify both functional and aesthetic building needs within the financial ecosystem. Some buildings that become real estate assets are valued using models that consider some proxies for understanding value, but these features are abstract and may misidentify the sub-optimal differentiation that design brings. The lack of feedback between real estate valuation and building design often leads to poor design and economic outcomes. To address this miscommunication, we investigate the transaction price performance of four external architectural form features—diagonality, curvature, setbacks and podiums. Whilst controlling for drivers that are known to explain transaction price variation, we find that diagonality and podiums have a positive pricing differential of 12.4 and 9.7% more than rectilinear control buildings, respectively. Buildings with setbacks have a negative pricing differential of 10%. Furthermore, these results are also consistent for rental valuation. Results suggest that there is a significant economic impact of some architectural form interventions that differentiate commercial buildings and contribute to the role of form in design, planning and commercial real estate.

Keywords: architecture; design; built environment; finance/financialization; valuation; asset pricing

1. Introduction

What are the value drivers for a building? This is an important question for disciplines within the built environment associated with the design and development of buildings, as 50% of our building stock is actively traded in the real estate market. Asset valuation models have been steadily improving for the past 50 years and are developing to consider real estate value drivers. Predominantly, they are used to understand neighborhood and building feature value impacts. Historically, the valuation literature has relied on the hedonic asset pricing model, or some derivation, the hybrid or repeat sales approach [1]. Rosen [2] denoted that the model was intended as a tool to understand product differentiation and variation that leads to increased or decreased value in the marketplace. Simply, the model aims to measure the drivers of utility that users are willing to pay for and, when using historical data and a regression, have been empirically shown to pay for. The drivers could be as specific as distance to parks as well as rather qualitative changes such as urban improvements [3]. As a statistical tool, it is a multi-variate framework that intends to explain the drivers of a building's price, rent, appraisal value, cost, etc. Although the variables generally used to measure differentiated value are crude and abstract, such as building size, age, number of stories, status of renovation, location and proximity to the Central Business District (CBD) [2], it is the basis behind appraisal analysis and asset valuation econometrics. However, these building and neighborhood features describe only the simplest building elements and their context, which have already been specified as guidelines prior to the design of the physical structure.

Designers, on the other hand, consider much more qualitative and tactile elements of architecture during the design process—such as materiality, geometry, daylight, views, and spatial flexibility—to cater to both functional, regulatory and permitting, as well as aesthetic needs. Historically, this question has been answered by the peer recognition of awarded architectural design, which has historically shown a value premium [4–9]. Moreover, design elements, features and characteristics that differentiate buildings are entirely dismissed and overlooked by the current financial practice of commercial real estate valuation, either due to a previous lack of means to collect data about building features, or limited knowledge of the design discipline. In general, data from buildings is seldom distributed beyond design company borders [10]. However, omitting these features from asset valuation may leave a missed opportunity to understand the extent to which the actual building design features and program impact the property market value and product differentiation during individual real estate transactions. Therefore, we ask, how do design features contribute to building value?

To answer this question, we identify and catalog design features of commercial office buildings and operationalize their geometric measurements using a 3D model of New York City. We construct metrics for four distinct external architectural design elements that relate to transforming a building's design and form. These design features are diagonal intersections, building curvature, setbacks, and podium extrusions. All of the above represent design interventions that architects made to differentiate the spatial extrusion of the building in response to regulatory standards and potentially financial constraints. We then pair these building features with genuine individual transaction prices and rental contracts in the Manhattan property market from U.S. data providers Real Capital Analytics and Compstak (in New York City, NY, USA) over the 2001 to 2017 period and then compare these to buildings transacted without the four specified design features measured in this paper.

The results of our analysis indicate that there are some design features that demonstrate product differentiation and increased value relative to their market peers. Namely, buildings with diagonality and podium extrusions have a positive and statistically significant pricing differential relative to their control sample peers of 12.4 and 9.7% more, respectively. These results suggest that there is a positive impact of architectural design features that aesthetically and functionally enhances the building. On the other hand, setbacks have a negative pricing differential relative to their building peers of 10%. Furthermore, these results are robust to another measure of value differential, commercial rental values, where buildings with diagonality and podium extrusions have a positive and statistically significant pricing differential relative to their control sample peers of 2 and 3.5% more, respectively. Finally, with added standard controls for design and historical value, results of the valuation models remain consistent, robust and in-line with the literature.

Understanding pricing differentials from design can help align designers and financial decision makers around what creates a long-term value proposition. One may argue that it costs more to execute these design strategies, or that that these strategies are a response to regulatory and geographic constraints. In either case, there remains evidence of a relative value proposition in differentiating the structural design features of the building as evidenced by what building owners were historically willing to pay. Furthermore, we see that the value of design interventions and of the design community remains consistently robust, whether for awarded design, or looking at a new financial medium like commercial rents, there is a growing body of literature to support considering design value [4–9]. In this way, there is a growing precedent for paying for and justifying the value of designers and the strategies that they implement to differentiate buildings.

The remainder of this paper is laid out as follows. In Section 2 we outline the literature that looks at prior research on design value. In Section 3, we outline the design elements we developed for this paper. In Section 4, we document our dataset, descriptive statistics and geographical characteristics. In Section 5, we outline our hedonic methodology. In Section 6, we document our transaction and rental results. In Section 7, we discuss these results and their contribution to the design and the real estate valuation literature.

2. Valuing Design: A Review

In general, the literature that measures architectural design features rather than involvement of awarded architects is limited. Current research identifies market response to design awards as a measure of architectural design quality which can have financial value. Important architectural projects, as represented by awarded designers, may generate a real estate value premium [4–9] and may perform as a positive externality for nearby building valuations [11]. Common practice to measure architectural quality and assess how design differentiates involves using a hedonic pricing model, conducting surveys, interviews and expert-led grading [5,6,8,12].

In their seminal work, Hough and Kratz (1983) document the economic impacts of architectural design in commercial buildings for buildings in the Chicago CBD and focused on the designation of a building as a landmark, and(or) award-winning status with value premiums. Other attributes that they were able to be quantifiably measure, such as the radial distance of an office building from the CBD, building age, total gross floor area, number of floors and the presence of a restaurant. Asabere et al. [13] focused on historical architecture and categorized the samples into architectural styles—colonial, federal, garrison, and Victorian architectural styles—townhouse, duplex, condominium, and ranch housing styles in order to detect economic impacts of architecture style on home value. Plaut and Uzulena [14] conducted similar research in Riga, Latvia by studying buildings from different time periods. Buitelaar and Schilder [15] looked into architectural styles but included many specific characteristics in their hedonic price model—plot size, construction year, dwelling type, parking type, and land lease conditions, thereby controlling for design value more closely.

Another approach has been to look at awarded designers. Cheshire and Derick [16] and Fuerst, McAllister, and Murray [8] focused on architectural projects by the Pritzker Prize and/or American Institute of Architects (AIA) Gold Medal winning architects in the USA. Both papers found evidence of correlation between buildings by award-winning architects and their economic value. However, the research did not scrutinize the impacts of other aspects of architectural design and attributed the additional economic value to the reputation of famous architects. So-called "Good" architecture, be it an award-winning project, a project designed by a famous architect, or a building with high ratings from experts, may bring significant value premiums [4–9].

Few researchers have attempted to identify the term "design," with one exception, Lindenthal [17] who documents a hedonic pricing relationship between design form homogeneity for residential houses in Rotterdam, the Netherlands, where heterogenous or differentiating housing forms earned a discount. People's interpretations of design works are likely to involve the communicative intentions embedded in those designs [18]. Different combinations of individual design attributes are likely to shape viewers' perception of design style [19] or recognition of the overall image [20]. To further understand the value of design, thus, requires research to identify and quantify design attributes for in-depth valuation. Architectural form is an important place to start.

3. Identifying Design Features

Nascent research in this field took "design" as an explicit subject of the architect, mainly his(her) prowess or measured accomplishments, without looking into the underlying features of design. Early work in this domain is provided by Ching [21] who deconstructs architectural design into compositional features through an analysis of form, space, and spatial order. As an art, architecture is more than satisfying the purely functional requirements of a building program. Fundamentally, the physical manifestations of architecture accommodate human activity. However, the arrangement and ordering of forms and spaces also determine how architecture might promote endeavors, elicit responses, and communicate meaning [21]. While examining and illustrating abstract concepts of design, such as point, line, and plane, Ching devoted extensive effort into categorizing formal elements—surface, primary solids, and openings with planes—or elements that may directly shape a building's form—linear organization, structural proportion, and configuration of the path, just to name a few. Similarly, Ching [22] focused on providing extensive illustrations of key terms used in architectural practice. This line of research is also explored by Rem Koolhaas [23] where architecture fundamentals are dissected into fifteen primary components, such as wall, floor, ceiling, corridor, and facade. Bille and Sorensen [24] focused more on the conceptual, atmospheric aspects of design.

One way we have advanced across domains is in computation. In the valuation practice in real estate, methodologies currently used to observe and evaluate the built environment are based on the data available from transaction prospectus or rent contracts, which presents only a minuscule fraction of the large data sets and features we are equipped to gather. In contrast, we identify and construct a new set of data on design metrics to provide reference and guidelines for both designers and developers for some external architectural design elements. This aligns with recent studies which begin to evaluate the economic impacts of qualitative factors in architectural design, such as daylight and form [17,25].

Considering both the internal and external design features that are outlined by Ching [22] and Koolhaas et al. [23] there are extensive design features that can be potentially measured inside and outside of the building. Internal design metrics require comprehensive floor plans and sections details of each building which are currently scattered across individual architecture firms, inconsistently collected by the planning authority and unavailable to collect for many properties. However, it is important to consider in the design catalogue as commercially available reality capture technology can help document the details of every physical space in a building.

In this paper, we focus on individual features of external building form. The selected design metrics may produce noticeable changes on the exterior of buildings, hence significantly shaping the overall building design and differentiation of the structure relative to its peers. The four metrics are diagonal intersections, curvature, setbacks and podium extrusions. They are detailed further in Figure 1. First, the sites of buildings that sit on diagonal road intersections usually have a unique geometry, which would require architectural designers to come up with design solutions involving use of non-90-degree angles. Although the Flatiron building is famous for dealing with land constraints, it is not a unique building in Manhattan. There are 198 buildings that respond to diagonal intersections with non-rectangular diagonal forms. Second, we see curvature as a design feature which might make the buildings more utility enhancing than buildings without significant exterior features according to the design literature. In addition, the presence of curvature may also reflect the developer and designer's effort to create a leading real estate product in the market. The third feature is the setback feature. The city's 1916 Zoning Resolution forced buildings to push back from the street above a certain height to ensure the access of light and air from the street level. As a result, designers had to design a terrace-like form for the upper portion of many buildings, hence creating a geometry that is different from other buildings. This has led to the later development of the podium, which as a design feature was meant to meet strict zoning requirements, while embracing alternative mixed-use commercial space for retail needs on the bottom floor. The following documents the precedents in design that differentiate these external architectural elements from their peers.

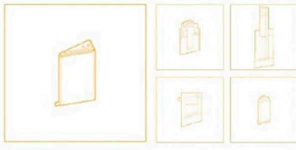
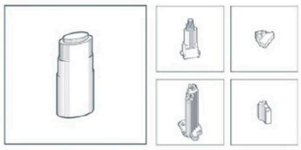
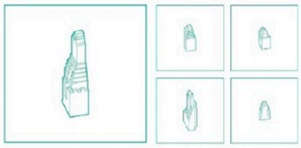
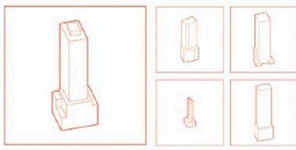
Name	Design Examples	Description
Diagonal intersection		Buildings located on diagonal roads and intersections. Given that Manhattan uses an extensive urban grid to organize its urban space, most building sites are contained within rectangular blocks. Hence, building sites along diagonal roads are usually non-rectangular. Since land value is so high in Manhattan so that most build developments would tend to maximize building footprint by occupying as much site area as possible. In that sense, buildings on diagonal intersections would usually have a unique geometry due to the rather irregular shape of site.
Curvature		Buildings with calculated non-90 degree envelope features in plan or elevation. Curved features, especially large-scale features, might require special design of structural system and increase the budget. However, curved features "… can be more vigorous and expressive in nature. Their shapes change dramatically as we view them from different perspectives" [21].
Setbacks		Building with a terraced form in the upper part of the structure. The zoning regulation required buildings to set back the street-facing façade as the building height increased. As a result, high-rise buildings designed and constructed when the 1916 Zoning Regulation was active all had a terrace-like geometry on the upper portion. Some designers responded to this regulation by putting additional amenities on the terrace rooftop, while some chose to set back the façade more than required distance to create generous terrace space. Even during periods when the 1916 Zoning Regulation became inactive, some designers still chose to reproduce the terrace-like form for high-rises.
Podium extrusion		Buildings with a horizontal base on the lower floors of the structure. Podium extrusion was a popular design feature of modernist architecture. Many famous buildings constructed after WWII, such as the Lever House and the UN Headquarters, all had a podium extrusion. Some recent design, such as the Heart Tower, Beekman Tower, Hampshire's Dream Hotel (under construction), also included podiums. Podium extrusion is useful in that it provides a separated spatial layout that may be home for different commercial real estate programs, turning the building into a mix-use complex.

Figure 1. External Architectural Design Features. Figure 1 documents the descriptive elements of four external design features, diagonal intersection, curvature [21], setbacks and podium extrusions as a few external design interventions investigated in this paper. Image: MIT Real Estate Innovation Lab Adaptation, Source: NYC 3D Model by Community District [26].

3.1. Diagonal Intersection

The Commissioners Plan of 1811 imposed a rigid gridiron plan on the island of Manhattan, whose proponents saw as "legible, accessible, efficient, traditional, and perhaps, even egalitarian" [27]. Since "straight-sided and right-angled houses were the least expensive to build and most convenient to live in" according to the city commissioners, grids were intended to maximize the value of real estate and make the division of land into saleable lots more easily [28]. The grid laid out 155 east–west streets and twelve north–south avenues, halting at 155th street due to challenging ground conditions. Two elements stood out as exceptions to the rule: Central Park and Broadway were foreign elements that disrupted the regularity of the grid and confused traffic. However, the legacy of this tension is the production of a major public open space approximately every ten blocks. Whenever Broadway crosses an Avenue, it creates a large six-way "bowtie" intersection, generously providing room for public space such as parks or seating areas around the buildings, thereby enhancing safety, pedestrian traffic and liveliness [29]. A few examples include squares such as Union Square at 14th Street, Madison Square Park at 23rd Street, Herald Square at 34th Street, Times Square at 46th Street, and Columbus Circle at 59th Street [30].

3.2. Curvature

In general, the way curvilinearity affects human perception has been studied widely across scales in the built environment: from product graphics and container designs [31] to cars [32] and architectural interiors [33]. Scholars have long studied the relationship between curvilinearity and form, from the perspective of psychology, philosophy, evolution and aesthetics [34–38]. More generally, curved lines have often been considered as "more harmonious, relaxing, or pleasant"—and more in consonance with nature than straight "or broken lines" [39]. This harmony is supported by research emerging from environmental science, Shepley's comparison of two different interior environments show that people of various ages more frequently prefer curved walls as object-orienting spaces as opposed to squared-off walls as spatially-orienting spaces [40]. Vartanian et al. [33] have conducted an fMRI study where participants responded to images of interior architectural spaces with various degrees of curvature and sharp angles. The study found rooms with curved spaces to be subjectively preferred overall [33], but data shows that too much curvature makes a participant experience feelings of confusion and anxiety [41].

3.3. Setbacks

According to Ely Jacques Kahn [42], "The New York zoning laws protecting property rights, light, and air have encouraged a new art by reason of the very restrictions they contain." Passed by the City's Board of Estimate on 25 July 1916, the zoning ordinance applied the principle of the zoning envelope to all commercial high-rise buildings. Five formulas that were based on the width of the street and the angle of the setback were used to define the physical envelope of a building. The numerous permutations of the formula provided by different widths of the street encouraged the "wedding cake" setback. The shape of the building was effectively pre-designed by code [43] and by the mid-1920s, a number of architects and critics were writing about a new design approach which some labeled the "setback style" [44]. This had the impact of increased privacy, exposure, light, and air, as well as use of an outdoor space were the inherent advantages identified in the new "setback style" [45].

3.4. Podium Extrusion

A classical skyscraper consists of a base, a shaft and a crown, which is a morphology that emerged in the 1920s. It is defined by Britannica as "any of various elements that form the "foot", or base, of a structure, such as a raised pedestal or base" [46]. Due to its form and proportions, podiums conveniently incorporate programs which require horizontal spaces, such as conference halls, or street space such as shops or other public amenities. In order to assist developers and architects in designing tall buildings, numerous cities provide tall building guidelines to establish standards and recommendations where the podium of a tall building "anchors the tower and defines pedestrian experience at the street level...[in which its] location and height should frame and create a positive relationship to the street" [47]. Brook McIlory emphasizes the importance of creating a connection between the public and private realm through the podium, while ensuring vibrancy throughout the day [47].

4. A Geometric, Geospatial and Relational Dataset

First, to assess the external architectural differentiation of the city, we need to examine the geometry of New York City. The NYC Department of Information Technology & Telecommunications (DOITT) has released a 3D model of NYC at the level of detail (LOD) one to two scale. Level of Detail at the one or two level means that external building features and iconic building features can be identified through each building's geometry across the entire city. We then classify the geometry of every building in the city, according to our four external architectural features. Using the 3D model of NYC, we assign a dummy variable of one to each building if it has a design feature, and zero otherwise. Some buildings may have more than one design feature. Figure 2 depicts the Manhattan building geometry in 3D and isolates the diagonal inters, building curvature, setbacks, and podium extruded buildings across the city. We find that there is concentration of buildings with podium extrusions in Midtown and Downtown Manhattan, whereas buildings located on diagonal intersections are spread throughout NYC. Similarly, buildings with curvature in their exterior envelope are distributed across the city.

We then pair the building geometry of our selected sample to their geolocational attributes using New York City's geocoding tool GeoBat, Geosupport Desktop Edition for the City of New York, NYC, USA by the NYC Department of City Planning, to identify unique building identification numbers (BIN). We then match the BIN of the 3D models with our building dataset and assign a variable to each of the design metrics. Finally, we use commercial building transaction data provided by Real Capital Analytics (RCA) and building feature and rental contract data from Compstak to provide fundamental hedonic variables for our transaction and rental pricing models and test the model in New York City. RCA specializes in property transaction data in New York City and provides building transaction data that include financing details, prior transaction history, and true owner identification. Compstak provides crowdsourced information such as lease contract characteristics, tenant profile, and market variables from verified professionals from commercial brokerage and appraisal firms.

We extract location and transaction time data for individual property transactions from the RCA dataset to control for time and location. We use the submarket designation provided by RCA to control for relative location quality. There are seven areas specified in the data: Downtown, Midtown East, Midtown South, Midtown West, Upper East Side, Upper Manhattan and Upper West Side. During estimation, we use the categorical location fixed effects relative to a base submarket, Midtown West.

To control for different types of real estate buyers and sellers, we control for buyer type, seller type and lender type data provided by RCA. These buyer and seller types range from corporations, funds, governments, institutional, offshore, private and Real Estate Investment Trusts (REITs).

We then extract the building class feature for each building that transacted from the Compstak dataset to control for the overall quality of the buildings in the sample dataset and match the observations from the RCA dataset. There is not a third-party standard or designation for building quality, which is bestowed upon commercial buildings by tenants, owners and brokers. The Building Owners and Managers Association is the only group with a working definition for building class. Class A buildings are the most prestigious buildings competing for premier office users with rents above average for the area. Buildings have high quality standard finishes, state of the art systems, exceptional accessibility and a definite market presence; Class B Buildings competing for a wide range of users with rents in the average range for the area. Building finishes are fair to good for the area. Building finishes are fair to good for the area and systems are adequate, but the building does not compete with Class A at the same price; Class C buildings are competing for tenants requiring functional space at rents below the average for the area [48]. Since the correlation between building class and architectural style could be a factor in the model, we control for building class in the model. The correlation coefficients for building classes A, B, and C and the architectural features do not exceed 0.29, which suggests that these factors should be included in the model, but does not indicate a violation of Best Linear Unbiased Estimator (BLUE) assumptions.

Figure 2. Geographic variation of external architectural design features. Figure 2 depicts the geographic variation of external architectural design features—diagonal intersection, curvature, setbacks and podium extrusions have their building geometry highlighted across Manhattan, New York.

In addition to these two datasets, we include a WalkScore variable from RCA to measure the walkability of a neighborhood and its accessibility to public transit with a score range from 0 to 100. Further, we use data from Kang [10] to include whether an architect or architectural firm has been awarded, at least one or many, of the significant architectural awards to our model to strengthen the ties between both the prior financial literature and newly developing literature of architectural features.

Kang [10] comprehensively researched the award status of every building across every industry architecture award to include prestige architects young and old and architectural firms, including the RIBA Royal Gold Medal, AIA Gold Medal, the Pritzker Prize, the UIA Gold Medal, Cooper Hewitt National Design Award and the Wall Street Journal Innovation Awards in Architecture, the Golden Lion for Lifetime Achievement Award and the AIA Architecture Firm Award. In total, we have the complete database for all the variables for 3037 observations for commercial real estate in Manhattan over the 2001 to 2017 period.

Table 1 shows the dependent and independent variables included in the analysis and compares the average characteristics of buildings with visible external design features with that of control samples. Buildings with measured design features yielded higher average transaction prices compared to the control samples. Buildings with podium extrusions yielded an unusually high average transaction price and high price variability. However, the price variability of buildings with other design features is generally lower than that of the control samples.

Buildings designed by awarded architects or firms are rare across the full sample, but are highly correlated with buildings with curvature at about 49%. Buildings with design features are, on average, taller than the control buildings, except buildings with curvature. Most buildings with design features are in Class A or B, while the control buildings are mostly in Class A and Class B too, with two exceptions buildings with curvature and podiums are mostly in Class A buildings All building samples have similar walk scores due to the high connectivity of Manhattan's urban environment.

The average age of buildings with setbacks and podiums are both lower than that of the control sample, 69.9 years, 41.8 years, and 82.7 years, respectively. In fact, nearly 20% of buildings with setbacks have been built in the last fifty years, well after the 1916 Zoning Ordinance was superseded by the 1961 Zoning Resolution. In addition, podiums remain present in new constructions after 2000. Our samples indicate that setbacks and podiums remain a stylistic design choice made by architects still to this day.

Our samples indicate that most buyers (41%) are real estate private companies. Such a trend remains consistent across building samples with design features and the control samples. A total of 37.5% of buyers of buildings at diagonal intersections are also private companies. Even if buildings with curvature have only 28.5% of buyers that are private companies, the percentage remains the largest. In general, none of the buildings with design features or control buildings have attracted many buyers from any specific buyer type besides private companies.

Private companies are also the largest sellers of both buildings with design features and control building samples. A total of 27.5% of buildings are sold by private companies, similar to the 30.9% of control buildings sold by private companies. However, the percentages of sellers from private companies in buildings with design features are noticeably lower than the former two—16.4% for buildings at a diagonal intersection, 14.3% for buildings with curvature, 23.8% for buildings with setbacks, and 17% for buildings with podium extrusion.

As for lending types, our sample shows that buildings with curvature have a combination of lenders in four categories—Commercial Mortgage Backed Security (CMBS), international bank, national bank, and regional/local bank. The control buildings also have a similar mix of lenders. However, buildings with other design features have a particularly high concentration of lenders from CMBS and, in general, a relatively small concentration in regional/local bank. Detailed descriptive statistics for rental contract data provided by Compstak are documented in Appendix A.

Table 1. Descriptive statistics of building characteristics and transaction details by geometry. Table 1 highlights the mean and variation of building characteristics for the building samples with curvature, site location on a diagonal intersection, podium, and the New York City setback geometry.

Variable	Control Sample	Diagonal	Curvature	Setbacks	Podium	Full Sample
	Mean (Std. Dev. *)	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**
Awarded Design						
Awarded Architects	0.008 (0.091)	0.000 (0.000)	0.429 (0.514)	0.008 (0.090)	0.059 (0.237)	0.013 (0.113)
Awarded Firms	0.006 (0.080)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.030 (0.170)	0.006 (0.077)
Awarded Architects and Firms	0.016 (0.124)	0.000 (0.000)	0.000 (0.000)	0.003 (0.057)	0.081 (0.275)	0.016 (0.125)
Building Information						
Price (in million USD)	91.490 (182.330)	176.274 (241.860)	348.359 (415.899)	156.136 (208.046)	537.065 (508.438)	137.556 (245.204)
Age	82.667 (30.262)	75.883 (34.203)	23.429 (16.266)	69.900 (22.139)	41.830 (29.483)	77.036 (30.571)
Number Floors	13.336 (11.347)	18.266 (15.240)	30.571 (12.445)	22.704 (10.960)	33.356 (13.823)	17.075 (13.218)
Building Class A	0.238 (0.426)	0.305 (0.462)	0.857 (0.363)	0.377 (0.485)	0.859 (0.349)	0.312 (0.463)
Building Class B	0.522 (0.500)	0.578 (0.496)	0.143 (0.363)	0.490 (0.500)	0.126 (0.333)	0.494 (0.500)
Building Class C	0.240 (0.427)	0.117 (0.323)	0.000 (0.000)	0.133 (0.340)	0.015 (0.121)	0.194 (0.395)
Square Meters	16,975 (29,841)	29,942 (32,354)	45,489 (38,653)	33,589 (39,491)	84,830 (66,688)	25,465 (38,668)
Renovated	0.182 (0.386)	0.227 (0.420)	0.000 (0.000)	0.208 (0.407)	0.222 (0.417)	0.193 (0.395)
Walk Score	99.233 (1.262)	99.406 (0.900)	98.786 (1.968)	99.206 (1.180)	99.067 (1.328)	99.229 (1.230)
Buyer Type						
Corporation	0.052 (0.221)	0.023 (0.152)	0.000 (0.000)	0.045 (0.208)	0.015 (0.121)	0.046 (0.210)
Fund	0.023 (0.148)	0.023 (0.152)	0.000 (0.000)	0.024 (0.154)	0.030 (0.170)	0.023 (0.149)
Government	0.026 (0.160)	0.023 (0.152)	0.000 (0.000)	0.032 (0.177)	0.015 (0.121)	0.026 (0.160)
Institutional Investor	0.020 (0.139)	0.047 (0.212)	0.000 (0.000)	0.023 (0.149)	0.037 (0.190)	0.022 (0.147)
Offshore	0.029 (0.168)	0.055 (0.228)	0.143 (0.363)	0.050 (0.218)	0.089 (0.286)	0.037 (0.189)
Private	0.441 (0.497)	0.375 (0.486)	0.286 (0.469)	0.362 (0.481)	0.304 (0.462)	0.410 (0.492)
Real Estate Investment Trust	0.016 (0.126)	0.031 (0.175)	0.071 (0.267)	0.026 (0.159)	0.081 (0.275)	0.023 (0.151)
Real Estate Operating Company	0.003 (0.058)	0.000 (0.000)	0.071 (0.267)	0.005 (0.070)	0.037 (0.190)	0.006 (0.075)
Retailer	0.002 (0.044)	0.008 (0.088)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.002 (0.041)
Unknown	0.388 (0.487)	0.414 (0.494)	0.429 (0.513)	0.432 (0.496)	0.393 (0.490)	0.405 (0.491)

Table 1. *Cont.*

Variable	Control Sample	Diagonal	Curvature	Setbacks	Podium	Full Sample
	Mean (Std. Dev. *)	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**
Seller Type						
Corporation	0.048 (0.215)	0.047 (0.210)	0.000 (0.000)	0.0178 (0.132)	0.037 (0.190)	0.041 (0.198)
Fund	0.012 (0.108)	0.023 (0.152)	0.000 (0.000)	0.028 (0.164)	0.022 (0.148)	0.016 (0.126)
Government	0.030 (0.172)	0.016 (0.125)	0.000 (0.000)	0.015 (0.120)	0.015 (0.121)	0.025 (0.157)
Institution	0.016 (0.124)	0.039 (0.195)	0.071 (0.267)	0.028 (0.164)	0.037 (0.190)	0.020 (0.140)
Offshore	0.020 (0.139)	0.008 (0.088)	0.214 (0.426)	0.037 (0.189)	0.044 (0.207)	0.025 (0.156)
Private	0.309 (0.462)	0.164 (0.372)	0.143 (0.363)	0.238 (0.426)	0.170 (0.377)	0.275 (0.447)
Real Estate Invetment Trust	0.010 (0.099)	0.031 (0.175)	0.000 (0.000)	0.013 (0.113)	0.000 (0.000)	0.011 (0.105)
Real Estate Operating Company	0.001 (0.031)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.007 (0.086)	0.001 (0.031)
Retailer	0.002 (0.044)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.001 (0.036)
Unknown	0.552 (0.498)	0.672 (0.471)	0.571 (0.514)	0.625 (0.485)	0.667 (0.473)	0.584 (0.493)
Lender Type						
Commercial Mortgage Backed Security	0.196 (0.397)	0.281 (0.451)	0.643 (0.497)	0.278 (0.449)	0.407 (0.493)	0.234 (0.423)
Financial	0.047 (0.211)	0.055 (0.228)	0.000 (0.000)	0.036 (0.185)	0.030 (0.170)	0.043 (0.203)
Government Agency	0.002 (0.044)	0.008 (0.088)	0.000 (0.000)	0.002 (0.040)	0.000 (0.000)	0.002 (0.048)
Insurance	0.044 (0.205)	0.086 (0.281)	0.000 (0.000)	0.074 (0.263)	0.133 (0.340)	0.057 (0.232)
International Bank	0.100 (0.300)	0.133 (0.341)	0.071 (0.267)	0.099 (0.299)	0.096 (0.296)	0.104 (0.305)
National Bank	0.121 (0.327)	0.141 (0.349)	0.071 (0.267)	0.149 (0.356)	0.074 (0.263)	0.125 (0.330)
Pension Fund	0.001 (0.038)	0.000 (0.000)	0.000 (0.000)	0.003 (0.057)	0.000 (0.000)	0.002 (0.041)
Private	0.018 (0.132)	0.000 (0.000)	0.000 (0.000)	0.005 (0.070)	0.015 (0.121)	0.014 (0.115)
Regional/Local Bank	0.161 (0.367)	0.102 (0.303)	0.071 (0.267)	0.117 (0.321)	0.037 (0.190)	0.139 (0.346)
Unknown	0.310 (0.463)	0.195 (0.398)	0.143 (0.363)	0.238 (0.426)	0.207 (0.407)	0.281 (0.450)
Number of observations	2042	128	14	618	135	3037

* Std. Dev. for Standard Deviation.

Among the 3037 observations, 198 buildings are located on diagonal roads or intersections, 26 buildings have curvature, 740 buildings have setbacks, and 194 buildings have podium extrusion. Indeed, some buildings contain more than one design feature, as shown in Figure 3, where 51 buildings have both setbacks and diagonal intersections; 26 buildings have setbacks and podium extrusions; 8 buildings have both curvature and podium extrusions; 13 buildings are at diagonal intersections and have podium extrusions; 2 buildings have curvature and setbacks; 1 building has curvature, setbacks, and a podium extrusion, 2 buildings located on diagonal intersections have setbacks and podium extrusions. From there, we may re-group our building samples to select the "pure" samples, in order to generate a more accurate statistical result on each of the design features' impact on transaction price. There are 128 buildings located on diagonal roads; 14 buildings have curvature; 618 buildings have setbacks and 135 buildings have podium extrusions exclusively.

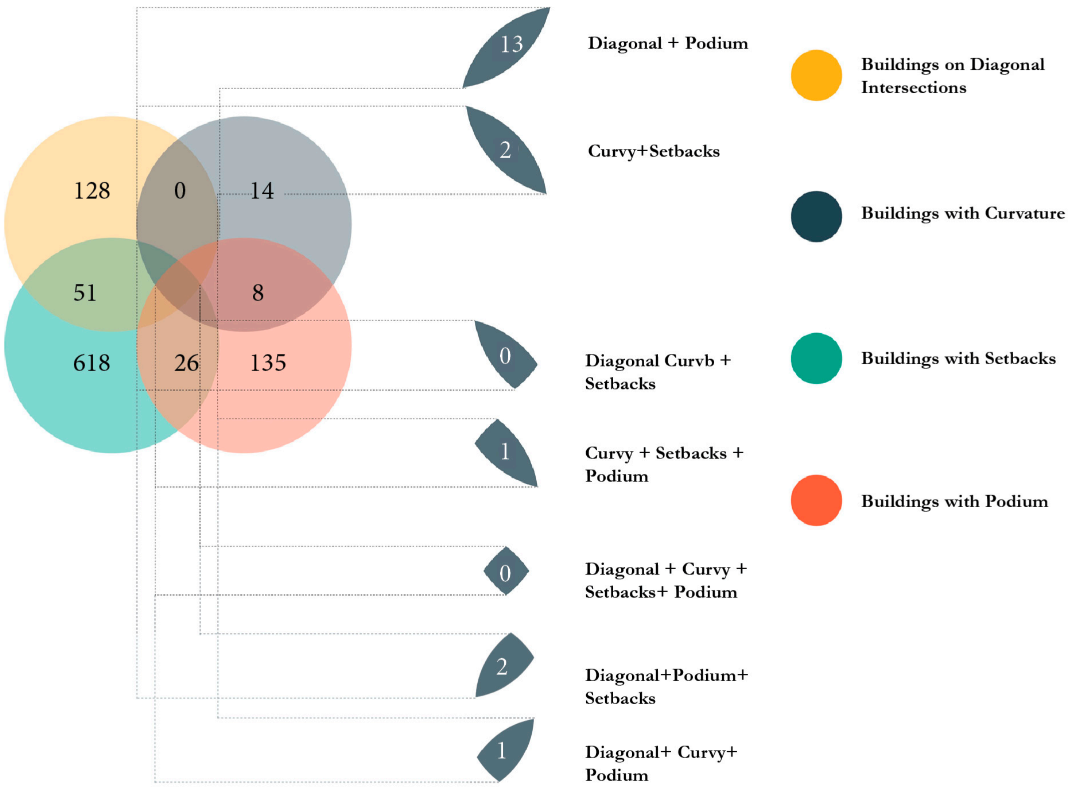


Figure 3. Incidence of external architectural design features. Figure 3 documents the incidence and overlaps of external architectural design features in our data set suggesting that some architectural features are related to one another.

5. Methodology

In this study, we employ the hedonic pricing method to analyze and understand commercial real estate pricing dynamics. The hedonic pricing method captures the impact on asset pricing of both internal and external characteristics of a property, allowing an analysis of a cross-sectional dataset and measurement of design features in the real estate marketplace. However, while New York City has a rich database in the built environment, little information exists on the subject of design, especially on design features examined from an architectural perspective. A key contribution of this research is the construction of a design dataset that begins to measure design characteristics, which may serve as support or guide to the designer's future work as design becomes increasingly important in development projects.

To measure the impact of external design features we operationalize the control samples a semi-log model to understand the impact of external architectural design features with Equation (1) outlined here:

$$logP_i = \alpha + \beta X_i + \delta G_i + \varepsilon_i, \quad (1)$$

where the dependent variable is the logarithm of the transaction price P in commercial office buildings i. X is a vector containing hedonic characteristics of buildings i and G is a vector of design feature variables with the value of 1 if building i falls into the category of design metric specified, and 0 otherwise. α, β and δ are estimated coefficients and ε is an i.i.d. error term.

6. Results

6.1. Transaction Value Results

Employing Equation (1) we estimate the impact of external architectural design features upon the logarithm of building transaction prices. The results of the model explain between 86 and 88% of the variation in the logarithm of transaction prices for commercial office buildings. Table 2 documents the results for structures without the four design features in NYC in column one, in columns two to five we document the impact of each design feature. In column six we document the results of all design features relative to control buildings. In column seven, we document the effect of awarded design to strengthen ties between both the prior financial literature and newly developing literature of architectural features.

Table 2. Transaction prices of buildings with architectural design features with dependent variable: Logarithm of transaction price. Column one: Base model with control sample (with none of the design features). Column two: Added diagonal intersection. Column three: Added curvature. Column four: Added setbacks. Columns five: Added podium. Column six: Added full sample (with all design features) and column seven: Full sample with the impact of awarded design.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Control Sample	**Diagonal**	**Curvature**	**Setbacks**	**Podiums**	**Full Sample**	**Awards**
Design Features							
Diagonal		0.060				0.113 ***	0.124 ***
		[0.044]				[0.037]	[0.026]
Curvature			0.218 *			0.034	−0.007
			[0.128]			[0.105]	[0.110]
Setbacks				−0.119 ***		−0.115 ***	−0.100 ***
				[0.026]		[0.025]	[0.025]
Podium Extrusion					0.146 ***	0.104 **	0.097 **
					[0.057]	[0.047]	[0.046]
Awarded Design							
Awarded Architects							0.190 **
							[0.088]
Awarded Firms							0.451 ***
							[0.093]
Awarded Architects and Firms							0.289 ***
							[0.060]
Building Features							
Age	−0.006 ***	−0.006 ***	−0.006 ***	−0.005 ***	−0.005 ***	−0.005 ***	−0.005 ***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]

Table 2. *Cont.*

	(1) Control Sample	(2) Diagonal	(3) Curvature	(4) Setbacks	(5) Podiums	(6) Full Sample	(7) Awards
Number Floors	−0.000	−0.001	−0.000	0.001	0.001	0.001	0.002
	[0.002]	[0.002]	[0.002]	[0.001]	[0.001]	[0.001]	[0.001]
Log (Square Meters)	0.800 ***	0.802 ***	0.798 ***	0.807 ***	0.804 ***	0.810 ***	0.804 ***
	[0.012]	[0.011]	[0.012]	[0.010]	[0.012]	[0.010]	[0.010]
Class B	−0.203 ***	−0.211 ***	−0.206 ***	−0.220 ***	−0.216 ***	−0.231 ***	−0.226 ***
(Relative to Class A)	[0.037]	[0.035]	[0.037]	[0.030]	[0.035]	[0.027]	[0.027]
Class C	−0.314 ***	−0.317 ***	−0.316 ***	−0.344 ***	−0.321 ***	−0.344 ***	−0.340 ***
(Relative to Class A)	[0.044]	[0.042]	[0.044]	[0.037]	[0.043]	[0.036]	[0.036]
Renovated	0.094 ***	0.097 ***	0.094 ***	0.112 ***	0.100 ***	0.107 ***	0.113 ***
	[0.033]	[0.031]	[0.033]	[0.027]	[0.032]	[0.025]	[0.025]
Walk Score	0.018 *	0.019 *	0.020 *	0.017	0.018 *	0.016	0.014
	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]
Buyer Type Relative to Private Buyers							
Corporation	−0.030	−0.024	−0.032	−0.038	−0.027	−0.032	−0.034
	[0.050]	[0.049]	[0.050]	[0.045]	[0.050]	[0.044]	[0.044]
Fund	0.254 ***	0.262 ***	0.254 ***	0.287 ***	0.272 ***	0.301 ***	0.314 ***
	[0.075]	[0.072]	[0.075]	[0.068]	[0.073]	[0.063]	[0.062]
Government	−0.046	−0.073	−0.048	−0.079	−0.046	−0.096 *	−0.092 *
	[0.066]	[0.065]	[0.067]	[0.057]	[0.065]	[0.055]	[0.055]
Institution	0.296 ***	0.295 ***	0.294 ***	0.251 ***	0.293 ***	0.238 ***	0.218 ***
	[0.061]	[0.057]	[0.061]	[0.053]	[0.060]	[0.049]	[0.048]
Offshore	0.325 ***	0.346 ***	0.324 ***	0.331 ***	0.331 ***	0.342 ***	0.328 ***
	[0.073]	[0.069]	[0.072]	[0.057]	[0.065]	[0.049]	[0.048]
Real Estate Investment Trust	0.353 ***	0.363 ***	0.333 ***	0.269 ***	0.371 ***	0.254 ***	0.237 ***
	[0.085]	[0.079]	[0.085]	[0.069]	[0.070]	[0.055]	[0.055]
Real Estate Operating Company	0.515 ***	0.524 ***	0.418 **	0.214	0.279	0.107	0.057
	[0.169]	[0.166]	[0.174]	[0.232]	[0.171]	[0.164]	[0.177]
Retailer	0.407 ***	0.305 **	0.410 ***	0.402 ***	0.424 ***	0.288 **	0.210
	[0.097]	[0.124]	[0.097]	[0.107]	[0.097]	[0.139]	[0.158]
Seller Type Relative to Private Sellers							
Corporation	−0.051	−0.050	−0.048	−0.050	−0.041	−0.029	−0.031
	[0.051]	[0.051]	[0.051]	[0.050]	[0.051]	[0.049]	[0.048]
Fund	0.334 ***	0.332 ***	0.336 ***	0.230 ***	0.289 ***	0.213 ***	0.225 ***
	[0.095]	[0.086]	[0.095]	[0.076]	[0.089]	[0.066]	[0.066]
Government	−0.051	−0.050	−0.0448	−0.050	−0.041	−0.029	−0.031
	[0.060]	[0.061]	[0.061]	[0.056]	[0.061]	[0.057]	[0.056]
Institution	0.090	0.113	0.104	0.115 *	0.104	0.131 **	0.120 **
	[0.078]	[0.072]	[0.076]	[0.064]	[0.076]	[0.059]	[0.059]
Offshore	0.235 ***	0.223 ***	0.211 **	0.205 ***	0.179 **	0.151 **	0.141 **
	[0.088]	[0.087]	[0.085]	[0.068]	[0.087]	[0.063]	[0.062]
Real Estate Investment Trust	0.213 ***	0.253 ***	0.213 ***	0.159 **	0.192 **	0.148 **	0.131 **
	[0.079]	[0.074]	[0.079]	[0.069]	[0.079]	[0.062]	[0.059]

Table 2. *Cont.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Control Sample	**Diagonal**	**Curvature**	**Setbacks**	**Podiums**	**Full Sample**	**Awards**
Real Estate Operating Company	0.140	0.161	0.139	0.168	0.336 *	0.374 **	0.414 **
	[0.186]	[0.183]	[0.188]	[0.141]	[0.188]	[0.174]	[0.184]
Retailer	0.583 ***	0.582 ***	0.584 ***	0.562 ***	0.579 ***	0.562 ***	0.575 ***
	[0.196]	[0.198]	[0.192]	[0.189]	[0.201]	[0.199]	[0.198]
Lender Type Relative to Private Lenders							
Commercial Mortgage Backed Security	0.019	0.030	0.023	0.009	0.056	0.073	0.077
	[0.090]	[0.090]	[0.090]	[0.088]	[0.096]	[0.092]	[0.092]
Financial	0.028	0.020	0.030	−0.028	0.060	0.013	0.018
	[0.095]	[0.095]	[0.095]	[0.094]	[0.102]	[0.098]	[0.098]
Government Agency	−0.255 **	−0.128	−0.258 **	−0.344 ***	−0.207 *	−0.146	−0.135
	[0.109]	[0.147]	[0.110]	[0.118]	[0.119]	[0.147]	[0.149]
Insurance	−0.259 **	−0.294 ***	−0.257 **	−0.208 **	−0.179 *	−0.178 *	−0.180 *
	[0.104]	[0.102]	[0.104]	[0.096]	[0.107]	[0.099]	[0.098]
International Bank	−0.041	−0.042	−0.042	−0.054	0.002	−0.028	−0.025
	[0.089]	[0.089]	[0.089]	[0.087]	[0.096]	[0.092]	[0.092]
National Bank	−0.159 *	−0.159 *	−0.156 *	−0.136	−0.116	−0.095	−0.097
	[0.088]	[0.088]	[0.088]	[0.086]	[0.095]	[0.091]	[0.091]
Pension Fund	−0.016	−0.014	−0.014	0.007	0.016	0.057	0.078
	[0.447]	[0.436]	[0.446]	[0.289]	[0.455]	[0.291]	[0.288]
Regional/Local Bank	−0.249 ***	−0.257 ***	−0.245 ***	−0.244 ***	−0.205 **	−0.206 **	−0.203 **
	[0.086]	[0.087]	[0.086]	[0.086]	[0.093]	[0.090]	[0.090]
Location and Time FE	YES	YES	YES	YES	YES	YES	YES
Constant	8.310 ***	8.195 ***	8.147 ***	8.206 ***	8.228 ***	8.296 ***	8.437 ***
	[1.046]	[1.031]	[1.039]	[1.067]	[1.028]	[1.001]	[1.005]
Observations	2042	2170	2056	2660	2177	3037	3037
R-squared	0.865	0.869	0.867	0.873	0.880	0.885	0.886
F Adj R-Squared	0.860	0.870	0.860	0.870	0.880	0.880	0.880

Robust standard errors in brackets and statistical significance denoted by *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In column one we document the impact of location, time, building features such as age, number of floors, size, building class, status of renovation and walk score, transaction features such as buyer type, seller type and lender type, for the control samples in the dataset, which are buildings without any of the four design features. The model establishes the baseline expectations for the model in line with the commercial office building literature for NYC. In some prior asset valuation research, "log price per square meter" is used as the dependent variable as opposed to "log price" because it accounts for the impact of building size. Pricing quotes in the marketplace are reported on a price per square foot or meter basis and potentially intend pricing for economies of scale, despite this dependent variable typically yielding a lower R^2 value [49–51]. To be clear for the commercial building valuation literature, we execute the model using the "log price per square meter" as our dependent variable to also take into account these features of "price per square meter" as a robustness check. Results from the "log price per square meter" estimation are consistent with those of the "log price" estimation but with a lower R^2 value of 0.49. In this model, diagonality and podium have positive and significant coefficients of 12.1 and 10.3, respectively, under the 0.05 *p*-value threshold, setbacks has a negative and significant coefficient of 10.6 with a *p*-value of below 0.01.

In column two we document the impact of diagonality on transaction prices relative to the control sample observations, with controls for location, time, building and transaction features. Buildings with diagonality price do not depict a statistically significant coefficient. In column three we evaluate the impact of curvature. Buildings with curvature yield a positive 21.8 and marginally statistically significant coefficient at the 10% level, which should be yielded with caution. Pricing for other factors remains consistent with the base model in column one. In column four we examine the impact of setbacks. Buildings with setbacks yield a negative 11.9% and statistically significant coefficient, whilst not impacting other pricing features, but improving the fit of the model marginally by 1%. In column five we document the impact of podium extrusions on transaction prices and find a positive transaction premium of 14.6% with a statistically significant coefficient. Results now show that 88% of the variation in the logarithm of transaction price is explained by podium extrusion, location, time, building and transaction features.

In column six we measure the impact of all design features diagonal, curvature, setbacks, and podium extrusion on the logarithm of transaction prices relative to the control sample. Interestingly, when factoring in all design features there is a shift in statistical significance for the design features where diagonal buildings trade for a statistically significant 11.3% more, curvature loses statistical significance altogether, setbacks continued to trade at a relative discount of 11.5% less and podium extrusions traded at 10.4% more than the control sample, ceteris paribus. Furthermore, results show that 88% of the variation in the logarithm of transaction price is explained by these features. Finally, in column seven we add the impact of awarded designers and firms upon transaction prices alongside the model specified in column six. After accounting for the impact of awarded designers, the results remain consistent and in line with the prior literature, awarded designers impact the value of commercial office buildings transaction price, but this has a marginal impact on the external architectural design features outlined in this model.

As a final check, we surveyed all the historic buildings in New York City and recorded this as a variable in our data set. Among the 116 buildings recognized by the US government as National Historic Landmarks in New York City which are listed on the country's National Register of Historic Places (NRHP) [52], only 11 buildings are commercial properties which have transacted in the last twenty years. Among these, only two buildings include one or more of the four design features outlined in this paper. The correlation between historic buildings and the design features is extremely low. As a further robustness check, we ran a pricing regression to include factor loadings on historic buildings and obtained a statistically insignificant coefficient of 0.161. Furthermore, after including the historic building variable, the signs and significance of the coefficients for the four design features remain constant.

6.2. Rental Value Results

As a robustness check, we assessed the rental value of these external architectural design features by running the hedonic regression model with a rental contract data source for NYC, Compstak. CompStak is crowd-sourced database of commercial lease contract data which is cross-checked against multiple broker submissions. We use the net effective rent per square meter in US Dollars as our dependent variable, which is defined by Compstak as the "actual amount of rent paid subtracting lease concessions from starting rent". The four architectural design features—diagonality, curvature, setbacks and podium, remain as our variables of interest, but we also include awarded architectural design similar to the transaction analysis. In our model, we take into account market conditions such as submarkets to adjust for location fixed effects, macroeconomic conditions such as period of transaction, contract terms conditions such as space type, lease transaction type, lease term duration, free rent period, sublease, tenant broker, landlord broker, landlord concessions, and building characteristics such as building class, age, size and status of renovation. This model is consistent with rental pricing models in the commercial building literature.

To measure the impact of external design features on rental values, we operationalize a semi-log model to understand the impact of external architectural design features with Equation (1), where the dependent variable is the logarithm of the net effective rent per square meter R for rental contract observation i. X is a vector containing hedonic characteristics of rental contract i, including exogeneous hedonic building characteristics (such as age, class, number of floors), lease contract terms (such as lease duration, landlord concessions), exogenous location fixed effects by Manhattan neighborhoods, and time fixed effects by quarter and year that the lease is executed between 2001 to 2017. G is a vector of design feature variables with the value of one if rental contract i falls into the category of design metric specified, and zero otherwise. α, β and δ are estimated coefficients and ε is an i.i.d. error term.

Results from this model show consistency in both significance and direction of signs as the results we obtain from the RCA transaction data model, as shown in Table 3. The results of the model explain between 62 and 64% of the variation in the logarithm of rent per square meter. In column seven we document the full specification of the model and find that diagonal yields 2.0% more per square, curvature remains statistically insignificant, setbacks rent for 2.4% less, and podium extrusions rent for 3.5% more than the control sample, ceteris paribus. The descriptive statistics for the rental analysis can be found in Table A1 in the Appendix A.

Table 3. Net effective rent per square meter of buildings with architectural design features with dependent variable: Logarithm of net effective rent per square meter. Column one: Base model with control sample (with none of the design features). Column two: Added diagonal intersection. Column three: Added curvature. Column four: Added setbacks. Columns five: Added podium. Column six: Added full sample (with all design features). Column seven: Full sample with the impact of awarded design.

	(1) Control Sample	(2) Diagonal	(3) Curvature	(4) Setbacks	(5) Podiums	(6) Full Sample	(7) Awards
Design Features							
Diagonal		−0.013				0.017 *	0.020 **
		[0.012]				[0.009]	[0.009]
Curvature			0.028			−0.021	−0.018
			[0.021]			[0.016]	[0.016]
Setbacks				−0.033 ***		−0.033 ***	−0.024 ***
				[0.006]		[0.005]	[0.005]
Podium Extrusion					0.037 ***	0.027 ***	0.035 ***
					[0.010]	[0.007]	[0.007]
Awarded Design							
Awarded Architects							0.184 ***
							[0.022]
Awarded Firms							0.182 ***
							[0.025]
Awarded Architects and Firms							0.078 ***
							[0.012]
Building Features							
Age	−0.006 ***	−0.008 ***	−0.006 ***	−0.006 ***	−0.009 ***	−0.007 ***	0.007 ***
	[0.001]	[0.001]	[0.001]	[0.000]	[0.001]	[0.000]	[0.000]
Number Floors	0.004 ***	0.004 ***	0.004 ***	0.002 ***	0.006 ***	0.002 ***	0.002 ***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Log (Square Meters)	−0.007	0.001	0.006	0.010**	−0.010*	0.012 ***	0.008 **
	[0.006]	[0.005]	[0.006]	[0.004]	[0.005]	[0.003]	[0.003]
Class B	−0.155 ***	−0.132 ***	−0.152 ***	−0.132 ***	−0.088 ***	−0.102 ***	−0.105 ***
(Relative to Class A)	[0.013]	[0.013]	[0.013]	[0.008]	[0.013]	[0.007]	[0.007]
Class C	−0.260 ***	−0.223 ***	−0.249 ***	−0.258 ***	−0.194 ***	−0.012 ***	−0.225 ***
(Relative to Class A)	[0.024]	[0.023]	[0.024]	[0.018]	[0.023]	[0.003]	[0.017]
Renovated	0.024 ***	0.020 ***	0.023 ***	0.027 ***	0.008	0.009 *	0.012 **
	[0.008]	[0.007]	[0.008]	[0.006]	[0.007]	[0.005]	[0.005]

Table 3. *Cont.*

	(1) Control Sample	(2) Diagonal	(3) Curvature	(4) Setbacks	(5) Podiums	(6) Full Sample	(7) Awards
Walk Score	0.016 ***	0.021 ***	0.004	0.016 ***	−0.003	0.004	0.005
	[0.006]	[0.005]	[0.006]	[0.003]	[0.006]	[0.003]	[0.003]
Transaction Type Relative to New Lease							
Early Renewal	0.367 ***	0.374 ***	0.353 ***	0.225 ***	0.196*	0.214 ***	0.226 ***
	[0.030]	[0.029]	[0.029]	[0.107]	[0.115]	[0.072]	[0.064]
Lease Expansion	0.064 ***	0.067 ***	0.064 ***	0.049 ***	0.046 ***	0.043 ***	0.041 ***
	[0.012]	[0.012]	[0.012]	[0.010]	[0.011]	[0.008]	[0.008]
Lease Extension	−0.070 **	−0.061 **	−0.067 **	−0.042 *	−0.046 *	−0.018	−0.017
	[0.030]	[0.028]	[0.030]	[0.024]	[0.028]	[0.023]	[0.023]
Lease	−0.037	−0.048	0.028	−0.022	−0.047	−0.003	0.006
Extension/Expansion	[0.179]	[0.176]	[0.143]	[0.141]	[0.129]	[0.091]	[0.090]
Lease Renewal	0.013	0.007	0.012	0.011 *	0.017 **	0.013 **	0.012 **
	[0.008]	[0.008]	[0.008]	[0.006]	[0.008]	[0.006]	[0.006]
Lease	0.020	0.015	0.022	0.007	0.058	0.036	0.041
Renewal/Contraction	[0.053]	[0.057]	[0.051]	[0.046]	[0.046]	[0.039]	[0.038]
Lease	0.037	0.007	0.038	−0.011	0.024	−0.019	−0.018
Renewal/Expansion	[0.033]	[0.031]	[0.031]	[0.024]	[0.026]	[0.019]	[0.019]
Log (Transaction Size)	−0.009 **	−0.006	−0.011 ***	−0.002	−0.007 *	0.001	0.001
	[0.004]	[0.004]	[0.004]	[0.003]	[0.004]	[0.003]	[0.003]
Lease Duration Relative to Lease term <5 years							
6−10 years	0.040 ***	0.037 ***	0.040 ***	0.037 ***	0.049 ***	0.043 ***	0.044 ***
	[0.009]	[0.008]	[0.009]	[0.007]	[0.008]	[0.006]	[0.006]
11−15 years	0.091 ***	0.091 ***	0.097 ***	0.084 ***	0.108 ***	0.094 ***	0.098 ***
	[0.011]	[0.010]	[0.011]	[0.008]	[0.010]	[0.007]	[0.007]
16−20 years	0.157 ***	0.167 ***	0.160 ***	0.159 ***	0.179 ***	0.171 ***	0.175 ***
	[0.019]	[0.018]	[0.018]	[0.014]	[0.016]	[0.012]	[0.012]
21−25 years	0.142 ***	0.149 ***	0.137 ***	0.131 ***	0.202 ***	0.202 ***	0.201 ***
	[0.038]	[0.035]	[0.038]	[0.032]	[0.034]	[0.026]	[0.026]
Free Rent Periods Relative to No Free Rent							
<6 months free	−0.000	0.004	−0.002	−0.002	0.018	0.017	0.021
	[0.018]	[0.017]	[0.018]	[0.014]	[0.018]	[0.014]	[0.014]
6−12 months free	−0.038 *	−0.039 **	−0.042 **	−0.046 ***	−0.032 *	−0.043 ***	−0.039 ***
	[0.020]	[0.019]	[0.020]	[0.016]	[0.019]	[0.015]	[0.015]
13−18 months free	−0.120 ***	−0.115 ***	−0.128 ***	−0.119 ***	−0.115 ***	−0.116 ***	−0.115 ***
	[0.025]	[0.024]	[0.025]	[0.020]	[0.023]	[0.018]	[0.018]
19−24 months free	−0.176 ***	−0.186 ***	−0.191 ***	−0.172 ***	−0.134 ***	−0.141 ***	−0.152 ***
	[0.059]	[0.058]	[0.058]	[0.047]	[0.049]	[0.038]	[0.038]
Landlord Concessions Relative to Tenant Improvement							
As−Is	0.026	0.036	0.033	0.033	0.047 *	0.050 ***	0.054 ***
	[0.026]	[0.026]	[0.025]	[0.021]	[0.025]	[0.019]	[0.019]
Built to Suit	−0.303 ***	−0.301 ***	−0.297 ***	−0.153 **	−0.290 ***	−0.149 ***	−0.123 *
	[0.022]	[0.021]	[0.022]	[0.071]	[0.020]	[0.056]	[0.064]
NBI	0.047 ***	0.046 ***	0.048 ***	0.054 ***	0.056 ***	0.062 ***	0.063 ***
	[0.017]	[0.016]	[0.017]	[0.012]	[0.015]	[0.010]	[0.010]
Other	−0.072	−0.086	−0.071	−0.107	−0.047	−0.047	−0.030
	[0.097]	[0.095]	[0.096]	[0.068]	[0.076]	[0.068]	[0.073]
Paint and Carpet	0.066	0.106	0.064	0.011	0.004	0.026	0.032
	[0.100]	[0.081]	[0.083]	[0.049]	[0.097]	[0.045]	[0.046]

Table 3. *Cont.*

	(1) Control Sample	(2) Diagonal	(3) Curvature	(4) Setbacks	(5) Podiums	(6) Full Sample	(7) Awards
Pre Built	0.090 ***	0.111 ***	0.092 ***	0.100 ***	0.095 ***	0.116 ***	0.115 ***
	[0.029]	[0.026]	[0.027]	[0.018]	[0.024]	[0.015]	[0.015]
Turnkey	0.138 ***	0.130 ***	0.136 ***	0.127 ***	0.143 ***	0.148 ***	0.115 ***
	[0.049]	[0.047]	[0.051]	[0.035]	[0.050]	[0.034]	[0.033]
Unspecified	0.025 ***	0.021 *	0.024 **	0.035 ***	0.035 ***	0.037 ***	0.038 ***
	[0.011]	[0.011]	[0.011]	[0.008]	[0.011]	[0.008]	[0.008]
Sublease	−0.155 ***	−0.151 ***	−0.158 ***	−0.163 ***	−0.164 ***	−0.162 ***	−0.159 ***
	[0.014]	[0.013]	[0.013]	[0.011]	[0.012]	[0.009]	[0.009]
Landlord Broker	0.027 ***	0.024 ***	0.025 ***	0.039 ***	0.025 ***	0.033 ***	0.033 ***
	[0.009]	[0.008]	[0.009]	[0.007]	[0.008]	[0.006]	[0.006]
Tenant Broker	−0.004	0.005	−0.004	−0.005	−0.002	0.005	0.004
	[0.007]	[0.007]	[0.007]	[0.007]	[0.007]	[0.007]	[0.007]
Location and Time FE	YES	YES	YES	YES	YES	YES	YES
Constant	4.829 ***	4.262 ***	5.941 ***	4.681 ***	6.706 ***	5.575 ***	5.791 ***
	[0.607]	[0.536]	[0.613]	[0.322]	[0.616]	[0.301]	[0.295]
Observations	5848	6515	6014	9609	7142	12,772	12,772
R−squared	0.646	0.630	0.644	0.631	0.636	0.617	0.624
F Adj R−Squared	0.640	0.630	0.640	0.630	0.630	0.620	0.620

Robust standard errors in brackets and statistical significance denoted by *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

7. Discussion and Conclusions

We examined the impact of architectural design features upon building valuation. Distinct from the current design valuation literature for commercial real estate—which only includes awarded designers—we measure architectural form at a feature level to assess the impact of external architectural form on transaction and rental prices. Importantly, disassociating design as part of a cohort of various architectural styles or as functional components, such as the number of floors, inclusion of amenities, or views to the exterior, this study attempts to understand the relationship between architectural form and real estate value. After controlling for building features, contract features, location and transaction time and other features included in past research. We document that architectural form decisions have a statistically and economically significant impact on the value of commercial buildings, in addition to that of an architectural award designation.

The fundamental challenge of assessing the impact of an isolated variable is to control for other exogenous and omitted variables that also determines the transaction price. For that, we used a hedonic price model and executed various robustness checks, such as historical precedence, awarded design and commercial rental market outcomes to determine whether there is evidence of a price differential due to form. After controlling for building, neighborhood, contract and awarded design features, these models explained 88% of the variation in the logarithm of transaction price and 62% of the variation in the logarithm of effective rents per square meter.

Two design features yielded positive impacts on transaction price—diagonality and podium extrusion. These design features shaped the exterior appearance of buildings and created a positive value differential. Diagonality and podium extrusion were estimated to have a 12.4% and 9.7% transaction price premium, respectively, relative to buildings without these features. Both the diagonal feature and the podium extrusion feature yielded a positive and significant impact on transaction and rental values. The added amenities intended by these design strategies may be correlated with this value, namely these design features add new extensions to the urban environment in the case of diagonality and the addition of more physical space with the development of podiums.

In contrast, buildings with curvature did not statistically and economically differentiate from a transaction or rental price perspective. This may be highly correlated with the size of the sample, the high correlation of curvature with other design features or the very high correlation of curvature with awarded design. However, setbacks returned a statistically significant and negative result. Initially, we understood this design feature as a result of the new zoning law implemented in 1916, which forced buildings to push back from the street above a certain height to ensure the access of light and air from the street level, adopting a terrace-like form for the upper portion of the building. However, this result suggests that this design strategy created negative value differentiation amongst their rectilinear building peers in New York City. Given that rents for these spaces are consistently negative, this may be due to the fact that the terrace-like form for the upper portion of tall buildings reduces rentable building footprint significantly and adds difficulty in floor plan layouts. Unlike buildings with podiums, buildings with setbacks lose square footage without providing enough mixed-use commercial amenities to balance the loss in a transaction price. Although these design feature correlations suggest economic differentiation, prior research supports the premise that techtonic structure is related to the attractiveness of buildings [53]. Distinct design factors such as biophilia, dividing up the rigidity of rectangular geometry, enhances visceral attraction to buildings and may help us to further understand the value differentiation these design features provide [53].

Principally though, research at the intersection of design and finance is very new. More research is needed to help limit the lack of data, improve existing 3D models, and standardize collecting building design data. Architectural design as a novel field of data science is advancing as big data and quantitative methodologies play a bigger role in the field and as computation becomes more prevalent in practice. For future work, incorporating alternative technologies and approaches are needed to identify potentially omitted attributes or quantifying other building design metrics, such as algorithmic measurement of 3D complexity [54,55], and computer vision technology for recognizing the presence of greenery or identifying building materials. In line with others who have used geometric form in the asset valuation literature [17], we have found a value differential. Our work seeks to expand understanding of architectural form in relation to commercial buildings. Omitting architectural formal features from asset valuation may leave a missed opportunity to understand product differentiation and impact on the property market value caused by actual building design features during individual real estate property transactions. This then poses the same problem to both sides, diminished design agency for both financial and design stakeholders during design, development and negotiation processes.

It is imperative to further develop a systematic approach to recognize and describe design attributes to facilitate the communication among designers and researchers when discussing forms and styles of design outcomes in buildings [56]. In this way, research on the value of design is moving beyond measuring design through assessing involvement of award-winning architects and moving into the study of physical design features. Although, we find that both are important for commercial buildings the distinction is economically important as not all architects come to be prize winning nor do all developers employ award winning designers, yet it is the form beyond the awards that can advise designers and planners on financially successful strategies. In this way, we may be able to understand the design decisions that create value and align the wider design community with valuation precedents. Our contribution is to create a relational understanding between building geometry, geography and real estate valuation techniques. Expanding the knowledge base of design and its impact on finance and economics will enable designers, building engineers and real estate economists to engage in interdisciplinary exchange. Further, it may also magnify the agency of design in fields that emphasize quantitative analysis and outcomes.

Author Contributions: Conceptualization, H.H.R.; M.K. and A.C.; Data curation, H.H.R. and J.Y.; Formal analysis, J.Y. and M.K.; Funding acquisition, A.C.; Investigation, J.Y. and M.K.; Methodology, H.H.R. and A.C.; Project administration, A.C.; Resources, A.C.; Supervision, A.C.; Validation, H.H.R.; Visualization, H.H.R. and J.Y.; Writing—original draft, H.H.R. and J.Y.; Writing—review & editing, M.K. and A.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Real Capital Analytics, JLL, EY, Compstak, and Center for Real Estate Class of 1988 Memorial Fund.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1 shows the dependent and independent variables included in the rent analysis and compares the average characteristics of buildings with external architectural design features with that of the control sample. The net effective rent is $543.75 per square meter, with a standard deviation of $225.26 per square meter. Buildings with measured design features yielded higher average net effective rents per square meter compared to the control sample. Buildings with podium extrusions yielded an unusually high average net effective rent per square meter ($154.65 per square meter higher than the net effective rent of control buildings).

Further factors of interest within the rental valuation model are transaction types, lease durations, rent free periods, landlord concessions and brokerage. We find that the types of leases offered within the control sample are quite similar to that of diagonal, curvature, setback and podium buildings. Namely, there is a higher proportion of new leases represented in the sample at least 70% of the time. Lease duration is consistently between six and 15 years. The rent-free period is predominantly less than six months. Tenant improvements are given on average over 70% of the time as a concession by landlords and tenants are represented by brokers a little over 40% of the time.

Table A1. Descriptive statistics of building characteristics and lease contract details by geometry. Table A1 highlights the mean and variation of building characteristics for the building samples with curvature, site location on a diagonal intersection, podium, and the New York City setback geometry.

Variable	Control Sample	Diagonal	Curvature	Setbacks	Podium	Full Sample
	Mean (Std. Dev. *)	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**
Awarded Design						
Awarded Architects	0.036 (0.186)	0.000 (0.000)	0.169 (0.376)	0.002 (0.040)	0.012 (0.107)	0.021 (0.144)
Awarded Firms	0.013 (0.115)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.047 (0.212)	0.011 (0.104)
Awarded Architects and Firms	0.043 (0.203)	0.000 (0.000)	0.000 (0.000)	0.002 (0.046)	0.070 (0.254)	0.029 (0.167)
Building Information						
Effective Rent/Square Meter	541.65 (229.19)	496.26 (174.73)	591.24 (159.77)	498.51 (194.01)	696.30 (260.41)	543.75 (225.26)
Age	64.946 (32.434)	65.863 (37.040)	23.783 (4.472)	69.718 (22.371)	40.764 (20.405)	62.989 (29.886)
Number Floors	28.303 (14.213)	26.177 (13.516)	38.392 (4.921)	31.616 (15.236)	38.390 (10.521)	31.434 (15.725)
Building Class A	0.555 (0.497)	0.453 (0.498)	1.000 (0.000)	0.551 (0.497)	0.985 (0.123)	0.616 (0.486)
Building Class B	0.404 (0.491)	0.529 (0.500)	0.000 (0.000)	0.428 (0.495)	0.015 (0.123)	0.358 (0.479)
Building Class C	0.040 (0.196)	0.018 (0.133)	0.000 (0.000)	0.021 (0.143)	0.000 (0.000)	0.025 (0.157)
Square Meters	48,986 (46,940)	57,886 (43,819)	41,038 (29,813)	53,402 (42,548)	109,549 (58,652)	60,566 (53,123)
Renovated	0.635 (0.481)	0.576 (0.495)	0.168 (0.376)	0.779 (0.415)	0.590 (0.492)	0.661 (0.473)
Walk Score	99.396 (0.719)	99.190 (0.681)	98.440 (1.425)	99.185 (1.296)	99.094 (0.733)	99.287 (0.942)
Transaction Type						
Lease Early Renewal	0.000 (0.013)	0.000 (0.000)	0.000 (0.000)	0.000 (0.016)	0.001 (0.028)	0.000 (0.018)
Lease Expansion	0.076 (0.265)	0.087 (0.282)	0.054 (0.227)	0.073 (0.259)	0.124 (0.330)	0.080 (0.272)
Lease Extension	0.010 (0.010)	0.008 (0.086)	0.006 (0.078)	0.010 (0.101)	0.005 (0.068)	0.009 (0.094)
Lease Extension/Expansion	0.001 (0.023)	0.000 (0.000)	0.006 (0.078)	0.000 (0.016)	0.002 (0.040)	0.001 (0.025)
Lease Renewal	0.177 (0.382)	0.141 (0.348)	0.163 (0.370)	0.180 (0.385)	0.149 (0.356)	0.173 (0.378)
Lease Renewal/Contraction	0.001 (0.029)	0.000 (0.000)	0.000 (0.000)	0.000 (0.016)	0.000 (0.000)	0.001 (0.023)
Lease Renewal/Expansion	0.011 (0.103)	0.013 (0.115)	0.024 (0.154)	0.011 (0.104)	0.019 (0.135)	0.012 (0.110)
New Lease	0.725 (0.447)	0.751 (0.433)	0.747 (0.436)	0.725 (0.447)	0.701 (0.458)	0.724 (0.447)
Transaction Size	18,385 (43,333)	22,511 (47,515)	14,499 (25,292)	15,956 (38,935)	38,877 (86,941)	20,496 (50,549)

Table A1. *Cont.*

Variable	Control Sample	Diagonal	Curvature	Setbacks	Podium	Full Sample
	Mean (Std. Dev. *)	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**	**Mean (Std. Dev. *)**
Lease Duration (years)						
Lease term less than 5 years	0.229 (0.420)	0.252 (0.434)	0.193 (0.396)	0.214 (0.410)	0.196 (0.397)	0.221 (0.415)
Lease term 6–10 years	0.377 (0.485)	0.375 (0.484)	0.404 (0.492)	0.386 (0.487)	0.308 (0.462)	0.374 (0.484)
Lease term 11–15 years	0.327 (0.469)	0.285 (0.452)	0.355 (0.480)	0.338 (0.473)	0.351 (0.477)	0.329 (0.470)
Lease term 16–20 years	0.056 (0.230)	0.076 (0.266)	0.048 (0.215)	0.057 (0.232)	0.123 (0.328)	0.066 (0.249)
Lease term 21–25 years	0.010 (0.100)	0.012 (0.109)	0.000 (0.000)	0.005 (0.069)	0.022 (0.148)	0.011 (0.103)
Free Rent Periods (months)						
No Free Rent	0.033 (0.178)	0.064 (0.246)	0.012 (0.109)	0.030 (0.170)	0.017 (0.129)	0.031 (0.174)
Less than 6 months free	0.710 (0.454)	0.672 (0.470)	0.681 (0.468)	0.712 (0.453)	0.608 (0.488)	0.695 (0.460)
6–12 months free	0.205 (0.404)	0.213 (0.410)	0.271 (0.449)	0.214 (0.410)	0.282 (0.450)	0.218 (0.413)
13–18 months free	0.048 (0.214)	0.051 (0.220)	0.036 (0.187)	0.042 (0.200)	0.083 (0.277)	0.051 (0.220)
19–24 months free	0.004 (0.063)	0.000 (0.000)	0.000 (0.000)	0.003 (0.058)	0.009 (0.096)	0.005 (0.068)
Landlord Concession (Work Type)						
As-Is	0.019 (0.136)	0.016 (0.127)	0.024 (0.154)	0.015 (0.121)	0.007 (0.083)	0.016 (0.127)
Built to Suit	0.000 (0.013)	0.000 (0.000)	0.000 (0.000)	0.001 (0.023)	0.000 (0.000)	0.000 (0.015)
New Building Installation	0.024 (0.154)	0.025 (0.158)	0.006 (0.078)	0.038 (0.191)	0.019 (0.138)	0.027 (0.163)
Other	0.000 (0.018)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.001 (0.028)	0.000 (0.015)
Paint and Carpet	0.001 (0.029)	0.003 (0.055)	0.006 (0.078)	0.002 (0.046)	0.001 (0.028)	0.001 (0.036)
Pre-Built	0.012 (0.110)	0.013 (0.115)	0.018 (0.134)	0.018 (0.133)	0.015 (0.123)	0.015 (0.120)
Tenant Improvement	0.826 (0.379)	0.820 (0.384)	0.843 (0.365)	0.801 (0.400)	0.909 (0.288)	0.829 (0.377)
Turnkey	0.002 (0.041)	0.000 (0.000)	0.000 (0.000)	0.003 (0.059)	0.000 (0.000)	0.002 (0.046)
Unspecified	0.115 (0.319)	0.121 (0.327)	0.102 (0.304)	0.122 (0.328)	0.048 (0.214)	0.109 (0.312)
Other Leasing Information						
Sublease (1 = yes)	0.084 (0.278)	0.097 (0.297)	0.108 (0.312)	0.066 (0.249)	0.161 (0.367)	0.089 (0.285)
Landlord Broker (1 = yes)	0.286 (0.452)	0.256 (0.437)	0.307 (0.463)	0.295 (0.456)	0.344 (0.475)	0.294 (0.456)
Tenant Broker (1 = yes)	0.429 (0.495)	0.354 (0.479)	0.446 (0.499)	0.424 (0.494)	0.552 (0.498)	0.435 (0.496)
Number of observations	5848	667	166	3761	1294	12,772

* Std. Dev. for Standard Deviation.

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