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The Shadow Cost of Parking Minimums: Evidence from Los Angeles County

Sofia Franco
University of California, Irvine, sofiaf1@uci.edu

W. Bowman Cutter
Pomona College, bowman.cutter@pomona.edu

Skyler Lewis
UC Berkeley, skylerlewis@berkeley.edu

Exploring the Shadow Cost Gradient of Parking Standards:

A Geographically-Differentiated Approach

W. Bowman Cutter*   Sofia F. Franco**   W. Skyler Lewis***

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Abstract

Minimum Parking Requirements (MPRs) are almost universal in U.S. cities and common in the rest of the world. In the U.S., parking requirements for commercial buildings commonly require 700 ft^2 of parking for each 1000 ft^2 of floor space. To the extent this is a binding requirement, MPRs could result in distortion in commercial development. MPRs require either the allocation of land for parking, or very costly substitution of structured parking for land. Therefore, MPR distortions are likely to increase with the value of land. A steep gradient in the cost of the MPRs leads to the possibility that MPR costs could be high enough to change where developers find it profitable to locate commercial development. In particular, MPR costs may be high enough in dense, high land-value areas to discourage development or move it to outlying areas. We use a Mixed Geographically Weighted Regression (MGWR) approach to estimate a hedonic specification using sales of office properties in Los Angeles County. This approach allows local variation in the estimates of marginal values of key parameters, including the value of on-site parking. To control for unobservables, we use the Linn (2013) method to incorporate pre-period prices into the MGWR estimator. Then we use these hedonic estimates plus locally-specific estimates of parking costs to estimate the cost of MPRs on a property by property basis. We check the robustness of the results by comparing our estimated costs to the in-lieu-of-parking fees that are offered by some of the cities in our sample. Our estimates of MPR costs are close to these market values for escaping the parking requirement. Our results show a significant gradient in MPR costs. Smaller properties in dense, high land value areas in Los Angeles can have MPR costs that amount to about 30% of building construction costs while properties in outlying areas often do not have binding MPRS. This gradient is likely to be sufficient to move development from high land value, dense, city centers into lower value areas. Our suite of methods could be applied to other building and zoning regulation, such as height regulation and inclusionary housing where the cost gradient is also likely to be important.

*Pomona College, Department of Economics, Claremont, CA 91711; Telephone 909-607-8187; Email Bowman.Cutter@Pomona.edu.
** **Corresponding Author**. University of California, Irvine-Department of Economics, 3151 Social Science Plaza, Irvine, CA 92697-5100, USA; Email: sofiaf1@uci.edu.
***Pomona College, Department of Economics, Claremont, CA 91711; Email wsl02012@mymail.pomona.edu.

1. Introduction

Most cities across the globe have parking standards (also called minimum parking requirements (MPRs) or parking minimums) for residential and nonresidential buildings which require developers to provide a minimum amount of off-street parking. Parking minimums are typically spatially invariant, related to the land-use type and generally set based on historical patterns of the relationship between key land use types and auto travel to those land uses.

The goal of MPRs is to ensure adequate parking at a low price to limit local congestion and to stimulate local business (Shoup, 1999a). Yet, critics of MPRs (Shoup 1999a, 2005, 2018; Willson,1995) state that at a minimum these standards create parking oversupply which decreases the cost (direct and time) of parking, encouraging more automobile trips (Shoup 1999a, 2005; Shoup and Pickrell,1978). The more expansive critique is that MPRs, if binding, force developers to devote more land to parking than their profit-maximizing decision and make development in areas where land has a high value much more expensive and less profitable (Willson, 1995, Cutter and Franco 2012). As a result, critics suggest that MPRs influence the location of new development and contribute to the sprawling of impervious parking surfaces at the expense of the environment (Feitelson and Rotem, 2004) and urban design (Mukhija and Shoup, 2006).[1]

Therefore, coalitions of parking reform-makers have been challenging MPRs in cities around the world, from Auckland to Berlin and from Mexico City to Seattle, Portland or even Los Angeles. While many European cities are ahead of the United States (U.S.) on this trend to reform parking

[1] Critics also invoke equity issues as the costs of providing parking are incorporated into the price of other goods purchased by a variety of consumers who may not have used those parking spaces.

minimums, parking reform is still catching up in the U.S. as many cities are still leaving their parking standards untouched (Franco 2020).[2]

This paper uses geographically weighted regression, combined with a variety of identification strategies, to identify the cost-gradient for this building regulation. Our strategy could nevertheless be extended to a variety of land use and other types of regulations that target a continuous land-use variable, such as height restrictions, inclusionary housing, minimum lot size and open-space requirements. City officials typically argue that these regulations are necessary to relieve congestion, provide open space, improve urban health, or make a city “beautiful.” But if this is the case, what is the “right” regulation that best balances the trade-offs? For instance, inclusionary zoning (IZ) is another controversial building regulatory example with similar criticisms to MPRs. IZ is an affordable housing tool that links the production of affordable housing to the production of market-rate housing.[3] Opponents of this regulation, particularly mandatory ones, argue that the additional costs imposed on developers will raise the price of market-rate housing (ultimately reducing rather than increasing affordability) and reduce the housing supply (Ellickson, 1981; Emrath, 2006). Moreover, it is also argued that developers will move to other areas where development is more profitable and as such, it is an incentive that could lead to urban sprawl (Pendall, 2008). FAR limits are also thought to reduce housing supply, raise prices and lead to longer commutes (Bertaud and Brueckner, 2005; Brueckner and Singh, 2020).

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[2] Amsterdam, Berlin, Copenhagen, Hamburg and Paris have reduced or eliminated parking requirements over the last 15 years. Progressive land-use reforms are nevertheless also taking root in the city of Los Angeles and in other American cities. Cities like Lancaster, Santa Monica, San Diego, San Francisco, Houston and Cincinnati have already eliminated parking requirements – either citywide or for central districts. And in the case of Los Angeles, since 2014, the L.A. City Planning Department has been working on a city community plan update, called DTLA 2040, which approved would eliminate MPRs for all of downtown Los Angeles.

[3] A 2016 survey found that 886 jurisdictions in 25 states in the United States and the District of Columbia have inclusionary zoning programs, although nearly 90 percent of them were in New Jersey, Massachusetts, and California (Thaden and Wang 2017). Inclusionary zoning also exists in European countries (e.g. UK, Spain, the Netherlands and Italy). While in the US the drive for IZ began in the 1970s, European countries started to work with this tool about 25 years ago.

Given the extent of the controversy around land use regulations such as FAR limits, MPRs and IZ, it is important to fully understand and quantify how their stringency varies across location and their spatial economic effects on land values and real estate development. Such a knowledge will enable policy makers to better spatially tailor these policy tools to make them more effective and to use the necessary development incentives to mitigate or offset their costs which, if excessive, can discourage development projects or lead to inefficient private decisions regarding the size and where to locate such projects. In addition, effective building policies can also mitigate existing residential and economic inequalities due to racial, economic and development segregation.

In the case of MPRs, which is the focus of our paper, there are two critical assumptions behind the criticisms. MPRs critics suggests that the cost of MPRs is far greater in dense, high-value urban areas than in the low-value areas, because parking either consumes land or requires costly parking structures, that is, they assume an MPR cost-gradient. However, this intuition neglects how congestion and customer demand in dense, high-value areas may influence the value of parking. Also, technological options such as structured parking may blunt the cost differences of MPRs between low and high land-value areas. The current literature does not contain, to our knowledge, an empirical analysis of the MPR policy cost gradient, and this gradient is key to the more expansive critique of MPRs. Second, these critiques assume that MPRs have a large net private cost, that is, that they strongly bind the private developer. The current literature does not examine for what types of properties and geographic areas this assumption is true.

Shoup (1999a, 2005) and Willson (1995) provide case studies where there is reason to believe that parking requirements have forced developers to place more parking than they would in the absence of this regulation. To our knowledge the only broad-based empirical evidence in the literature on the strength of the effect of MPRs on off-street parking supply is Cutter and Franco

(2012). Using a hedonic approach, the authors found that MPRs bind in several non-residential property segments. However, Cutter and Franco (2012) use global OLS and spatial hedonic methods that cannot capture geographic non-stationarity in the coefficients of the hedonic property value regressions. Sunding and Swoboda, (2010) as well as Redfearn (2009) show the importance of the location and existence of local “micro-markets” in real estate using the same GWR methods used in this paper. That GWR method allows us to avoid possible Simpson’s paradox type bias in global estimates of the cost of MPRs.

Dense, high-value areas (which Shoup (2005) typically uses to demonstrate the high cost of MPRs) often have more structured parking (above or underground) than sprawling suburbs. Structured parking is far more expensive than surface parking, and underground parking more expensive than surface (Franco 2016). This implies that one of the key decisions to model when examining the impact of MPRs is the choice of parking type. Brueckner and Franco (2017) use a two-zone spatial theoretical analysis of residential parking, focusing on the choice among different parking technologies (surface, structural and underground) and on the effect of MPRs on residential parking supply. Here, we develop a theoretical model that shows how non-residential developers will switch from surface to structured parking as land costs increase and how a binding parking constraint implies a wedge between the marginal value and construction cost of parking. Our theoretical results further reveal the critical necessity of including the construction cost of the type of parking used on a property in the analysis, and also including properties with structured parking in the empirical data.

Analyzing the two critical assumptions mentioned earlier requires a geographically-differentiated approach. We use a hedonic approach with a sample of 2,616 office property sales across Los Angeles County to examine these two key assumptions. This paper proceeds with such analysis by: (1) using a mixed geographically weighted regression (MGWR) approach that estimates how the local values of land and parking vary across the geography of Los Angeles County, and; (2) estimating location specific construction costs for surface, above and below-ground structured parking. Combining these two approaches allows us to estimate the wedge between parking construction cost and value. That is, we estimate a spatially varying property specific net private cost of MPRs. Our theoretical model shows that this wedge is positively and monotonically related to the implicit tax on density imposed by MPRs.

Then, we examine whether the geographic distribution of the gap between the value and full cost of parking corresponds to the analytical assumptions of the critics of MPRs. First, we examine the extent to which this cost gap is large, comparing it to the cost of floor space. Then, we examine whether there is a large difference between MPR costs in dense, high-value areas compared to lower land-value areas. For completeness, we also explore (1) which factors are correlated with the regulatory cost of MPRs including the size of the parcel and the value of the land, and (2) how in-lieu parking fees compare to our measure of the private shadow cost of MPRs. [4] In-lieu parking fees offer developers the option of paying a fee in lieu of providing the required parking. Our theoretical results further show that in-lieu fees can be used to proxy developers' cost with building regulations. Therefore, these fees in a per square foot of building area may also reveal the implicit impact fees in the MPRs. It should nevertheless be noted that our paper does not examine the full social welfare net cost of MPRs, but knowing the magnitude of developers´ MPR costs will shed light on whether they are likely to outweigh the policy congestion benefits.

The rest of the paper is organized as follows. Section 2 presents the theoretical model and constructs the indirect measure of the extent of the minimum parking requirement constraint,

[4] Shoup (1999b) shows that several cities in United States, Canada, the United Kingdom, Germany, South Africa, and Iceland all have in-lieu parking fees for office buildings in CBDs.

which we then test empirically. Section 3 develops the empirical strategy. Section 4 describes our data and variables. Section 5 compares the Global OLS and MGWR hedonic regressions. Section 6 describes our methodology for calculating the marginal value of land and parking, and then presents our simulation results on the net costs of MPRs. Section 7 implements several robustness tests of our findings.

2. The Theoretical Setup

The cost of regulation may be measured in different ways. For instance, Cheshire and Hilber (2008) build on the implicit tax of regulation developed by Glaeser and Gyourko (2003) and estimate costs of planning constraints (such as height restrictions) in British office markets by comparing the price of an additional floor to the cost of constructing it.[5] Another example is the Sunding and Swoboda (2010) study. In contrast to the previous study, Sunding and Swoboda (2010) focus on the residential market in the Inland Empire of Southern California and develop a condition, referred as "regulatory rationing", to measure the shadow price of regulatory constraints on the allowable number of housing units. This shadow price of housing regulation is measured through a wedge between the price of housing and the value of the structure and land. Recently, Brueckner et al. (2017) develop a new approach for measuring the stringency of building height restrictions, and apply it to a data set of land-lease transactions from China. This new approach implies that relaxation of a Floor-to-Area (FAR) restriction increases the land price, and that the elasticity of land price with respect to FAR is an indicator of the stringency of the restriction.

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[5] This study finds that regulatory costs differ vastly across markets and over time, with the highest regulatory costs being observed in the Greater London Area and with the time trend being positive in most markets. These findings provide important insights; however, the study does not consider the regulatory cost imposed on housing and the sample does not include more rural local planning authorities.

We follow closely the definition of the shadow price of regulation used by Sunding and Swoboda (2010) while focusing on the non-residential market. Here we provide and interpret key equations of a representative non-residential developer' problem and we discuss how the shadow cost of parking standards for properties with surface or structured parking can be measured.

Model Assumptions

Suppose that the office-space bid rent in a given location is represented by:

$$B = f(N, A) \tag{1}$$

where B is the office rent per square foot of floor space, N is total parking spaces and A is a vector of locational amenities, including distance to the CBD, that affect the attractiveness of the site. We assume that (1) is concave in its arguments. Parking can be either surface or underground.[6] Surface parking refers to lots directly on land and underground parking consists of structured parking under multi-story buildings. Total parking is represented by:

$$N = N_s + N_u \tag{2}$$

where N_s is the number of surface parking spaces and N_u is the number of underground parking spaces.

Office floor space is produced with a strictly concave, constant-returns production function, $H = f(K, L)$, where K is capital or non-land inputs used to produce office floor space and L represents the acres of land physically covered by K, which we denote as covered land.

[6] Aboveground structured parking is an intermediate case between underground and surface parking. It has lower costs than underground but higher land use. Restricting ourselves to the two extreme cases allows us to present the key findings of the model without unnecessary complexity.

Let $h(S)$ be the intensive form of the production function. It denotes square feet of office floor space per acre as a function of structural density S, which equals capital per acre of covered land. We further assume that h satisfies $h' > 0$ and $h^{//} < 0$ and that L is fixed and set to 1.

Parking costs differ depending on the type of parking provided. Total costs for surface parking are the sum of construction costs and land costs:

$$C_s(N_s) = N_s(p_k \overline{K} + p_l \bar{l}) \quad (3)$$

where p_l and p_k are the prices per acre of land and for capital, $\overline{K}$ is the fixed amount of capital per surface parking space and $\bar{l}$ is the fixed amount of land per surface parking space.

We assume that no additional land is necessary for underground parking since it will be built below the building. Thus, total costs for underground parking reflect mainly its construction costs:

$$C_u(N_u, S) = p_k \overline{K} N_u + p_k K(N_u, S) \quad (4)$$

where $K(N_u, S)$ is the capital cost requirement per underground parking space and is assumed to be a convex function.[7]

There is a MPR expressed as number of parking spaces per square feet of gross floor space:

$$N \geq aLh(S) \quad (5)$$

with $0 < a < 1$ a parameter set by the city government.[8]

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[7] As more underground parking is added more units of capital are necessary to fortify the building structure and to provide vertical-transportation requirements.

[8] Note that *H(K,L)=Lh(S)*. Since *H(K,L)* is concave and homogenous of degree one, it follows that *H(K/L,1)= h(S).* Also, the value of *a* can be lower, equal or higher than the value of *a* that would exist in an unconstrained market. However, for the purpose of exploring the effects of minimum parking requirements we consider the case where *a* is such that the constraint is always binding and thus, affects the market equilibrium. If for example, *a* =1/200sft, it means that developers are required to provide one parking space for each 200sft of gross floor area.

Type of parking provided

The developer determines which type of parking will be provided based on the marginal cost. The private marginal cost per underground parking space is given by

$$p_k\left[\overline{K}+\frac{\partial K(N_u,S)}{\partial N_u}\right]. \tag{7}$$

The first component of (7) is the marginal cost for the additional underground parking space, which is the same for all parking spaces in the structure. The second component of (7) is the infra-marginal cost associated with the additional underground space.

On the other hand, the private marginal cost per surface parking space is given by

$$p_k\overline{K}+p_l\bar{l}\ . \tag{8}$$

The first component of (8) is the marginal cost for the additional surface parking space and the second component is the marginal cost of land.

Comparing (7) and (8), the marginal cost of underground parking is greater than the marginal cost of surface parking if the cost of land is small relative to the degree of diminishing marginal returns:

$$p_k\frac{\partial K(N_u,S)}{\partial N_u}>p_l\bar{l}\ . \tag{9}$$

According to (9) developers switch to structured parking if the cost of land is high relative to the cost of parking construction. Typically, this result, and the analysis provided by Brueckner and Franco (2017), suggest that Central Business District (CBD) developers provide underground parking, since land is very expensive in CBD areas, and suburban developers provide surface parking. But this depends crucially on the cost of structured parking.

2.1. The Shadow Cost of MPRs in CBDs

Parking requirements are mostly criticized because they force developers to provide more parking than they would supply voluntarily and to provide parking spaces that lose money. Since this is the interesting case, we restrict the discussion to that case in this section.

The developer's problem in the CBD is to choose structural density and underground parking spaces that maximize profit per acre of covered land taking into account the MPR constraint:[9]

$$\underset{N_u,S}{Max} B(N_u,A)h(S) - p_k S - p_l - p_k\left(N_u\bar{K} + K(N_u,S)\right)$$
$$\text{s.t. } N_u \geq ah(S) \tag{10}$$

In this regulated equilibrium (with binding MPRs), the following conditions must be satisfied:

$$N_u = ah(S) \tag{11}$$

$$p_k(\bar{K} + \frac{\partial K(N_u,S)}{\partial N_u}) - \frac{\partial B(N_u,A)}{\partial N_u}h(S) = \lambda > 0 \tag{12}$$

$$B(N_u,A)\frac{\partial h(S)}{\partial S} = p_k\left(1 + \frac{\partial K(N_u,S)}{\partial S}\right) + \lambda a\frac{\partial h(S)}{\partial S} \tag{13}$$

with λ the shadow price of the binding parking constraint. Condition (11) reveals that the regulation imposes a binding minimum number of parking spaces per square feet of office floor space and that a developer will supply this minimum amount (but not more).

Condition (12) states that the marginal cost of parking will be above the marginal value of that parking to the property. This inequality follows because the parking requirement binds ($\lambda > 0$), with N_u restricted above its optimal private value suggesting developers supply more spaces that their private optimal decision. This inequality condition can be tested to measure the shadow cost

[9] Note that (10) implies that total floor space and parking space are "bundled" and rented as a package to the tenants of a building. For example, in nearly all buildings in Los Angeles today, parking is included in the price or rent of the unit. Tenants do not have the option of "unbundling" the cost of parking from their purchase or rent. The main exception is in the Downtown area where some buildings do not include parking in their rental rates.

of such regulation in downtown areas. The more stringent (and thereby costly) the parking standard, the larger the wedge represented in (12).

Condition (13) reveals that parking requirements also cause problems in the office floor space market. The wedge defined by (12) affects the optimal condition of office density (13) through λ. When MPRs bind, the excess parking results in a deficit for the developer of a new building. This induced deficit constitutes an indirect cost on building square footage ($\lambda a \frac{\partial h(S)}{\partial S}$), which is again proportional to the wedge in (12). This, in turn, creates a disincentive to high-density development because it imposes an extra wedge between the marginal revenue gain from additional building square footage and marginal construction costs.[10]

Finally, it is possible to illustrate how the cost of complying with default parking requirements may increase the total cost of constructing, for example, $h(S)$ square feet of an office building with underground garage. Assume that each parking space takes up $\bar{l}$ sqft of parking area, a are the required parking spaces per $h(S)$ sqft of building area and the MPR cost per sqft is $\lambda/\bar{l}$. Then, every foot of building office space is mandated to have $a\,\bar{l}$ feet of parking. At this ratio, this implies a cost increase in building development costs of λa per sqft.

2.2. The Shadow Cost of MPRs in Suburban Areas

The developer's problem in the suburbs is similar to the one described for CBD sites:

$$\underset{N_S,S}{Max}\, B(N_S,A)h(S) - p_k S - p_l - N_s(p_l\bar{l} + p_k\bar{K})$$
$$\text{s.t. } N_S \geq ah(S) \qquad (14)$$

[10] Like MPRs, FAR limits are also established in a sort of ad-hoc way, often based on what regulators think it is appropriate, or are politically salable, and are not tied to any economic analysis that weighs the costs and benefits of restrictions. Our gap between the price per square foot of building area and the construction cost per square foot approach could also be applied to examine the stringency of FAR limits. In an unregulated market, this gap or regulatory tax should be absent, and its existence would then imply that a FAR limit is constraining building heights.

Again λ represents the shadow cost associated with the binding MPR constraint. All the optimal conditions in this case are similar to those described by (11)-(13). Like in downtown areas, binding MPRs enforce an oversupply of parking in suburban areas. In the suburbs, the shadow cost of this regulation can also be measured through the following wedge:

$$p_l\bar{l} + p_k\bar{K} - \frac{\partial B(N_s,A)}{\partial N_s}h(S) = \lambda > 0. \quad (15)$$

Condition (15) is similar to (12), if parking constraints bind, then the marginal cost of parking will exceed its value. Note that because of (9), if developers choose underground parking, and the marginal value of parking is the same, the wedge between parking value and its cost will be greater in the property with underground parking or in CBD areas where the compliance is mostly done with underground parking.

Non-residential properties are likely to differ in both their parking requirements "*a*", since "*a*" is set by the city based on the use of building, and their marginal value of parking.[11] Moreover, as seen in (3) and (4) the cost per parking space includes land and construction costs and can differ across parking designs (underground versus surface lots). Land costs, input materials (capital and labor) as well as geologic conditions can also vary across settings (urban/suburban), geographic areas, and location within a particular city. Land costs in urban centers are generally much higher than in suburban areas. Also, while geologic conditions vary across regions, developers have a greater choice of sites when considering development in suburban and rural areas. In central locations, sites are scarcer and soil with geologic constraints may be more difficult to avoid. Our theory underlines the importance of looking at marginal values and costs for a specific location when assessing the shadow cost of parking requirements.

[11] For example, the city of Los Angeles requires that restaurants and coffee shops provide 1 parking space per 100 sq.ft and commercial or business office uses to provide 1 parking space per 500 sq.ft.

Finally, one can argue that because developers do not take into account the external benefits (e.g. reduction of street congestion) of supplying on-site parking when making their development decisions, they undersupply on-site parking spaces. Therefore, proponents of a MPR argue that such a land use regulation would correct for such an externality by forcing developers to supply the “optimal social” amount. Theoretically, it is conceivable that these locally-constructed regulations have worked out as a system that functions like a Pigouvian tax internalizing the offsetting parking externalities of new construction. Yet, such a view seems debatable. Getting the right local policy requires that these minimum standards be set based on local characteristics (e.g. existence of public transit and off-site parking supply), local demand and on whether they may induce more building elsewhere. Very few localities actually take these features into account when setting their parking minimums. As such, critics argue that MPRs are just too excessive, especially in downtown areas, being welfare decreasing. While in this paper we do not examine the full social welfare net cost of MPRs, our estimates of (12) and (15) can shed light on whether MPRs costs are likely to outweigh the policy congestion benefits (as any reduction in street congestion and in density levels would also affect property prices and therefore the marginal value of parking).

2.3. In-Lieu Parking Fees

Another way to examine the developers' cost of complying with parking requirements is to examine the value of in-lieu parking fees. Some cities provide developers with the option of paying a fee as an alternative to providing the parking required by the development code or ordinance. The intent is to give developers greater flexibility with regard to providing parking, particularly in areas where providing on-site parking would be unfeasible due to cost or site characteristics. The revenues from the in-lieu fee typically contribute to funding new parking facilities or other area improvements. This fee might be required up-front or financed over a period of time. Developers usually have also the option to opt-in to an in-lieu parking program with all of their parking requirements or just a portion of the required spaces. What a developer pays is related to the number of spaces involved and the construction, operations, and maintenance cost of shared parking facilities. The city can use an appraisal process that sets the fee on a case-by-case basis, or, what is more commonly done is that a flat fee per space is set for all participants in the in-lieu parking program. Additionally, cities can also set a fee that is lower than the actual cost of constructing an on-site parking space to incentivize participation into the program. Regardless of how the fee is set, it must maintain a rational nexus with the parking provision requirement.

To understand the relationship between an in-lieu parking fee and our measure of the shadow cost of parking requirements, note that in-lieu parking fees are usually levied per required parking space not provided, while MPRs set parking spaces in proportion to building area. But our shadow cost measure (12) reveals the net cost of an additional mandated parking space. Therefore, the value of an in-lieu parking fee also reveals the implicit tax in the MPR. For the sake of space, let´s focus on the case of a CBD developer.

Let f denote the in-lieu fee levied per required parking space not provided in office buildings in the CBD. Therefore, the in-lieu fee per square foot of building area is given by

$$f * a \qquad (16)$$

since $0 < a < 1$ represents the number of required parking spaces per square feet of gross building floor space. Three notes are now in order. First, both (12) and (16) represent an implicit tax in the parking requirements and can be used to understand the private costs of complying with this land use regulation. Second, the implicit tax associated with (16) resembles an impact fee which depends both on the values of the in-lieu fee and of the MPRs set for the land use in the analysis.

This suggests that cities with similar in-lieu fees may have different implicit parking taxes if their MPRs differ. In particular, we expect that cities with high MPRs for the same land use also exhibit high values for (16). Third, since impact fees are calculated based on the cost of supplying a public parking space, our shadow cost measure (12) should have a ceiling equal to (16). That is, we expect that $\lambda \leq f$. To understand such ceiling note that

$$p_k\left(\bar{K} + \frac{\partial K(N_u,S)}{\partial N_u}\right) = f > p_k(\bar{K} + \frac{\partial K(N_u,S)}{\partial N_u}) - \frac{\partial B(N_u,A)}{\partial N_u} h(S) = \lambda > 0. \qquad (17)$$

In-lieu fees can also be used to measure the complying costs of other land use regulations. If a developer is willing to pay the in-lieu fee to forgo complying with the regulation then this suggests that compliance reduces more the value of the development project than the in-lieu fee paid. One other regulatory example where in-lieu fees can be used to proxy for the private cost of the regulation is inclusionary zoning. All inclusionary zoning programs require developers to allocate a specific proportion of their development activity to affordable housing. For mandatory programs, it is also common that developers have the alternative of paying a one-time fee rather than complying with the program.

One other interesting result from our theoretical analysis, is that MPRs impact building density (see (13) for example). As a result, MPRs can reinforce existing density distortions where density ceilings are also binding. In the case of inclusionary zoning, it is not uncommon to allow developers to build above the maximum density as an incentive for developers to participate in the inclusionary housing program. However, in the case of MPRs in order for such a similar incentive to work it is necessary that the additional net profit of the bonus density would outweigh the negative net profit of complying with the required number of parking spaces. While the case where both FAR and MPRs are binding constraints is worth investigating, it is beyond the scope of this paper and is left for future work.

3. Empirical Strategy

Our goal in the empirical section of the paper is to estimate the components of shadow cost of MPRs on the RHS of equations (12) and (15) for our sample of office properties. We calculate, using the estimated parameters from hedonic regressions, the marginal values of land and parking. We use five different specifications of OLS and Mixed Geographically Weighted Regression (MGWR) estimators. Both approaches allow us to estimate geographic distributions of the coefficients. We also estimate locally-specific costs for structured parking as well as surface parking construction, the details can be found in Franco (2016). Finally, with these values, we can then calculate the distribution of the MPR wedge in (12) and (15).

3.1. Geographic Distribution of Coefficients.

Both OLS and MGWR can obtain a geographic distribution of coefficients. In our case, we are interested in obtaining estimates of marginal parking and land values that are specific to a property. Real estate price models typically use the natural log of price as the dependent variables, a simplified form is

$$\ln(p_i) = a + x_i' b \tag{16}$$

where x_i is a vector of property attributes. One possible strategy for unobserved attributes is to include fixed effects and control for as many area attributes as possible in the OLS regressions, resulting in an equation such as:

$$\mathbf{\ln(p_i) = \alpha + x_i'\beta + z_i'\gamma + f_i} \tag{17}$$

where $\mathbf{z_i}$ are attributes of the local area such as infrastructure, distance to nearest CBD, zoning, and local land value and f_i are geographic fixed effects.

Geographic fixed effects (or interactions variables with geographic fixed effects) assume sharp boundaries that must be imposed on the data and constant coefficients within the geographic areas. Redfearn (2009) finds that this fixed effects strategy can still result in biased coefficients because residential micro-markets don't correspond to city or zip code boundaries. Though coefficients may be correct on average for a geographic area, they are unlikely to be correct at the individual property level. This is a particular problem for our application, because we require accurate estimates of marginal values for each individual property in order to estimate the distribution of MPR costs. In addition, fixed-effect interaction strategies require the estimation of more parameters than MGWR (McMillen and Redfearn 2007.) For robustness, however, we examine fixed effects specification for both OLS and MGWR estimators.

Redfearn (2009) and McMillen and Redfearn (2010) show that GWR is a nonparametric approach that can reveal coefficient distributions and nests the global OLS approach. This is an appealing approach because it does not require that we control for all important area attributes or impose geographic structure in order to correctly estimate the marginal values of land and parking. Past econometric research shows that GWR methods can capture complex, irregular, spatial effects for residential properties (McConnell and Redfearn 2010). To our knowledge, GWR has not been employed with non-residential properties. It seems likely that spatial influences would be as complex in non-residential property markets as they have been found to be in residential property markets.

In non-residential markets sales are geographically sparse enough that even GWR estimates might contain some variation in local area attributes. We use Mixed GWR (MGWR), which allows certain (mainly local area) parameters to remain fixed as in ordinary least squares (OLS) and others to vary spatially (mainly property attributes) as in GWR. In the MGWR framework, a total of $\boldsymbol{k_\alpha}$

global parameters $\boldsymbol{\gamma}$ are estimated in the manner of OLS. A total of $\boldsymbol{k_{\beta}}$ local parameters $\boldsymbol{\beta_{im}}$ are estimated at each geographic point $(\boldsymbol{u_i}, \boldsymbol{v_i})$ for each observation $\boldsymbol{i}$ (Fotheringham et al. 2002):

$$\mathbf{ln}(\boldsymbol{p_i}) = \boldsymbol{\alpha_i} + \boldsymbol{x_i'\beta_i} + \boldsymbol{z_i'\gamma}. \tag{18}$$

In the MGWR framework, the estimates for β_i at each point are obtained using a weighted least squares (WLS) regression in which the point itself receives the most weight, and points farther away receive less weight. At each specific point (u_I, v_I) with weight w_i calculated for each point i and center observation I receiving full weight, the local WLS coefficients are determined by a weighted regression:

$$\hat{b}_i = \left(X'W_iX\right)^{-1}\left(X'W_iY_i\right). \tag{19}$$

We use the bi-square function with k nearest neighbors as a spatial weighting function to determine the decay in weights w_i with distance (bi-square is recommended by Fotheringham et al. 2002.) The number of nearest neighbors is determined by maximizing the CV score using leave one out cross validation.

3.2 Econometrics Strategy for Omitted Variables.

The key concern in the paper is that omitted variables will bias the key coefficients. In particular, omitted variables could be correlated with the amount of parking on the property. Traditional approaches such as instrumental variables or regression discontinuity approaches are difficult with this data[12]. Bajari (2012) uses repeat-sales data to use the deviation from the predicted value of a past sale to condition for omitted variable bias. His key assumption is that buyers have rational expectations and that omitted property characteristics follow a Markov process. Bajari

[12] Bajari (2012) details why quasi-experimental approaches are difficult with property data. Later, in Section 8, we identify and estimate an IV strategy for a portion of the data for which historical parking requirements provide a plausible IV.

uses this to show that under rational expectations, conditional on past price information, innovations in the value of an omitted attribute are exogenous and previous prices can be used to control for omitted attributes. Linn (2013) uses a variation of this method for non-repeat sales data. He uses interactions of time period fixed-effects with pre-sample grid-square level median sales prices to account for omitted-variable bias at the grid-square level. This method assumes that omitted variables are correlated with neighborhood attributes, which in turn are captured in local area sale prices. Linn (2013) has enough repeat sales to be able to compare his approach to the Bajari (2012) estimator and he finds that the Bajari (2012) estimator yields similar estimates as a fixed effects version of the Linn (2013) estimator.

Hitaj et al. (2018) uses the Linn (2013) approach to estimate the association of air quality with the price of apartment buildings in Los Angeles. This is the same geographic area and similar market as our set of office buildings. They compare IV, first-difference (for repeat sales only), OLS, and the Linn (2013) version of Bajari' (2012) method. They find all methods produce comparable results. In an interesting experiment, they show that the rational-expectations method is robust to leaving out some important neighborhood attributes. This indicates that for a similar application as ours to the Linn (2013) method produces satisfactory results.

We use a similar method to Linn (2013) by using pre-period median house prices in the zip code of the property interacted with our quadratic year trend, and estimate the coefficients locally in our MGWR specifications.[13] The Linn (2013) assumes the geographic level of omitted attributes by taking the average grid-square price and, because it is not a GWR estimator, assumes the same coefficient across properties. In-contrast, the relevant price area for our MGWR specification is endogenously determined through cross-validation. In addition, each property has its own local

[13] House sales are much denser than office sales and therefore provide more local information.

estimated quadratic time-trend coefficients as well as interaction of this trend with pre-period average prices. In this way it is midway between the original Bajari (2012) method and Linn (2013).[14]

In addition, we control for median house prices in the zip code in which the property is located and the quarter in which the property is sold. Our approach does not eliminate all possible omitted attributes, but it does narrow the universe of omissions down to ones that are property-specific and uncorrelated with nearby office prices, house prices, property value assessments, pre-period prices, and our other local area controls and are not captured by our extensive list of property-level characteristics.

3.3 Model Selection

Theory suggests that locational attributes should be capitalized into the value of the real estate property, meaning the marginal value of various property attributes (Rosen 1974, Sheppard 1999). This suggests that a MGWR approach with a sufficiently small bandwidth should be able to capture this capitalization using property attributes alone. However, the sparseness of the actual data imply that locational attributes could vary across even small bandwidths. We first use a small set of controls for local density, nearby assessed land value, and local parking availability to control for this possible variation in location attributes. We also run models with a set of additional local characteristics that are likely to vary longer distances than our local property characteristics. These include: distance to freeways, ocean distance, crime, and zoning. Finally, we include specifications with location fixed effects. These specifications use several in and out-of-sample

[14] Linn (2013) also employs the Bajari (2012) repeat-sales methodology. We only see a few repeat sales in our data (we drop one of the repeats) so we cannot use the full methodology.

criteria to examine whether a sufficiently rich OLS model can perform as well as or better than a GWR model.

4. Data and Variables

4.1. Data Sets

Our questions require data on property characteristics, parking construction costs, parking requirements, building zoning requirements, and location characteristics. Table 1 contains summary statistics for the key variables for the GWR and OLS specifications. Property data on office sales from 1997 through 2005 over most of Los Angeles County was obtained through Costar Group, a national commercial real estate information provider (www.costar.com). The database contains the sales price of each property and a vector of structural characteristics (such as building area, land area, and the number of parking spaces) and a vector of location characteristics (such as zip code, geographic zone, latitude, and longitude).

In our data, we have the number of parking spaces but not the area of parking. To put our parking space measure in the same units (square feet) as our other property area characteristics, we use an estimate of 350 sqft/parking space from a local parking expert (personal communication, Willson, 4/06/06), which includes all lanes, medians, etc., that accompany spaces.[15]

The marginal cost of parking construction is determined by the type of parking at a site. To determine the type of parking (surface structural, semi-underground or underground) provided with each non-residential property we also developed an algorithm that would identify surface parking. We obtain a 100% accuracy for what the algorithm classifies as surface parking, with

[15] The data does not allow us to test whether it is parking area or the number of parking spaces that is valued by the market. The linear transformation does not relax this constraint. By transforming the parking space variables, the regressions are using units of 1/350th of a parking space, which is approximately equal to one square foot.

surface parking representing approximately 64% of the entire dataset. The remaining 36% of parking which cannot be accurately classified by the algorithm was done manually using Google Earth and Google Street View.[16] In our dataset we have a total of 323,007 parking spaces with the following distribution: 0.6% are underground mostly found in office properties and some in retail properties, 94% are surface, 4.7% are semi-structural mostly found in office properties and 0.7% are multi-structural also mostly found in office properties.

Unit construction costs for a particular type of parking (above or below grade parking) in different locations of the county was estimated using standard industry practices and published sources for local construction costs such as the construction cost estimates for parking garages published by *RS Means*. Historical cost indexes published by *RS Means* was also used to move construction costs forward or backward in time. Further details on parking construction costs are provided in Franco (2016).

4.2. Property and Location Variables.

Structural characteristics

The primary continuous property characteristics of interest are the total property land area (*pcsqft*), the parking area (*park*), and the total building floor area (*bldg*). Total building floor area is the sum of the floor area of all floors in the building. Property age (*age*) is also included as a structural control following from the hedonic model. All continuous property characteristics are log transformed. This follows the past hedonic literature and Cutter and DeWoody's (2010) finding that the log specification was superior for a comparable dataset. A series of binary variables for

[16] Full details on the algorithm developed for the classification of different types of parking for non-residential properties in the Los Angeles metro region and on the accuracy assessment results can be obtained upon request from the authors.

structural property characteristics are also included. These controls include corner location (*cnloc*), a set indicating building condition, a set indicating building material, and $looff$ and $offres$ indicating low-rise and office-residential configurations for office properties, and the number of floors.

Location characteristics

In order to control for location characteristics, we include a large set of location controls as robustness checks in some specifications. Building density (*dens*) is related to our key questions on the incidence of MPR cost. It is defined as building area square footage per total land square footage within 1/3 mile radius. The density of publicly available parking within 1/3 mile (an approximation for walking distance) is controlled for via two variables (*pkgarg* for garages, *pksup* for other supplemental parking) defined as parking area square footage per total land square footage. ZIP code median house price at the time of sale of the non-residential property (*DQhouseprice*) and total assessed land value for non-residential properties within 1/3 mile radius (*landval*, logged) control for underlying land value to isolate the more-relevant property value. We also include a selection of variables for amenities These included distance to the ocean (quadratic), distance to the nearest freeway (quadratic), four principal components derived from distances to various centers including but not limited to the CBD (Los Angeles is classified as a polycentric city (Sivitanidou 1996)), and the first of two principal components for weather variables. Additionally, a neighborhood crime rate index for the year 2000 ($crime$) was included as a locally varying estimate in MGWR. Finally, we control for the type of zoning in which the office is located.

5. Estimation and Results

In this section we examine OLS and mixed GWR (MGWR) estimates for different sets of variables and with and without fixed effects (see Table 2 for the list of variables). We compare the MGWR and OLS specifications on information criteria and LOOCV. Finally, we compare the OLS and MGWR results for the key coefficients to examine whether the results show spatial variability of coefficients.

5.1 Mixed GWR Choices

The MGWR model allows us to set some coefficients as global and others as locally estimated. This is necessary because many of the locational variables do not vary over our typical bandwidths. For example, distance to the ocean will vary little within a small number of nearest neighbors. A geographic fixed effect will not vary at all. Table 2 shows which coefficients are global and which ones are local. We attempted to estimate every variable local up to the limitations of the data. In all cases the key structural coefficients (log of building, land, and parking area, and the interaction of the log of building and parking area) are estimated locally. We also found we could estimate local coefficients for a quadratic in the year of sale that results in a good approximation to yearly fixed effects (year fixed effects were too collinear for MGWR estimation in some specifications).

5.2 Comparison of OLS and MGWR Estimation.

We estimate a range of specifications and compare OLS and MGWR in order to test for robustness. The specifications in Table 3 start from the very basic building characteristics (size of parcel and building amount of parking and age) in column 1 through the most complete set of controls in column 10.

The variability of the coefficients, an F-test of residuals, and Moran's I calculations (Table 3) all reject the null hypothesis of zero geographic coefficient variability. Table 4 shows that an F-test for spatial variability rejects the null of spatial variability for each key coefficient at any conventional significance level. An additional MGWR Anova test rejects the null of the global model as a whole at any conventional significance level. The Moran I results (Table 3) also indicate the MGWR significantly reduces spatial autocorrelation in the residuals relative to OLS for all property types.

Specification 3-5 perform similarly on AICc, BIC, and CV measures. [17] Specification five uses the MGWR version of the Linn (2013) rational-expectations estimator. Specification one (with only property-level controls) performs by far the worst. We use specification five for the marginal value calculation as it should control for unobserved attributes better than the other specifications and is only slightly worse on the out-of-sample criteria

Table 4 shows the key coefficients for the marginal values calculations in the next section for specification five. The OLS and the mean MGWR coefficients are similar. The key difference is the local variability in the coefficients of the MGWR estimator. This indicates that marginal values of property area and parking will vary substantially more in the MGWR estimator across local areas.

6. Shadow Cost of Parking Minimums

We now turn to the central questions of this paper. First, we discuss how large the MPR wedge would have to be to be economically significant. Then, we use the specifications from the OLS

[17] All fixed effect specifications performed poorly relative to their equivalent specifications-especially with regard to their CV score. Their Moran's I coefficients are also substantially higher. This indicates that the official borders do a poor job of capturing real estate submarkets. We don't present any of the FE results because of this poor performance. This finding also indicates that fixed effects interacted with attributes would also perform quite poorly.

and MGWR runs to calculate the MPR marginal cost wedge and its components from the specification coefficient estimates. Next, we calculate the distribution of MPR costs to determine the percent of properties that are likely to have economically significant MPR wedges. Finally, we examine whether there is a significant gradient in MPR size in building density, land value, and building size.

6.1 When are MPR Costs Likely to Matter?

How large do MPR costs have to be to plausibly affect building decisions or overall development costs? Offices in this period had a typical building construction cost of $150 per square foot.[18] A 10% addition to these costs would be a significant cost to the builder. What MPR cost would add 10% or $15 increase to these costs? A typical office property has an MPR of one space per 500 $ft.^2$ of building area and each parking spot takes up 350 $ft.^2$ That implies every foot of building space is mandated to have .7 feet of parking (=350 $ft.^2$/ 500 $ft.^2$). At this ratio, a $22/ $ft.^2$ MPR cost would add about $15 in net parking cost to the per foot cost of construction (remember the MPR cost is the *net* loss). This corresponds to the shadow cost λ. The market response to this additional cost depends on the building supply elasticity. The market would then need to be very inelastic for an MPR this size not to effect supply substantially.

6.2 Comparison of the distribution of marginal values and shadow cost of MPRS.

We calculate the shadow cost of MPRs according to (12) or (15), which is the difference between the marginal value of parking and the land and capital cost of supplying that parking.[19]

[18] Estimated using R.S. Means for 2006 data. Individual offices may vary.
[19] We calculate the marginal value of land by calculating the predicted price from the specification, then calculating the predicted price after adding a square foot amount of land. The difference is the marginal value of a square foot of land. We follow the same procedure to calculate parking and building floor area marginal value.

Table 5 shows that the average MPR cost is \$20 per ft^2 and above for all MGWR specifications and OLS specifications 3-5. For these specifications, the average MPR cost implies a wedge that is about 10% of building construction cost (per ft^2). Overall, the MPR costs estimated by MGWR are higher than OLS but comparable for the specifications with local controls (specifications 3-5).[20]

Table 5 also shows that the variance of MPR costs per ft^2 is greater in the MGWR models. Though the mean costs for the OLS specifications 3-5 are not too different from that of the better MGWR specifications, the spread of costs is much greater from the MGWR model. Figure 1 shows that the 75th percentile of MPR costs is \$37 per ft^2 (about 27% of building costs) and \$31 per ft^2 for OLS. At the 90th percentile the MPR cost is \$99 per ft^2 for the MGWR estimator. These estimates suggest that there are very large differences in MPR costs per ft^2 across properties. Our next section explores the MPR cost gradient with respect to local density, local land value, and building size.

6.3 Is the shadow cost gradient steep enough to affect property location or building decisions?

Recall that there need to be large differences in MPR costs for MPRs to plausibly affect urban form and support the strong form of the MPR hypothesis. Figures 2-5 map MPR costs and the components of the costs. From Figure 2 we observe that large portions of the county area have near zero or negative (non-binding) MPR costs. High MPR costs are nevertheless concentrated in the high land value corridor from Los Angeles Downtown west to the coast, the Wilshire/Santa

[20] OLS with few or no local controls (1 and 2) is a clearly a poor fit as shown by the negative marginal value of land. This occurs because larger properties are generally located farther from central areas so there is a negative correlation between land size and price if one does not control for local geographic characteristics. GWR has estimates that are economically possible and within a small range no matter the set of controls.

Monica Corridor (Figure 2 and Figure 3), with a few other hot spots.[21] The Wilshire/Santa Monica Corridor is also known as a high amenity zone in the county with trendy retail settlements and high-culture entertainment. It is also considered as the postmodern central core for the metropolitan region as it includes the traditional CBD only on its periphery (downtown LA), and it crosses several municipal boundaries. Inspection between Figures 2 and 3 further reveals that the MPR cost variation is largely due to land value (Figure 3)-though parking value is also low in the Wilshire/Santa Monica corridor, perhaps because of the high concentration of commercial parking garages (Figure 5). Overall, the maps show a large difference in MPR costs per ft^2 between the densest, most valuable areas of Los Angeles and other areas.

We use three different variables to characterize the difference in MPR costs per ft^2 between low and high-density areas. One local density measure is building square footage/per square foot land within one-third of a mile of the property (*density)* excluding the own property. We also use the log of total assessed land value in the same radius (*llandval)* as an indirect measure of density. These are interesting tests of the MGWR because they are not in the control variables for all specifications. Geometric limitations imply MPR costs per ft^2 are higher for smaller properties because a given MPR ratio is more difficult to fit in a small property that needs to consider lanes, setbacks, etc., so we also examine property size (*pcsqft)* to be sure property size is not confounding the density/value gradients.[22]

Table 6 shows our three specifications to characterize this gradient (variables are all standardized). The relevant coefficients are jointly and individually significant at the 1% level.

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[21] The Wilshire/Santa Monica corridor occupies a narrow band of space stretching from the Pacific Ocean at Santa Monica in an arc along the base of the Santa Monica Mountains through West L.A., Brentwood, Westwood, Century City, Beverly Hills, Fairfax/Melrose, West Hollywood, Hollywood, Silver Lake, Echo Park, Koreatown, and Westlake, and culminating in Downtown Los Angeles.

[22] We tested whether the influence of parcel size was due to our functional form and found that the log-log form clearly outperforms linear, quadratic, and the quadratic of the log forms (unreported regressions).

Our density metric shows that a standard deviation density is associated with an approximately $11 increase in the estimated MPR cost. Therefore, in comparing the average property one standard deviation above the mean density to one a standard deviation below the mean density a developer would face about a $23 difference in MPR costs, or about 10% of average building construction costs. The land value gradient is larger with a $15 increase associated with a standard deviation extra in (logged) land value. A one standard deviation increase in the size of the parcel is associated with about an $11 decrease in the MPR. This shows the MPR cost falls particularly hard on smaller properties in dense and high value areas. Figure 6 illustrates lowness curves for the estimated MPR cost for top decile and bottom quartile of assessed land values by the size of the property. Both high and low value properties that estimated MPRs decline with property size.

To get a true sense of these combined effects we can look at a small property in a dense, high land value area compared to a property on the other side of the spectrum using the estimated parameters in the fourth column in Table 9. A property exactly at one standard deviation above the mean in density and value (these are correlated at .8) and one standard deviation below the mean in land size is predicted to face a $39 MPR cost. A property that is one standard deviation below the mean in density and value and at the mean in land size is predicted to face a $4 MPR cost. This estimated differences in MPR costs is about 23% of the construction costs for these high density/value properties.

7. Robustness Checks

Market Test

We obtained the parking requirements for offices in each city for a largely overlapping dataset.[23] In this data, the parking requirement largely predicts the number of parking spaces. A simple regression of parking spaces on the properties' minimum requirement has a coefficient near one and an R^2 of .68. The median ratio of space to required parking is .97 and 50% of the data has a ratio between .7 and 1.3. This indicates that developers are seldom installing significantly more parking than required - which is consistent with binding MPRs. The 50% of properties with parking less than the MPR suggest that many developers find ways to decrease the burden of MPRs.

In-Lieu Parking Fee Test

One of these ways to decrease the burden of MPRs is to pay a fee in-lieu of installing required parking. In lieu fees can be established as a flat rate per parking space not provided or per square foot of floor area, or through a case-by-case determination for the development as a whole. We researched in-lieu fees for the thirty largest cities in Los Angeles county and found seven cities with clearly stated in-lieu fees (all on a parking space basis.)[24] The in-lieu fees are set by the cities in large part based on estimates of the cost of publicly supplying structured parking to replace the private parking spots.

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[23]. Some properties with all data necessary for the regression did not have a parking requirement that was clear from the city code and had to be dropped. These are not building level individual requirements, but rather the general parking requirement stated in the city code for the zone the office building is located in. These requirements can be increased or decreased because of zoning variances or other neighborhood factors.

[24] Additional cities had in-lieu fees on a case by case basis or there was no clear evidence on the amount of the in-lieu fee. There may be additional cities with in-lieu fees that our code search did not find. In our search we also found information for some cities not in the top 30 of population like Claremont. The in-lieu parking regulations are complex and often are only available for specific circumstances and geographic areas.

The in-lieu fees (measured per ft^2) are in the same range as the MPR costs for those cities (see Table 7). The higher cost cities such as Santa Monica and Beverly Hills have high in-lieu fees as well-and for all cities the in-lieu fees are in the same range as the MPR costs for those cities. According to our model, the MPR cost should also have a ceiling based on the cost of structured parking. The general correspondence of in-lieu fees with the MPR costs in Table 7 is consistent with this portion of our theory. The average parking in-lieu fee per ft^2 for our sampled cities in Table 7 is around \$57, and our average shadow cost of MPRs is \$44 per ft^2. MPRs cost estimates in Table 7 nevertheless still underestimate the cost of complying with MPRs somewhat, as developers supplying the mandated spaces must also pay property taxes and maintenance costs for the privately supplied spaces.

Robustness to Regulatory Stringency

A key remaining bias concern is that the parking amount could correlate with regulatory stringency. That is, a property with a large amount of parking is more likely to have higher parking requirements and more stringent Floor-Area Ratios or height limits than an otherwise similar property with less parking. City fixed effects can partially control for regulatory stringency as long as they are constant within the city. However, zoning requirements can differ within a city. Height and FAR requirements depend on the zoning designation as well as the city. Parking requirements can be nonlinear in building square feet. Therefore, the effect of these requirements could be different for different sized buildings within the same city.

If regulatory stringency is correlated with price (because, for example, price may partially depend on redevelopment value and that is a function of what the zoning allows to be built) and is correlated with the amount of parking or other building attributes, then leaving it out of the regressions could bias our results. We determined three key zoning requirements (at the date of sale) for a subset of the data: parking minimum requirements, floor area ratio maximums, and height limits. Our key variable for parking requirements is the average parking requirement. This is the number of square feet of parking required per building square feet (assuming 350 square-foot per parking space). The maximum height variable is in feet. The FAR variable is allowed building floor space per square foot of buildable area.[25] We then ran specification five for this subsample with and without these requirements.

We compare two MGWR specifications in Table 8. The first column presents results for the key coefficients for specification 5 and the subsample for which we were able to obtain the three requirements. The results are very similar to the full sample results in column two of Table 7. The second column uses the same subsample as column one, and uses specification five but with FAR, height, and parking controls. The size and the standard deviation of the (locally-estimated) coefficients is almost identical. The results suggest that the average parking requirement is significantly associated with property value but including these controls does not affect our main coefficients. We leave this interesting result for exploration in future research.

Using Historical Parking Requirements as an Instrumental Variable.

Another possibility for a bias concern is that our results on the low marginal parking value could be due to builders building more parking on relatively low value parcels, and that low value is not accounted for by any of our other empirical strategies (spatially-varying fixed effects,

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[25] For all cities except Los Angeles data we matched the location of properties to GIS maps of the zones within each city. Then we researched the general FAR and height limits and parking requirements for each zone. Some cities such as Burbank have more complex zoning overlays where zoning requirements can only be found property by property so these were dropped from the analysis. Los Angeles City has a complex zoning system but has an excellent property database (zimas.org) where we could individually match the property to it zoning and height and far requirements.

assessed land value control, other area controls, and the Linn (2013) estimator). For Los Angeles City there is good historical data on parking requirements for offices back to the inception of parking requirements in 1946. We use a strategy similar to 2SLS. The key identification claim is that this parking requirement is exogenous and unrelated to unobserved components of current underlying land value. This claim is plausible because within Los Angeles city the requirements for offices differ over time, but not area[26] (except for the Downtown parking district which began in 1968). Also, the redevelopment value effect of the parking requirements discussed on the previous section would be based on current rather than historical requirements- and these have changed for a majority (about 81%) of the properties. We estimate a first stage model that predicts the amount of parking based on the parking requirement, the building size, and the property size. We then replace the parking amount with this estimated parking amount.[27] We then use these estimated variables in specification two (the number of observations is much lower and therefore we use a specification with fewer variables.) Table 9 compares the OLS results using this pseudo-instrumental variables strategy compared to the original variables on the Los Angeles City sub-sample. The MPR cost, as well as the marginal building, parking, and land value are quite similar between the two.

8. Conclusions

Our theoretical model suggests that MPRs should bind more in dense areas where the value of land is high. In these areas, the marginal value of parking would tend to be less than the cost of land and/or parking construction cost. Even if non-residential property owners can build above or

[26] Since the late 1990s, Los Angeles City has increasingly gone to neighborhood specific parking requirements, but these are not applicable to our sample, which was built before these requirements went into effect.
[27] The actual variables in the specification are the log of parking area and the interaction of this variable with the log of building area. These non-linearities make the approach somewhat different than normal 2SLS estimation.

below structured parking, the high cost of such type of parking would tend to result in more binding MPRS. These theoretical insights can best be tested with an estimator that allows the parameters of the hedonic model to vary spatially. The MGWR model estimates property-specific coefficients that allows us to test our theoretical predictions.

We apply the MGWR model to data from Los Angeles non-residential property sales. We find that the MGWR model is significantly better than OLS in its out-of-sample prediction (CV score) and AICc. Then, we use the MGWR model parameters to estimate whether the marginal value of parking is less than the construction and/or land costs of providing that parking (shadow cost of MPRs). Both OLS and MGWR specifications indicate that a large proportion of properties have MPR shadow costs that are large enough to plausible effect building decisions.

Next, we determined in which circumstances MPRs tend to bind. Unsurprisingly, we find that in the high land value areas such as CBDs and coastal areas the evidence is consistent with more binding MPRs. Also, the evidence is consistent with smaller plots having more binding MPRs. These smaller plots tend to be in more-densely-built areas. The MGWR runs indicate that a majority of properties have substantial MPR shadow costs. A real-world market test and several robustness checks suggest that our methods produce accurate measures of the MPR cost-gradient. Our methods could be used to estimate the cost gradient for many different zoning and building regulations such as height, floor-area ratio, setbacks, and open space requirements. These cost-gradients may will influence urban density and form, which are key elements for the productivity of regions and countries as whole (Gilles, Duranton and Puga 2020).

We find a strong density and assessed land value gradient in our MPR costs estimates. The MGWR approach proved its efficacy at incorporating unobserved local influences into its estimates. The differences between dense, high value areas and others is large enough to decrease building in the dense/high value areas central areas relative to more sprawling outskirts if supply is at all elastic. Our findings support the strong view of Shoup and others that parking minimums could affect City form by imposing greater costs on older, denser, more valuable areas than lower land value, sprawling, areas.

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Tables and Figures

Table 1: Summary statistics for key variables used in the GWR model and/or the construction cost estimates.

Variable	Obs	Mean	Std.Dev.	Min	Max
Lot size (sqft)	2571	21994.531	22962.869	932.184	146797.188
Parking area (sqft)	2571	11275.039	14274.666	300.000	111300.000
Building floor area (sqft)	2571	13262.680	14595.052	1076.000	98728.000
Property Year Built (years)	2571	1963.890	19.758	1888.000	2006.000

Table 2: List of Variables by Global and Local

Local Variables		Global Variables
Lot size (sqft)	Construction	Brick
Parking area (sqft)		Frame
Building floor area (sqft)		Mixed
Property Year Built (years)		Other
Year of Sale-1996	Condition	Excellent
(Year of Sale-1996)2		Good
Pre-Period Average of median sales price		Average
Pre-Period median sale price growth		Fair
		Poor
	Zoning	Downtown
		Residential
		Mixed
		Office
		Industrial
		Commercial
	Local Area Controls	ZIP code median house price (US$)
		Total assessed land value within 1/3 mile
		Supplemental parking area within 1/3 mile
		Parking garage area within 1/3 mile
		Building density within 1/3 mi le
		Distance to ocean (mi)
		Distance to nearest freeway (mi)
		Crime Index in year 2000

Table 3: Measures of Fit for OLS and GWR

Specification	I		II		III		IV		V	
Estimator	**OLS**	**GWR**	**OLS**	**GWR**	**OLS**	**GWR**	**OLS**	**GWR**	**OLS**	**GWR**
AICc:	3,122	1,339	2,334	1,288	1,641	1,256	1,656	1,268	1,618	1,287
BIC/MDL:	3,222	4,132	2,480	4,025	1,868	2,589	1,854	2,546	1,857	2,684
CV:	0.197	0.098	0.145	0.096	0.111	0.096	0.112	0.096	0.110	0.097
Adjusted R square:	0.756	0.901	0.821	0.902	0.864	0.890	0.863	0.889	0.865	0.889
Bandwidth:	2571	95	2571	100	2571	242	2571	248	2571	271
Moran's I**	0.207	0.018	0.117	0.014	0.065	0.034	0.067	0.035	0.066	0.032
Control Variables:										
Local (for GWR)										
Basic Building	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Pre-Period Controls*	N	N	N	N	N	N	N	N	Y	Y
Global (GWR and OLS)										
Extended Building	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Basic Geographic	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Zoning	N	N	N	N	Y	Y	N	N	Y	Y
Amenities	N	N	N	N	Y	Y	Y	Y	Y	Y

*** Pre-Period house price level and trend variables.**

**** All results significant at the 1% level, one tailed test.**

Table 4: Coefficient Estimates for Principle Specification

	Specification V				
Key Variables	OLS Coefficient	GWR Coefficient Mean#	Estimates SD*	Test of Spatial Variability F-Statistic	(GWR) p-level
Intercept	13.88	13.88	0.19	8.4	0.00
ln(Lot ft2*)*	0.19	0.19	0.07	13.0	0.00
ln(*parking ft2)*	-0.55	-0.63	0.35	13.6	0.00
ln(building ft2*)*	-0.14	-0.24	0.40	10.7	0.00
ln(*parking)**ln(*building)*	1.14	1.34	0.72	30.2	0.00
ln(age)	-0.07	-0.07	0.04	13.2	0.00
Sale year-1997	-0.10	-0.12	0.30	13.4	0.00
(Sale year-1997)^2	0.43	0.43	0.34	13.7	0.00
Pre-period price*Sale year-1997	0.25	0.28	0.40	14.5	0.00
Pre-period price*(Sale year-1997)^2	-0.29	-0.28	0.44	23.6	0.00
Local (for GWR)					
Basic Building	Y	Y			
Pre-Period Controls*	Y	Y			
Global (GWR and OLS)					
Extended Building	Y	Y			
Basic Geographic	Y	Y			
Zoning	Y	Y			
Amenities	Y	Y			

* This is the standard deviation of the vector of coefficient estimates produced
for each variable by the GWR estimates.
** These are the variables for pre-period housing price level and growtrh.
# These are locally estimated so the individual estimates only can be evaluated for statistical significance.

Table 5: Marginal Values

Specification	MPR Cost ($)		Parking Value ($)		Land Value ($)	
GWR	Mean	SD	Mean	SD	Mean	SD
1	20	55	18	36	18	26
2	24	54	16	34	21	28
3	25	39	16	24	21	22
4	23	39	17	25	21	21
5	26	38	15	23	22	22
OLS	Mean	SD	Mean	SD	Mean	SD
1	-5	31	18	28	-7	6
2	11	31	15	30	7	8
3	24	33	16	27	21	19
4	22	33	17	28	20	19
5	25	32	16	26	21	19

Table 6: Density Gradient Regression results

	(1)	(2)	(3)	(4)
Dependent Variable	MPR_Cost $/ft2	MPR_Cost $/ft2	MPR_Cost $/ft2	MPR_Cost $/ft2
Property Area ftsup:2*	-11.571***			-10.983***
	(0.713)			(0.682)
Built Area Density (1/3 mile)*		9.934***		4.339***
		(0.723)		(0.972)
Land Value (1/3 mile)*			11.590***	7.664***
			(0.741)	(1.008)
Constant	26.123***	26.123***	11.501***	16.454***
	(0.713)	(0.723)	(1.177)	(1.442)
Obs.	2571	2571	2571	2571
R-squared	0.093	0.068	0.087	0.176
N aic bic	25747.158	25815.487	25763.804	25505.201

Standard errors are in parenthesis

**** p<0.01, ** p<0.05, * p<0.1*

Table 7: In lieu Fees Are in the Same Range as Estimated MPR Costs.

City		In-Lieu Fee/space	Fee/Ft^2	City MPR Cost mean /Ft^2	Obs
Carson		$ 7,000	$ 20.00	$ 4.77	12
Inglewood		$ 3,000	$8.57	$ 13.01	38
Walnut		$ 26,537	$75.82	$14.11	2
Claremont		$ 9,000	$25.71	$ 28.13	12
Glendale		$ 24,000	$68.57	$ 41.98	115
Beverly Hills					61
	Rodeo Drive	$ 35,704	$102.01	$ 72.92	
	Beverly	$ 28,653	$ 81.87	$ 72.92	
	Other CBD	$ 21,422	$61.21	$72.92	
Santa Monica		$ 20,000	$57.14	$ 77.26	78

Table 8: Robustness To Building Requirements (Specification V GWR Results).

	mean#	S.d. of Estimates*	mean#	S.d. of Estimates*
Intercept	13.877	0.170	13.878	0.168
lpcsqft	0.202	0.067	0.202	0.066
logpark	-0.597	0.329	-0.596	0.327
logbldg	-0.200	0.369	-0.201	0.365
logparkxlogbldg	1.244	0.676	1.243	0.671
lage	-0.084	0.040	-0.087	0.039
yearssince1997	0.101	0.107	0.102	0.107
yearssince1997sq	0.214	0.113	0.213	0.114
dqprgrowth	-0.004	0.083	-0.004	0.082
dqavprice	0.076	0.062	0.076	0.061
Local (for GWR)				
Basic Building	Y		Y	
Pre-Period Controls**	Y		Y	
Global (GWR and OLS)				
Property Regulation***	N		Y	
Extended Building	Y		Y	
Basic Geographic	Y		Y	
Zoning	Y		Y	
Amenities	Y		Y	

* This is the standard deviation of the vector of coefficient estimates produced for each variable by the GWR estimates.

** These are the variables for pre-period housing price level and growtrh.

*** Requirements for maximum floor area ratio, minimum parking, and maximum height/FAR.

These are locally estimated so the individual estimates only can be evaluated for statistical significance.

Table 9: Marginal Values from Pseudo IV Approach

Specification	MPR Cost		Parking		Land	
OLS	Mean	SD	Mean	SD	Mean	SD
IV	43	467	0	467	20	15
IV Sample	27	37	16	30	19	14

Figure 1: Estimated Percentiles for MPR Cost.
(specification V)

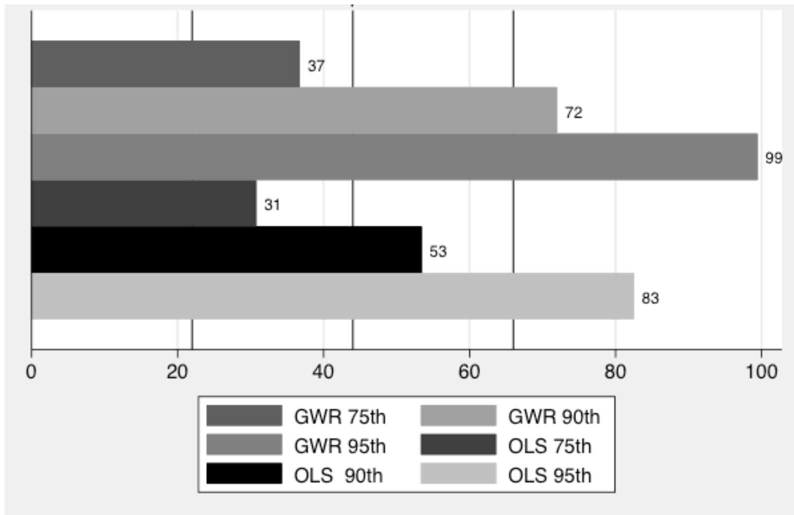

Figure 2: Marginal Cost of Minimum Parking Requirements

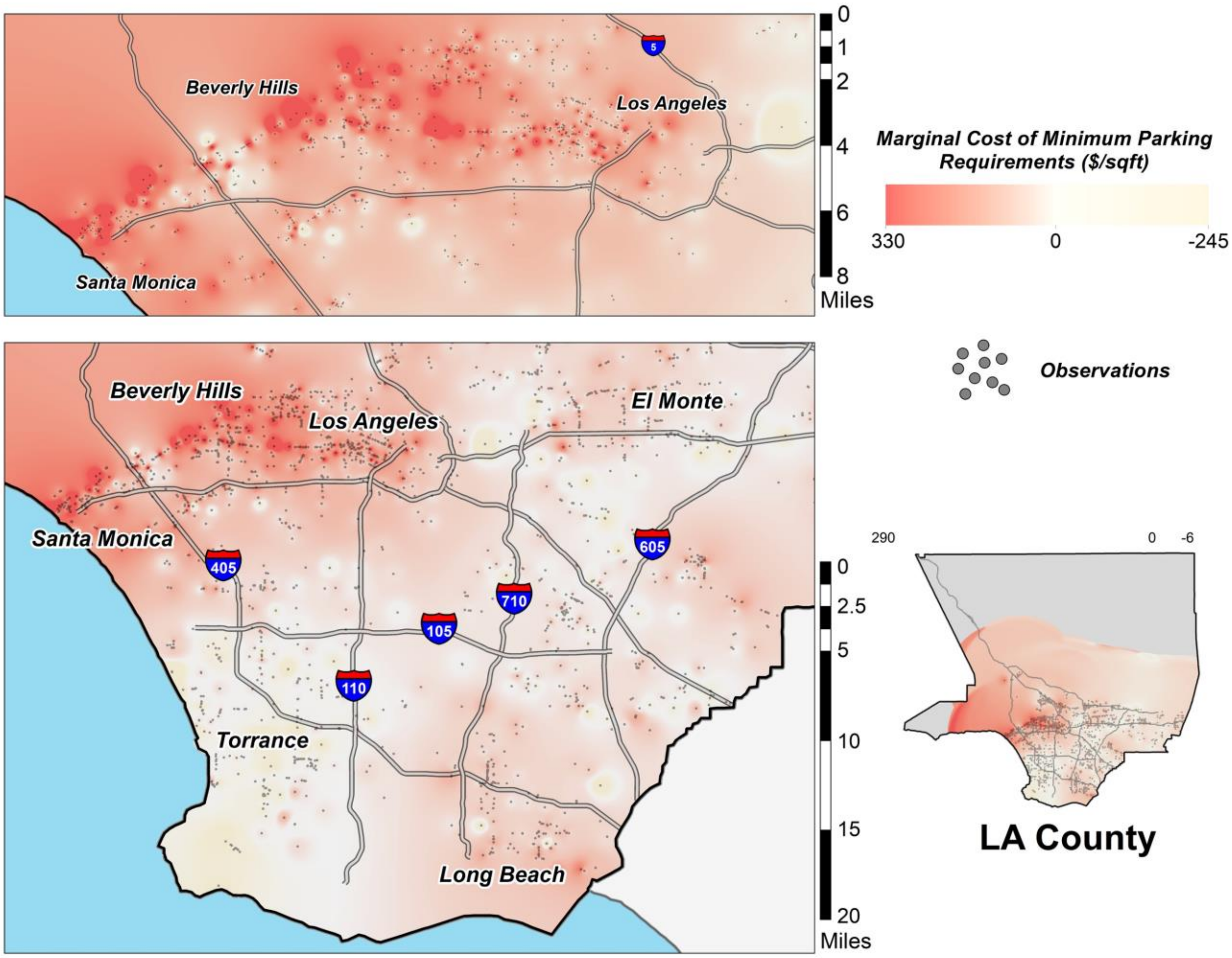

Figure 3: Marginal Value of Land

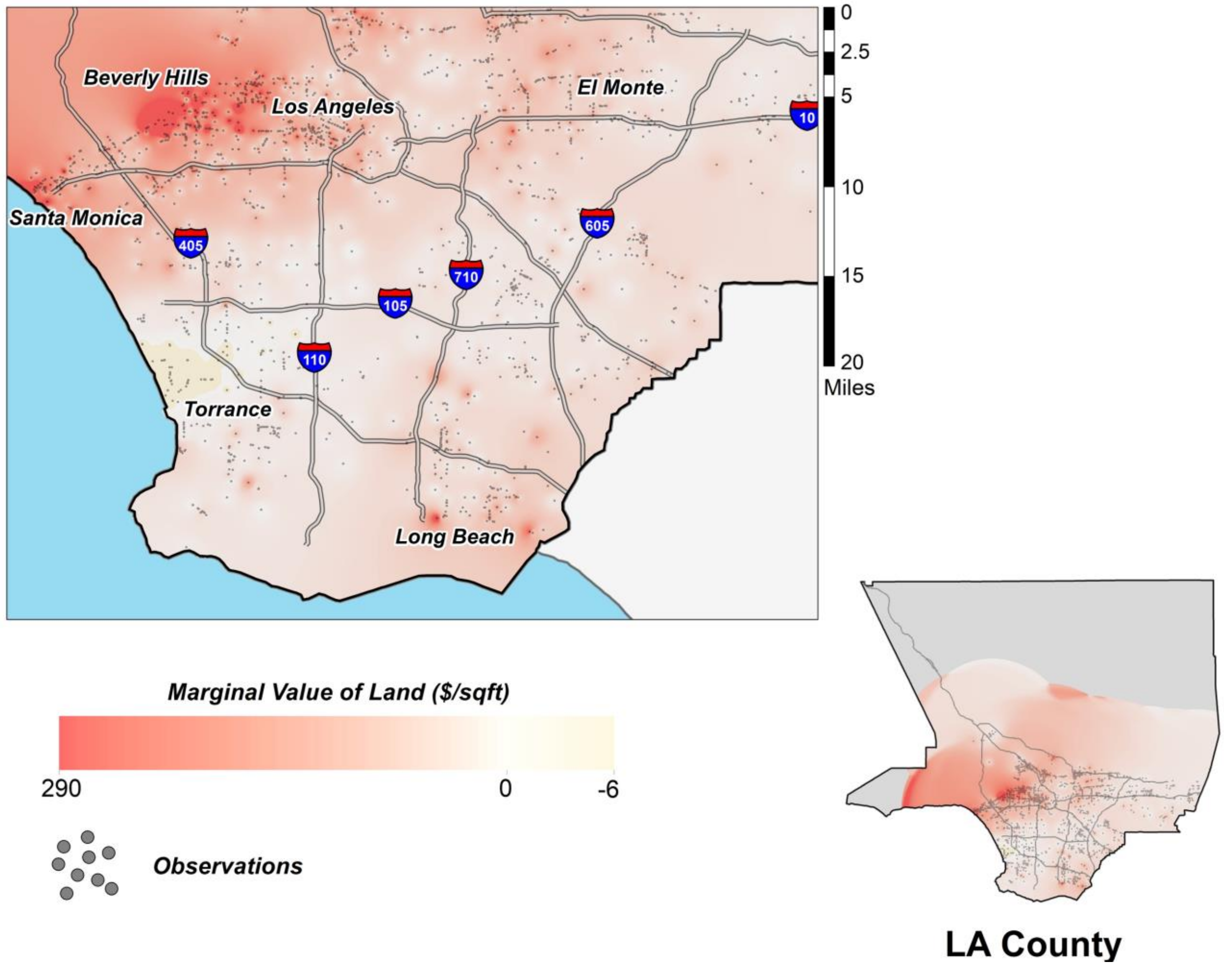

Figure 4: Marginal Value of Parking

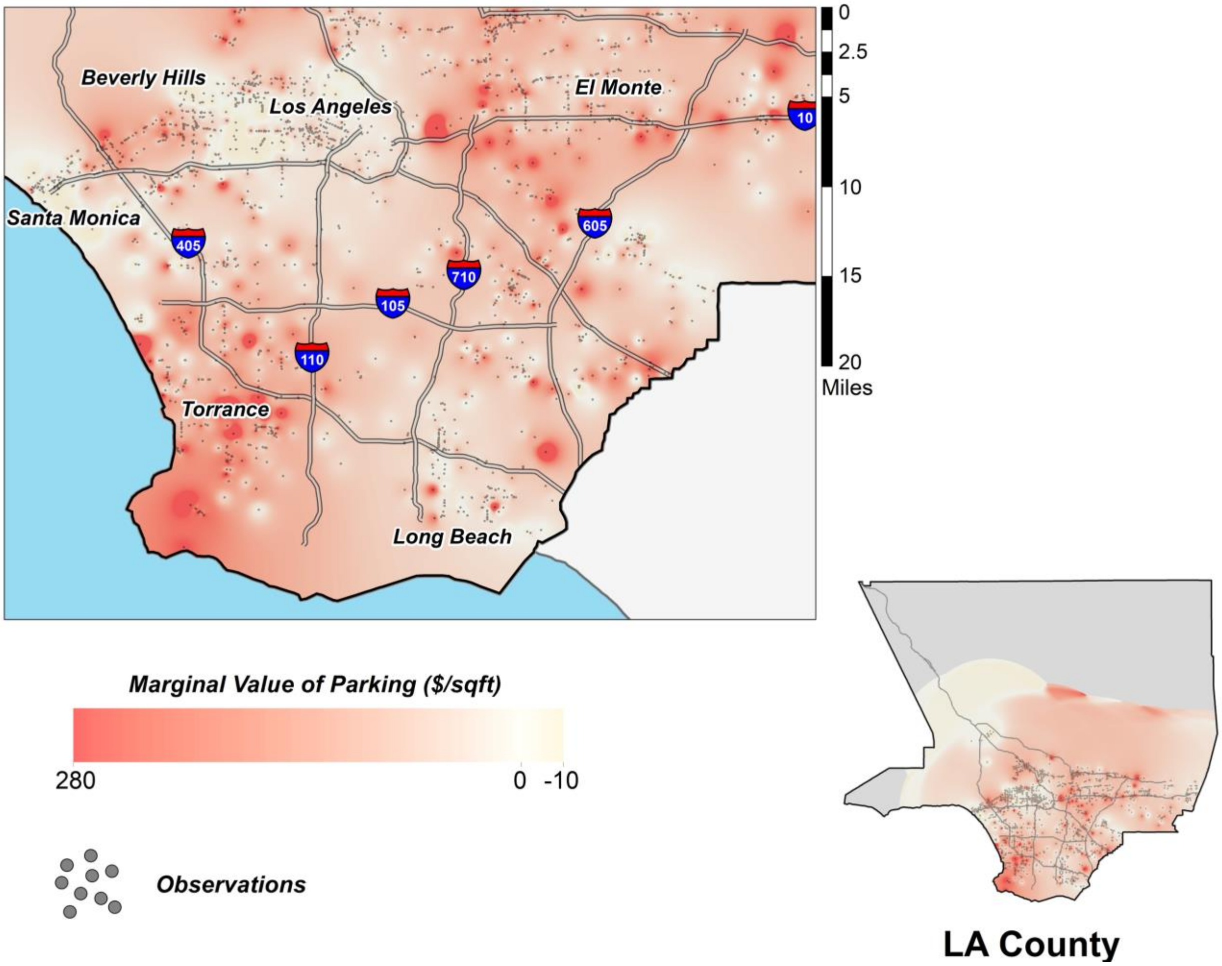

Figure 5: Location of Paid Parking.

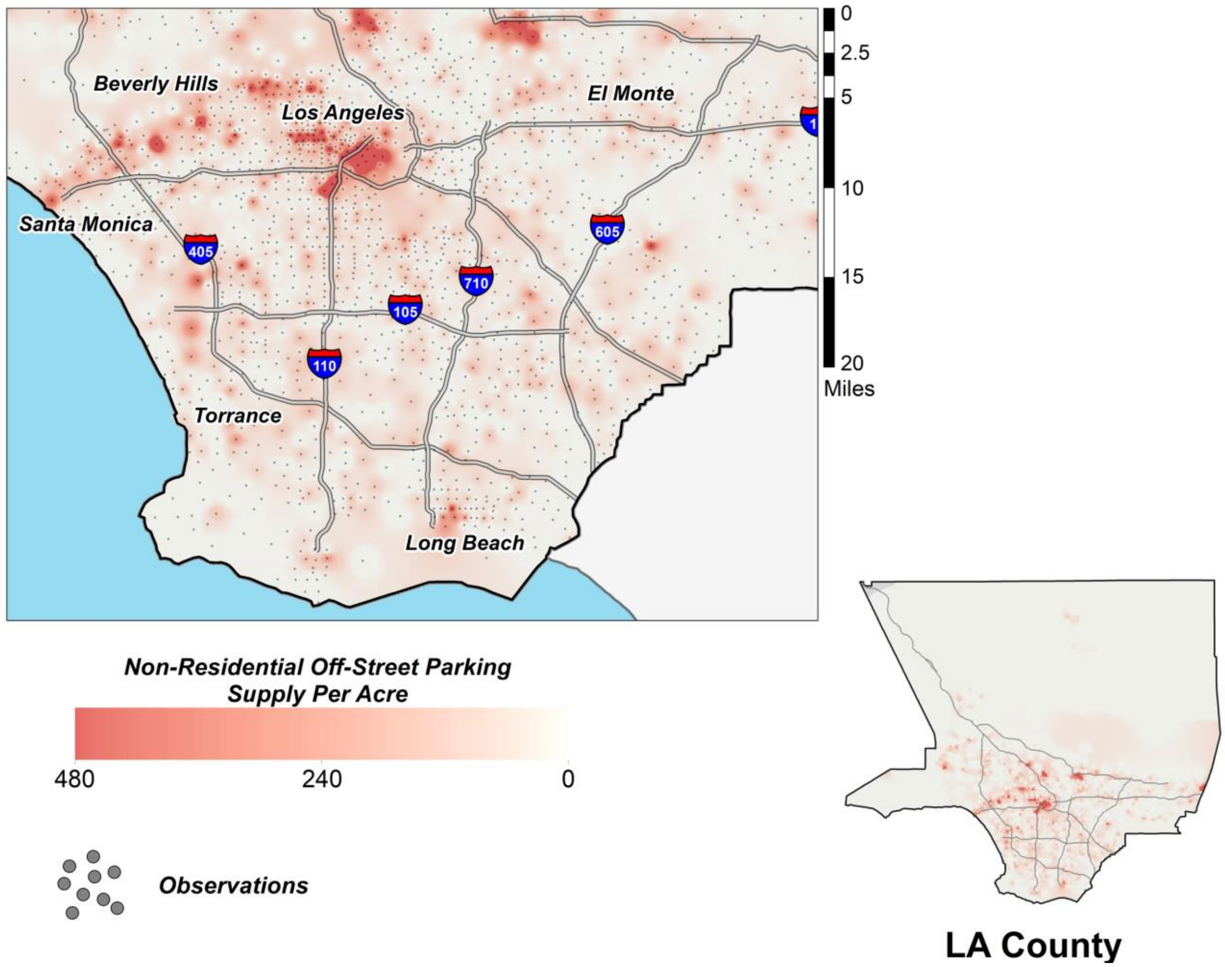

Figure 6: Minimum Parking Regulation Cost: Lowess Curves by Land Value and Property Size