Do Parking Requirements Significantly Increase The Area Dedicated To Parking? A Test Of The Effect Of Parking Requirements Values In Los Angeles County

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Do Parking Requirements Significantly Increase The Area Dedicated To Parking? A Test Of The Effect Of Parking Requirements Values In Los Angeles County.

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Minimum parking requirements are the norm for urban and suburban development in the United States (Davidson and Dolnick (2002)). The justification for parking space requirements is that overflow parking will occupy nearby street or off-street parking. Shoup (1999) and Willson (1995) provides cases where there is reason to believe that parking space requirements have forced parcel developers to place more parking than they would in the absence of parking requirements. If the effect of parking minimums is to significantly increase the land area devoted to parking, then the increase in impervious surfaces would likely cause water quality degradation, increased flooding, and decreased groundwater recharge. However, to our knowledge the existing literature does not test the effect of parking minimums on the amount of lot space devoted to parking beyond a few case studies. This paper tests the hypothesis that parking space requirements cause an oversupply of parking by examining the implicit marginal value of land allocated to parking spaces. This is an indirect test of the effects of parking requirements that is similar to Glaeser and Gyourko (2003). A simple theoretical model shows that the marginal value of additional parking to the sale price should be equal to the cost of land plus the cost of parking construction. We estimate the marginal values of parking and lot area with spatial methods using a large data set from the Los Angeles area non-residential property sales and find that for most of the property types the marginal value of parking is significantly below that of the parcel area. This evidence supports the contention that minimum parking requirements significantly increase the amount of parcel area devoted to parking.

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1. Introduction

Most cities in the US have parking standards which require developers to provide a minimum amount of off-street parking per square foot of floor space.[4] These minimum parking requirements are usually set by city planners from standardized transportation planning manuals, which typically measure parking and trip generation rates at peak periods with ample free parking and no public transit. The goal of Minimum Parking Requirements (MPRs) is to ensure adequate parking at a low price in order to limit local congestion and to stimulate local business (Shoup (1999)).

Minimum parking requirements have been criticized due to their land and transportation market distortions. Opponents of MPRs (Shoup (1999, 2005), Willson (1995)) argue that these parking standards create an oversupply of parking in most urban areas which decreases the cost (direct and time) of parking and therefore encourages more automobile trips (Shoup (1999, 2005), Shoup and Pickrell (1978)). In addition, critics allege that minimum parking requirements force developers to use more land space per square foot of building construction and make development in areas where land has a high value much more expensive and less profitable (Willson (1995)). As a result, minimum parking requirements influence the location of new development, make infill projects and historic building retrofits less attractive and feasible (Shoup and Pickrell (1978)) and contribute to the sprawling of impervious parking surface at the expense of the environment (Feitelson and Rotem (2004)) and urban design (Mukhija and Shoup (2006)). However, the previous debate does not consider other factors that may interact with MPRs such as Floor-Area-Ratio (FAR) restrictions.

The purposes of this paper are twofold. First, we develop an analytical model of building construction that includes MPRs, FAR restrictions and endogenous decision-making over surface versus below-ground parking. This theoretical model allows us to formally examine the impacts of minimum parking requirements on development density, parking external costs and amount of parking supplied, adding to a small analytical literature on this regulation. And second, we test the hypothesis that parking requirements cause an oversupply of parking using data on commercial and industrial, and retail property sales from Los Angeles County.

Even though parking requirements are intensely debated in urban and transport planning arenas, little effort has been devoted to the theoretical analysis of this instrument. The only analytical studies are by Shoup and Pickrell (1978) and Feitelson and Rotem (2004). Both studies

[4] For example, the zoning ordinance for Wilshire Boulevard in Los Angeles requires three parking spaces per 1,000 square feet of gross floor area for office buildings and other commercial uses (Shoup (2002)).

use graphical analysis to discuss the impacts of minimum parking requirements on parking price and quantity. Shoup and Pickrell (1978) focus their graphical discussion on how minimum parking requirements may affect the development of parking submarkets. They argue that if parking requirements are uniform throughout a jurisdiction while demand and supply vary by location, the requirements may force an increase in the total amount of parking provided but also an inefficient allocation of parking across space. Feitelson and Rotem (2004) focus their graphical discussion on the external costs of surface parking. The authors argue that even without minimum parking requirements, developers will oversupply parking because of the direct environmental negative externalities and the indirect sprawl-inducement externalities.

One of the advantages of constructing a theoretical model that captures the essence of the problems associated with minimum parking requirements is that such a model can develop and support hypothesis that we can test empirically. Moreover, it also may provide useful insights beyond those provided by earlier papers. For example, parking requirements can influence building density, but may not always be the largest barrier to density. Zoning conditions, in particular FAR restrictions may be a larger barrier in certain cases.

Thus, in contrast to Shoup and Pickrell (1978) and Feitelson and Rotem (2004), we develop a theoretical framework where we model separately the behavior of city center developers and suburban developers and where parking and floor space are bundled and rented as a package to tenants of a building. Both types of developers maximize profits. We extend previous analyses by considering two types of parking structures: underground parking or surface parking. [5] In our model surface parking also generates negative external costs.[6] Another feature of our model is the presence of a floor-to-area (FAR) restriction. Within this model we examine not only the impact of MPRs on total parking supplied but also on the supply of different types of parking (surface and underground), building square footage and level of parking externality.

Our analytical results show that surface parking is more efficient if the price of land is relatively low. For a sufficiently high price of land, the developer provides underground parking instead of surface parking. Because parking space is capitalized into rents, this will encourage developers to voluntarily supply parking space whenever the resulting revenue will cover its costs, even in the absence of parking requirements. Because developers do not take into account

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[5] We realize that there are also above-ground structure parking that is an intermediate choice between underground and surface parking, but we believe that the underground and surface parking captures the essential elements of the developer's parking choice problem.

[6] The imperviousness of surface parking areas leads to water pollution, storm water flooding and reduces the amount of open space available for recreation and for ecosystem services. Surface parking lots are also often unsightly and thus have deleterious visual effects. Finally, such areas contribute to the formation of the urban heat island, as they are likely to affect temperatures in their immediate vicinity.

parking external costs, developers will oversupply parking in an unregulated market. The main effects of MPRs are that parking spaces will be priced below the cost of providing them and the external costs associated with surface parking will be exacerbated because MPRs exacerbate the market oversupply of parking. In addition, MPRs constitute an indirect tax on building square footage which creates a disincentive to high-density development. In particular, minimum parking requirements may drive the total square footage allowed and potentially inhibit density below what a FAR limit permits. [7] However, in areas with stringent limits on building height and where parking can feasibly be provided, our analytic results suggest that FAR limits may be a more important constraint on densities.

Parking lots occupy a significant proportion of the built cover in many urban and suburban areas. Ferguson (2005) estimates that in multi-family areas parking lots comprise about 30% of the built cover and in commercial areas parking lots comprise about 60% of the built cover. Increases in impermeable surfaces such as parking have important environmental consequences because impermeable surfaces are thought to cause a variety of environmental, mainly water-related externalities (Arnold and Gibbons (1996)). If the effect of parking minimums is to significantly increase the land area devoted to parking, the increase in impervious surfaces would likely cause water quality degradation, increased flooding, and decreased groundwater recharge.[8] Thus, knowledge of whether or not MPRs are binding is important information.

Shoup (1999) and Willson (1995) provide cases 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. However, we are not aware of any broad based empirical evidence that tests whether it appears that developers are placing significantly more parking on their land than they would in the absence of parking requirements. In addition, to our knowledge there is also no study that examines which land use categories are most affected by minimum parking requirements.

In this paper we test the hypothesis that parking space requirements cause an oversupply of parking using both direct and indirect approaches. Our direct test compares actual versus required parking for a subsample of our data where we are able to approximate MPRs for the property.

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[7] This could occur whenever the amount of parking is constrained for example due to site geometry (size and shape) and/or inconvenient site topography (slopes and poor soil conditions) which substantially increase parking costs.

[8] Impervious surfaces decrease infiltration of rainfall into the soil and increase the volume and speed of surface runoff (Arnold and Gibbons (1996)). Increased impervious coverage leads to less groundwater recharge, increased erosion, destruction of stream habitat, and increased transport of pollutants. Impervious surfaces also quickly transport pollutants such as trash, toxics, and nutrients to water bodies (Arnold and Gibbons (1996)). Impervious surfaces therefore are a significant cause of the non-point source water pollution that the Environmental Protection Agency (1994) now believes is the largest remaining source of water quality problems.

Our indirect approach uses the gap between the marginal parking space costs and the marginal value of an additional parking space to the sale price to measure the extent of oversupply of parking. Based on our analytical results, this gap should be zero whenever MPRs are not binding. Therefore, if MPRs bind this wedge should be positive. Our indirect test is thus very similar to Glaeser and Gyourko (2002) who use the gap between real estate prices and the costs of producing a marginal apartment to measure the distortions in the housing market caused by zoning restrictions on new construction.[9]

We estimate the marginal values of parking and lot area with spatial and non-spatial methods from Los Angeles area non-residential property sales. The data encompass a wide variety of industrial, service shopping and general retail properties, and office properties from 1997-2005. We use a spatial hedonic approach that includes property and locational characteristics and various controls for spatial dependence.

Significant work has been done using hedonic methods to examine how various attributes affect the sale price of non-residential parcels. Most of this work relates to the determinants of commercial property sale indices.[10] This literature considers a variety of locational, neighborhood, building and parcel characteristics, but we are only aware of one previous study that considers the amount of parking on the property Cutter et al. (forthcoming). In addition, other work attempts to value environmental disamenities by examining whether property prices change in response to the listing or de-listing of hazardous waste sites near a property (Ihlanfeldt et al. (2004)). We use a hedonic approach where parking area, a characteristic that has only been included in Cutter et al. (forthcoming), is one of the characteristics of the property.

Our empirical results find that the marginal value of parking on a lot appears to be significantly less than the value of parcel area in several land-use categories in all specifications. The difference between the marginal parking and property area values is significant and supports

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[9] The authors provide evidence that zoning is in fact constraining the supply of housing in a number of housing markets across the United States.

[10] Some examples are Hodgson (2006) and Colwell (1998). Other empirical studies have examined demand side and supply side influences on office-commercial rents. Clapp (1980) tested the rent-accessibility trade-off using 105 office buildings data in Los Angeles and found significant evidence to support the negative rental function with respects to the distance from the CBD and the commuting time. His results also supported the importance of face-to-face interaction in the CBD. Using a more recent set of office rental data in Greater Los Angeles from the same source, Sivitanidou (1995) again found that the accessibility factors (distance to CBD, distance to airport and number of interstate freeways) are significantly reflected in variations of the office rental function. However, she found that the standard bid-rent function is incomplete in explaining office bid-rent relationships unless other variables like worker amenities, zoning and local institutional control are included in the model. Sivitanidou (1996) shows that office-commercial firms value access to service centers within Los Angeles PMSA (Primary Metropolitan Statistical Area). None of these previous studies examine how parking area influences office-commercial bid rent functions.

the contention that minimum parking space requirements substantially increase the amount of parcel area allocated to parking by developers. Our direct test of whether MPRs bind, which uses a subsample of office properties, shows also that properties tend to have just the minimum parking requirement or somewhat less parking than required.

The plan of the paper is as follows. Section 2 outlines the theoretical model and examines the impacts of minimum parking requirements on the supply of surface parking, supply of underground parking, building density and level of parking externalities. Section 3 develops the empirical model. Section 4 describes our data and variables. Section 5 discusses our parking regulation tests. Section 6 presents the empirical results and discusses their implications and finally, Section 7 offers conclusions.

2. The Analytical Model

This section describes the features of the analytical model we will use to examine the impacts of minimum parking requirements on structural density, amount of land developed and type of parking supplied. We also provide and interpret key equations associated with the developers' problem in the absence and presence of minimum parking requirements. Complete derivations are provided in Appendix A.

2.1. Model Assumptions

Office-Commercial Rents

Suppose that the office-commercial-space bid rent in a given location is represented by:[11]

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

where, B is the office-commercial rent per unit of floor space, N is total parking spaces and A represents a vector of amenities associated with the location.[12] Because we focus on a single location the value of A is fixed. We assume that (1) is concave in its arguments.

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[11] The office-commercial bid rent represents the maximum willingness-to-pay by a firm for commercial-office space in a building at particular location within the city. In this paper we focus on the behavior of developers and therefore, we do not derive analytically equation (1). However, a demand model for office space, see for example Sivitanidou and Wheaton (1992), would suggest that the quantity demanded is a function of rent, a firm's output, and the amount of office space it uses per worker. If the output market is competitive, in the long-run a firm's profit is zero. From this latter condition we can thus determine the equilibrium rent per unit of floor space (1). Moreover, for simplicity, we assume that bid rents reflect prevailing market prices for office floor space, so that the two are synonymous. Thus, the price of an office building would be the product of the bid-rent and total office floor space.

[12] Building characteristics can influence the bid rent for office-commercial space at a particular location. Rents are higher for buildings with greater total square footage, more floors and parking space. A higher total square footage may be also indicative of building amenities (e.g. restaurants), face-to-face agglomeration economies or shopping externalities. Office-commercial bid rents are also influenced by locational factors such access to the central business

Parking space can take two forms: surface parking and underground parking. Surface parking refers to lots directly on land and underground parking consists of structured parking under multi-story buildings. [13] Both forms are assumed to be perfect substitutes from the tenants' perspective and therefore, total parking spaces are represented by:

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

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

Building Technology

Office-commercial floor space is produced according to a strictly concave, constant-returns production function, $H = f(K, L)$, where K is capital used to produce floor space and L is the amount of land physically covered by K (referred to subsequently as "covered land"). The intensive form of this production function is written as $h(S)$, where S is capital per unit of covered land or structural density and h satisfies $h' > 0$ and $h^{//} < 0$. $h(S)$ represents office-commercial total floor space per unit of covered land. We assume that L is fixed.

Parking Costs

Parking costs differ depending on the type of parking facility provided. Construction costs (excluding land) per space of surface parking are higher than the construction costs per space for underground parking (Hunnicutt (1982)).[14] However, surface parking precludes alternative uses of land and hence its total costs are the sum of total construction costs and land costs ($C_s(N_s)$):

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

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

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district, access to surface and air transportation (freeways and major airports), access to good schools and level of crime. For empirical evidence on the determinants of office-commercial bid rents see Sivitanidou (1995) and Bollinger (1998).

[13] Other types of parking facilities include on-street parking, off-street parking and structured parking in multistory buildings. On-street parking consists of parking lanes provided within public road rights-of-way. Off-street parking are parking facilities on their own land, not on road rights-of-way. Structured parking (also called parkades or ramps) are parking facilities in or under multistory buildings. It is not uncommon to find structured parking in downtown areas since land costs are very high. For simplicity we only analyze the cases of surface and underground parking (structured parking under multi-story buildings). However, our results on underground parking can also be extended to other types of structured parking.

[14] Construction costs (excluding land) average about $1,600 per space for surface parking and $20,000 or more per space for underground parking (Hunnicutt (1982)).

We assume that no additional land is necessary for underground parking since it will be built below the office-commercial building. Therefore, total costs for underground parking reflects mainly its construction costs:

$$C_u(N_u, S) = N_u p_k K(N_u, S) \tag{4}$$

where $K(N_u)$ is the capital cost requirement per underground parking space and is assumed to be a convex function with $\frac{\partial^2 K(N_u, S)}{\partial N_u \partial S} > 0$. The reason is because as more underground parking is added more units of capital are necessary to fortify the building structure and to provide vertical-transportation requirements.

Surface Parking Externalities

Surface parking generates multiple environmental externalities. Let L_S be the amount of impervious land due to surface parking and $E(L_s)$ denote the external costs associated with impervious surfaces. We assume that $E(L_s)$ is linear in the amount of land allocated to surface parking:

$$E(L_s) = eL_s \tag{5}$$

where $e > 0$ is the unit of land external cost and $L_s = N_s \bar{l}$.

Parking Requirements

The city government imposes a minimum parking requirement expressed as numbers of parking spaces per square foot of gross building floor area:

$$N \geq aLh(S) \tag{6}$$

where $0 < a < 1$ is a parameter imposed by the city government.[15]

Floor-Area-Ratio (FAR) restrictions

There is also an upper limit on the square footage of office-commercial space per unit of land such that:

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[15] Note that *H(K,L)=Lh(S)*. Since *H(K,L)* is concave and homogenous of degree 1we have 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.

$$h(S) \leq \hat{h}(\hat{S}) \tag{7}$$

where $\hat{h}$ is the FAR limit per unit of land and $\hat{S}$ is the total structural density associated with $\hat{h}$.

2.2 Type of parking provided

Differentiating (1) with respect to N_s and N_u, yields the same marginal benefit for both types of parking spaces:

$$\frac{\partial B(N,A)}{\partial N}\frac{\partial N}{\partial N_s} = \frac{\partial B(N,A)}{\partial N}\frac{\partial N}{\partial N_u} \tag{8}$$

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

$$p_k \overline{K} + p_k N_u \frac{\partial K(N_u, S)}{\partial N_u} \tag{9}$$

The first component of (9) 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 (9) is the inframarginal cost associated with the additional underground space. Note that the marginal cost of underground parking increases with the height of the building because of the costs of providing vertical transport and supporting a heavier building.

The private marginal cost per space of surface parking is given by:

$$p_k \overline{K} + p_l \bar{l} \tag{10}$$

The first component of (10) is the marginal cost for the additional surface parking space and the second component is the marginal cost of land. In contrast to (9), the marginal cost of surface parking is constant and thus, it does not vary with the amount of parking space.

Comparing (9) and (10), 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:

$$p_k N_u \frac{\partial K(N_u, S)}{\partial N_u} > p_l \bar{l} \tag{11}$$

Equation (11) suggests that surface parking is more efficient if the price of land is relatively low.[16] For a sufficiently high price of land, the developer provides underground parking instead

[16] Structured parking typically becomes cost effective when land prices exceed about $1 million per acre.

of surface parking.[17] Given that land prices are typically very high in downtown areas, it is not surprising that most parking bundled with office-commercial development in Central Business Districts (CBD) is structured parking. In contrast, low-density office-commercial structures with large surface parking lots such as shopping malls are mostly found in suburban areas where the price of land is lower.

Next we specify the developer's problem separately for the suburbs and the central city. Given the preceding discussion, we assume that CBD developers provide underground parking and suburban developers provide surface parking.

2.3. Central Business District (CBD)

The developer's problem in the central city is to choose the level of structural density and number of underground parking spaces that maximize his profits per unit of covered land taking into account the FAR restriction and Minimum Parking Requirements (MPRs):[18]

$$\begin{aligned} &\underset{N_u,S}{Max}\, B(N_u, A)h(S) - p_k S - p_l - p_k N_u K(N_u, S) \\ &s.t. \quad \begin{aligned} &h(S) \le h(\hat{S}) \\ &N_u \ge aLh(S) \end{aligned} \end{aligned} \tag{12}$$

For the sake of expository convenience, we represent the Kuhn-Tucker conditions for an interior solution for problem (12) in Table 1, where λ_1 is the shadow price associated with the FAR constraint and λ_2 is the shadow price associated with the MPR constraint.[19] All the first-order conditions are evaluated at the optimum levels. For full details see Appendix A.

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[17] If the marginal benefit of underground parking exceeds the marginal benefit of surface parking because of differences in the costs and speeds of walking and elevator travel, then the developer may provide underground parking even if the price of land is relatively low:

$$\frac{\partial B}{\partial N} h(S)\left[\frac{\partial N}{\partial N_u} - \frac{\partial N}{\partial N_s}\right] > p_k N_u \frac{\partial K(N_u, S)}{\partial N_u} - p_l \bar{l}$$

If $\frac{\partial N}{\partial N_u} - \frac{\partial N}{\partial N_s}$ is large enough to offset the diminishing marginal returns from underground parking, then underground parking will be provided. Note also that a developer could choose a combination of surface and underground parking spaces that minimizes total costs of providing parking spaces. However, in this paper we focus only on boundary solutions and we assume that a developer can only provide underground or surface parking spaces, but not both types.

[18] Equation (12) also 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.

[19] This shadow price (the Lagrange multiplier) provides a measure of how a relaxation in the constraint will affect the developer's profit per unit of covered land. Thus, a high value of λ_i indicates that the profit per

There are three main conclusions that we can take upon examining table 1. First, because parking is capitalized into office-commercial rents, this will encourage developers to voluntarily supply parking whenever the resulting revenue will cover its costs, even in the absence of MPRs (($\lambda_1 = 0, \lambda_2 = 0$) and ($\lambda_1 > 0, \lambda_2 = 0$)). If the price of additional underground parking ($\frac{\partial B(N_u^*, A)}{\partial N_u} h(S^*)$) is at or above the marginal cost of providing it ($\frac{\partial C_u(N_u^*, S^*)}{\partial N_u}$), there is no reason why developers would not provide it on their own in downtown areas ($N_u^* > 0$). Thus, even in the absence of MPRs, developers can offer a bundle of (parking spaces, floor space) as a strategy to maximize profits. The main effects of MPRs (see both cases where $\lambda_2 > 0$) are that parking spaces will be priced below the cost of providing them (for example $\frac{\partial C_u(N_u^{mpr}, S^{mpr})}{\partial N_u} > \frac{\partial B(N_u^{mpr}, A)}{\partial N_u} h(S^{mpr})$) and total supply of parking will be above its market determined equilibrium level ($N_u^{mpr} > N_u^*$).

Second, parking requirements may also cause serious problems in the office-commercial floor space market. When MPRs bind ($\lambda_2 > 0$), the excess underground parking results in a deficit for the developer of a new building. This induced deficit constitutes an indirect tax on building square footage ($\frac{\lambda_2 L}{N_u^{mpr}} \frac{\partial h(S^{mpr})}{\partial S} > 0$). As a result, this creates a disincentive to high-density development ($S^* > S^{mpr}$) because it imposes an extra wedge between the marginal revenue gain from additional building square footage ($B(N_u^{mpr}, \overline{q}, A) \frac{\partial h(S^{mpr})}{\partial S}$) and the marginal construction costs ($p_k + \frac{\partial C_u(N_u, \hat{S})}{\partial S}$). Since the marginal cost of providing more parking spaces at a site usually increases dramatically for underground structures ($\frac{\partial^2 C_u(N_u, S)}{\partial N_u^2} > 0, \frac{\partial^2 C_u(N_u, S)}{\partial N_u \partial S} > 0$), this parking tax is also higher for larger buildings.

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unit of land could be increased substantially by relaxing the constraint. In contrast, a low value of λ_i indicates that there is not much to be gained by relaxing the constraint. When $\lambda_i = 0$, the constraint is not binding.

Finally, FAR restrictions also constitute a tax on building square footage which leads to building heights smaller than those in unconstrained markets ($S^* > S^{FAR}$). Based on current construction costs, a developer might want to build a taller structure than allowed by density controls and provide the requisite parking in order to maximize returns, even in the absence of parking requirements ($\lambda_1 > 0$, $\lambda_2 = 0$).

Minimum parking requirements may nevertheless drive the total square footage allowed and potentially inhibit density below what the FAR limit permits, in particular when the amount of parking is constrained due to site geometry (size and shape) and site topography (slopes and poor soil conditions). Site geometry and site topology may make the required parking not physically fit on to a site and increase substantially parking costs and thus, λ_2. In this situation $\lambda_1^{FAR} \frac{\partial h(\hat{S})}{\partial S}$ may be smaller than $\frac{\lambda_2^{mpr} L}{N_u^{mpr}} \frac{\partial h(S^{mpr})}{\partial S}$ and thus, $\hat{S} > S^{mpr}$. However, in areas with stringent limits on building height and where parking can feasibly be provided underground, parking requirements may not be the greatest constraint on densities. When both regulatory restrictions bind ($\lambda_1 = 0$, $\lambda_2 = 0$) they reinforce each other and it may be the case that the FAR limit pushes densities further down than MPR.

Our results thus show that minimum parking requirements have counterproductive results in downtown areas because they try to solve a problem in the transportation market that is only indirectly related to the office-commercial floor space market. Because minimum parking requirements increase the costs of new development, these minimum standards tend to decrease the potential office-commercial density of new projects which is counter the objective of most cities to promote downtown density to increase agglomeration economies and control for urban sprawl. In addition, minimum parking requirements may also counteract other local policies designed to encourage development in areas easily accessible by public transit as well as compromise the feasibility of mass-transit investments in certain downtown areas.

2.4. Suburban Areas

The developer’s problem in the suburbs is to choose the level of structural density and number of surface parking spaces that maximizes his profits per unit of land covered taking into account the FAR restriction and Minimum Parking Requirements (MPRs):

$$\begin{aligned}&\underset{N_S,S}{Max}\, B(N_S, A)h(S) - p_k S - p_l - \frac{N_s}{L}(p_l \bar{l} + p_k \overline{K}) \\ &s.t. \quad \begin{aligned} &h(S) \le h(\hat{S}) \\ &N_S \ge aLh(S) \end{aligned}\end{aligned} \tag{13}$$

Since the capital-to-land ratio tends to decrease with distance from a CBD, it follows that a FAR restriction will bind in the central part of a city, where the capital-to-land ratio would normally be high, being nonbinding farther from the center. Thus, we focus our discussion on the cases where only the MPR restriction is binding. The Kuhn-Tucker conditions for an interior solution for problem (13) when the FAR restriction is not binding are presented in Table 2. Again, λ_1 represents the shadow price associated with the FAR constraint and λ_2 is the shadow price associated with the MPR constraint. All first order conditions are evaluated at the optimum. For full details see Appendix A.

Upon examining Table 2, it is clear that whenever private decisions do not take into account the externalities associated with impervious surface, too much surface parking is provided in the suburbs even in the absence of MPR. The socially optimal number of surface parking spaces maximizes $\pi_s + \frac{eN_s \bar{l}}{L}$, where π_s are profits per unit of land covered. The first order condition for the social optimal surface parking spaces, N_s^o, is given by:

$$\frac{\partial B(N_s, A)}{\partial N_s} h(S) = \frac{(p_l + e)\bar{l} + p_k \overline{K}}{L} \tag{14}$$

Comparing (14) and the first order condition in absence of regulatory constraints ($\lambda_1 = 0$ and $\lambda_2 = 0$) one notices that because of the negative externalities associated with impervious surface, the social marginal cost of surface parking ($\frac{(p_l + e)\bar{l} + p_k \overline{K}}{L}$) is higher than the private marginal cost ($\frac{p_l \bar{l} + p_k \overline{K}}{L}$). As a result, the socially efficient amount of land in surface parking ($\bar{l}N_s^o$) is less than the privately optimal amount ($\bar{l}N_s^*$). Thus, if left to the market the supply of surface parking is likely to be excessive.[20] Not only are socially beneficial uses of surface parking

[20] Government can encourage the social amount of both surface and underground parking through the imposition of a Pigouvian tax, where the magnitude of the tax is set equal to the marginal external effect at the efficient allocation. This would require imposition of a per unit tax on surface parking, where the magnitude of the tax is set equal to the dollar value of the environmental external costs. Alternatively, the government can also set a maximum parking requirement for surface parking, where the requirement would be equal to the social optimum.

land foregone, but because land is paved, it also increases storm water runoff and has other negative environmental impacts.

In the context of the monocentric city model, the spatial area of the city can be found by adding total land in office-commercial use and total land in surface parking. Given that $\bar{l}N_S^o < \bar{l}N_S^*$ the market equilibrium is characterized by inefficient spatial expansion of the urban area, providing a basis also for criticism of urban sprawl.[21]

Like in downtown areas, MPRs also enforce an oversupply of parking in suburban areas ($N_S^{mpr} > N_S^*$) which, intensifies the external costs associated with impervious surface coverage: $e\bar{l}N_s^{mpr} > e\bar{l}N_s^* > e\bar{l}N_s^o$. Because minimum parking requirements increase the cost of development, densities are also lower in suburban areas compared to the unconstraint market outcome ($S^* > S^{mpr}$).

Note that in equilibrium, the shadow price associated with the MPRs satisfies:

$$\left[p_l \bar{l} + p_k \overline{K} - \frac{\partial B(N_S^{mpr}, A)}{\partial N_S} Lh(S^{mpr}) \right] a^2 h(S^{mpr}) = \lambda_2^{mpr} \tag{15}$$

From (15) land uses that have higher parking requirements such as retail versus warehouses and thus have a higher value of a, are expected to have also a higher shadow price, λ_2.

2.5. Testable Hypothesis

The predicted theoretical relationships between marginal parking use value, marginal land value, and marginal building area value give us the testable hypotheses for the empirical portion of the paper. If MPRs do not bind, then the marginal value of parking should be equal to the marginal value of additional land plus marginal parking construction costs. If the parking constraints do bind, then the marginal parking use value should be less than the land value plus construction costs. With proper data, we can thus estimate the shadow price associated with MPR and make inferences about the underlying equilibrium. For example, in the case of surface parking, the shadow price can be calculated with equation (15). Calculating the extensive margin value of land is simple once we have the construction cost data and the parking requirements data. However, the additional value of a property from adding an additional parking space cannot be calculated explicitly. It must be inferred using hedonic regression techniques to estimate the marginal contribution of each type of parking space to the price of the office-commercial building.

[21] Other causes of urban sprawl can be found in Brueckner (2000) and Bento et al. (2006).

Our model also implies that the marginal revenue from additional building area should equal marginal construction costs in the absence of binding parking requirements, but be greater than marginal construction costs if parking constraints bind. We do not test this second hypothesis in the present version of this paper, but may examine it in the future.

3. The Empirical Model

The empirical part of this paper focuses on the office-commercial-industrial property market within suburban areas of Los Angeles and on surface parking lots. The suburban market was chosen because, as our analytical results suggest, in downtown areas FAR restrictions are likely to bind which in turn can influence development density and the amount of land allocated to surface parking and parking density per acre.[22] Moreover, surface parking in downtown LA also results from a speculative decision process. Therefore, isolating the effect of MPR on the amount of land allocated to parking in the central area of LA may be tricky. In further research we hope to investigate the claims by critics that parking restrictions in fact prevent developers from attaining the maximum FAR. In addition, our analytical results also suggest that surface parking is more efficient if the price of land is relatively low. Given that land prices are typically lower in the suburbs compared to downtown areas it is not surprising that most surface parking occurs in the outskirts of the city.

We estimate the marginal values of parking and lot area with spatial and non-spatial methods from Los Angeles area non-residential property sales. In order to simulate the marginal on-site parking and parcel values we estimate a spatial error model for different land-use categories because, as shown in section 5.1, average parking regulatory stringency differs by property type.[23]

3.1. Hedonic Price Model[24]

The bid-rent function given by (1) is the starting point for our hedonic price function specification. This equation implies that office-commercial buildings can largely be considered as bundles of attributes that cannot easily be repackaged to suit individual preferences. The

[22] In some cases, zoning regulations include bonus programs that permit developers to exceed the base maximum FAR if they include certain amenities such as affordable housing.

[23] All spatial regressions were estimated using the Spatial Econometrics Package from James P. LeSage (http://www.spatial-econometrics.com).

[24] This section is largely similar to the same section in Cutter et al. (forthcoming).

attributes typically evaluated by buyers in the housing market include not only structural characteristics of the properties, but also neighborhood attributes linked to the properties.[25]

We use specifications of the following form in our hedonic price regression:

$$LP_{it} = \beta_0 + \sum_{j=1}^{J} \beta_j LX_{ijt} + \sum_{j=1}^{J} \delta_j D_{ij} + \sum_{t=1}^{T} \alpha_t Y_t + \varepsilon_i \qquad (16)$$

In (16) LP_{it} represents the log of the sale price of property i at time t, $t = 1997 - 2005$. X_{ijt} is a vector containing j continuous property characteristics of property i in time t, and $D_{i,j}$ are j binary property characteristics of property i.[26] Y_t is a dummy variable indicating the year the property was last sold. β_0 is the intercept regression coefficient and β_j, δ_j and α_t represent the regression coefficients associated with the explanatory variables. The error term is ε_i, and it is assumed to be normally distributed with constant variance. Note that our logarithmic form is an approximation to the nonlinearities usually involved in the solution of models such as the one presented in section 2.

3.2. Spatial Error Models

Spatial econometric techniques are now common in estimating the determinants of property prices because of the likelihood of unobserved spatial relationships. This is because nearby properties are likely to have similar unobservable characteristics (Bell and Bockstael (2000), Ihlanfeldt and Taylor (2004)). As a result, inference based on t-statistics will be misleading. The spatial econometric literature has focused on two different types of spatial dependence: correlation and spatial lag (LeSage, (1999)). Thus, we first estimate the joint spatial model that accounts for both types of spatial dependence:

$$\varepsilon = \rho W_1 \, LP + \lambda W_2 e + u \qquad (17)$$

where ρ measures the degree of spatial autocorrelation, W_1 is a nearest-neighbor spatial weighting matrix, LP is the vector of property prices, λ is a scalar measuring the degree of spatial correlation, W_2 is an inverse-distance weighting matrix, and e and u are i.i.d disturbances. If ρ is significant, then the non-spatial estimate will generally be biased. Therefore, it is important to test

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[25] Neighborhood attributes may include physical characteristics of the neighborhood, the socio-economic characteristics of the local residents, public service provisions, and environmental amenities.

[26] The log transformation of the continuous property characteristics is consistent with past hedonic literature on housing and commercial/retail/industrial properties (Hodgson et al. (2006)). In addition, Cutter et al. (forthcoming) shows that this specification is superior for a similar data set.

for spatial autocorrelation. Not accounting for spatial correlation does not bias coefficients, but does result in inefficient estimation.

3.3. Simulation Methodology

We use property-by-property simulation to calculate the marginal square foot values for on-site parking, building floor area, and parcel area. The estimated hedonic equation is non-linear and each property is at a different location on the hedonic surface. Therefore to estimate the distribution of these marginal values we estimate the values for each property's vector of attributes using the procedure of Krinsky and Robb (1986). This procedure takes a large number of draws from the distribution of the error terms and the joint distribution of the coefficients.

We begin by taking random draws $\overline{\beta}$ from a multivariate normal distribution with variance-covariance matrix $\hat{T}$ and mean $\hat{\beta}$:

$$\overline{\beta} \sim N(\hat{\beta}, \hat{T}) \tag{18}$$

We also draw a vector from the idiosyncratic error distribution:

$$\overline{u} \sim N(0, \sigma^2 I_n) \tag{19}$$

The observation error draw is generated by the following equation:

$$\overline{\varepsilon} = (I_n - \hat{\lambda} W_2)^{-1} \overline{\mu} \tag{20}$$

And a predicted sale price vector is estimated using this draw:

$$\overline{P}_i = \varsigma \exp(\overline{\beta} X + \overline{\varepsilon}_i) \tag{21}$$

where, $\overline{P}_i$ is the predicted price, $\varsigma = n^{-1} \sum_{i=1}^{n} \hat{\varepsilon}_i$ is the "smearing" adjustment for transforming the log price prediction into a consistent linear price estimate, and $X = [Ln(x)\ Y\ D]$ are the observed independent variables.

Next, we calculate a new matrix of independent variables based on adding a small area (denoted δ) to either on-site parking or parcel area and we recalculate our variables, including any interaction terms. This results in a new independent variable matrix, $\tilde{X}$. Then, we calculate a new predicted price based on $\tilde{X}$, $\overline{\beta}$ and $\overline{\mu}$:

$$\overline{\overline{P}}_i = \varsigma \exp(\overline{\beta} \tilde{X} + \overline{\varepsilon}_i) \tag{22}$$

Once we have (22), we calculate a vector of the price difference per change in area δ for each property:

$$D_i = \frac{\overline{\overline{P_i}} - \overline{P_i}}{\delta} \tag{23}$$

Finally, we repeat this procedure with 1,000 draws from the distributions of $\overline{\beta}$ and $\overline{\mu}$ and take the average over each D_i vectors as the mean marginal value for the change in area for property i. We use this procedure to approximate the mean and distribution of marginal values for parcel area and on-site parking area.

4. Minimum Parking Requirements, Data and Variables

4.1. Minimum Parking Requirements

The minimum parking requirements for cities in the Los Angeles area are Byzantine in their complexity.[27] Parking requirements can differ significantly across property types that would seem similar to the uninitiated. The basis also can differ. Many requirements are expressed as numbers of parking spaces per square foot of gross building floor area, but other depend on adjusted gross area, number of employees, number of seats in a restaurant, and other more complex ratios. In addition, cities often have different zones where different parking requirements apply. For all these reasons, a direct approach to estimating the effect of parking minimums on the amount of parking space, such as regressing parking area on the parking minimum and controls, faces serious obstacles because it would be very difficult to know which set of parking minimums apply to a property. This is the main reason we propose the indirect approach in this paper.

However, it is still useful to compare the results in the latter portion of this paper to a summary measure of parking requirements. Shoup (2005) states that many municipalities rely on the Institute of Transportation Engineers (ITE) parking generation rate studies, and in particular their maximum generation rate, to set minimum parking standards. We grouped their average generation rates from the ITE (1985) survey into the property use categories we use in this paper (to the degree possible) and took the average maximum parking generation rate, by category. The property categories, in order, were: service retail (restaurants, service stations) at 22.5 parking spaces per day per 1000 square feet of building area; shopping retail (shopping centers) at 3.85; offices at 3.425; general retail at 2.93, and; industrial at 1.80.

[27] For instance, the Santa Monica requirement for health clubs is "1 space per 80 sq. ft. of exercise area, 1 space per each 300 sq. ft. of locker room/sauna/ shower area, plus applicable code requirement for other uses."

4.2. Data Sets

Parcel-level data on non-residential property sales from 1996 through 2005 over a significant portion of Los Angeles County was obtained through Costar Group, a national commercial real estate information provider (www.costar.com). We removed several types of parcels[28] not suitable for the analysis and data with missing variables. In addition, we removed parcels whose characteristics indicated that they contained parking structures, including any parcels where building and parking area combined amounted to more than 110% of parcel space and any parcels where the property notes indicated underground parking or a parking structure. The remaining data fit the definition of suburban properties given in the analytical section. This means that our data may understate the impact of parking regulations because we do not include properties in denser areas where the shadow cost of parking restrictions may be higher.

The database contains the sales price of each property and a vector of structural characteristics (such as building square footage, parking lot spaces, and property code) and a vector of location characteristics (such as zip code, geographic zone, latitude, and longitude). We joined this data to information on median residential sale price by zip code for the years covered by the property sales. In order to put our parking space measure in the same units (square feet) as our other property area characteristics, we use an estimate of 350 square feet per space from a local parking expert (personal communication, Willson, 4/06/06), which includes all lanes, medians, etc., that accompany spaces.[29] For robustness we also use a value of 300 square feet per space as a lower end estimate and re-estimate all specifications and simulations with that value (we do not use an upper end value because that would only strengthen the conclusions of the paper).

The initial database assigned each observation as one of three general land use types: industrial, office or retail. We divided the large number of retail properties into service, shopping, and general retail which resulted in five broad property categories (see Table 3).[30] We used Los Angeles County local roll parcel data that contains the information on every parcel

[28] Parking, public facilities, residential, heavy industrial, industrial park, pleasure retail, retail-residential, retail-office, hi-rise-office. We removed categories where there were few observations and where it was not clear how to group them with other categories. Also, we dropped observations from 1996 because there were few observations.

[29] 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 $1/350^{th}$ of a parking space, which is approximately equal to one square foot.

[30] Light industrial and industrial were combined into industrial and office-residential, office-industrial and lo-rise office into the office category. Dummy variables for these subcategories are included in all specifications.

within Los Angeles County with GIS location information to generate the variables used to proxy for off-site parking availability. We first matched the property sales data set to parcels in the Los Angeles County local roll data, and then used GIS techniques to identify all other parcels within a given radius of each sold parcel.

4.3. The variables

The control variables X_{ijt} entering equation (16) are extensive. A complete listing of the variables and their definitions are available in Table 4. Summary statistics for key variables are presented by major land-use category in Table 5. The variables generally fall into two categories: property characteristics and neighborhood characteristics. Briefly, our property characteristics include property area (*pcsqft*), parking area (*park*), total building floor area (*bldg*), and building age (*age*). All size measurements are in square feet. We expect the first three variables to have a positive marginal effect on the sale price, and building age to have a negative marginal effect.

In addition, because demand for parking may increase with building floor area, we include an interaction term between parking and building size, *parkbldg*.[31] We expect this interaction term to have a positive coefficient as a larger building may have a higher demand and value for parking.[32] With the interaction terms the marginal value of parking or total building floor area can only be calculated by taking both coefficients into account.

Also, we control for nearby parking (one-third mile radius as well) in publicly-available lots (*pkgarg)* and nearby parking in private, not publicly available, lots (*pksup)* because the value of on-site parking may be affected by the proximity off-site parking.[33] We expect the coefficients on these variables to be positive as prices should be higher in denser areas and also higher where there is more nearby parking.

Finally, we roughly proxy for underlying land values by including the median house price in the zip code of the property (*logDQprice*) and total building floor area per square foot land area in a one-third mile radius (*ldens)*. We expect the coefficients to be positive.

[31] This interaction is log(*park*)*log(*bldg*).

[32] We also use dummy variables for year, property type, for four general geographic categories (Southwest Los Angeles, West San Fernando, San Gabriel, East San Fernando) and, following Ihlanfeldt and Taylor (2004), we also include a number of building construction and condition categories (see Table 4 for the categories). The full set of regression results is available on request from the authors.

[33] A review of walking distance literature (NJtransit (1994)) finds that most studies show that maximum walking distances are between .25 to .5 miles, with more studies in the .25 range. Therefore we chose one-third of mile as an approximation of walking distance. We also ran the same specifications with a .5 mile radius for *ldens, pkgarg, pksup* and found similar parameter values.

5. Parking Regulation Tests

Parking Regulation Direct Test

For some properties we collected data on current parking requirement and examined directly whether parking requirements appear to be binding. If buildings have the required amount of parking space that suggests the requirement is binding, if they have more parking spaces that suggests the parking requirement does not bind.

Office properties were the only category where we could gather consistent data across cities. Other property types either do not have consistent property categories across cities or have parking requirements that are based on property attributes we do not have data on (seats in a restaurant, for instance). This office dataset is different than the office category in the hedonic regressions because, since we are directly testing whether parking regulation binds, we could examine all office properties. For each of the properties we calculated the number of required parking spaces from the city regulations for thirteen cities with straightforward office parking requirements.[34]

This direct test is suggestive but not definitive for several reasons. First, parking requirements may have been different when the buildings were constructed. Second, zoning classifications for properties can change over time. And third, the office classification in the CoStar data may not correspond with the cities' zoning classification.

Keeping these limitations in mind, we examine the ratio of parking spaces to required spaces. If parking requirements are well enforced, the ratio should not be significantly less than one, though if the costs are as high as the hedonic estimates suggest, then developers will seek and obtain some variances from the parking regulation.[35] If parking requirements bind, the ratio should be equal to one, and if they do not bind the ratio should be greater than one. We examine a null hypothesis that the ratio of actual to required parking space is equal to one versus the alternative that the ratio is greater than one.

Parking Regulation Indirect Test

Equation (15) in the analytic model outlines the basic framework for the indirect test of parking requirements. It is likely that for some properties MPR's bind and the marginal value of

[34] Unfortunately the Los Angeles City requirements are not straightforward and office properties in the city could not be included.
[35] A variance is permission from the city government to depart from the normally applicable building or zoning codes.

additional parking spaces is less than the marginal cost of a parking space, but for other parcels MPRs do not bind:

$$p_l \bar{l} + p_k \overline{K} > \frac{\partial B(N_S^{mpr}, A)}{\partial N_S} Lh(S^{mpr}) \text{ if MPR bind}$$

$$p_l \bar{l} + p_k \overline{K} = \frac{\partial B(N_S^{mpr}, A)}{\partial N_S} Lh(S^{mpr}) \text{ if MPR do not bind} \tag{24}$$

Properties are likely to differ in both their parking requirements and their marginal value of parking. Our estimate of the marginal value of parking and land comes from equation (23). The marginal cost of asphalt paving is around 2.50 a square foot in 2006.[36]

6. Empirical Results

The estimation results are presented in tables 6 and 7 and are briefly discussed below.

Hedonic Price Models

Equation (16) is estimated using sale prices over the period 1997-2005. The length of this period provided a reasonable number of sales for each of the five land-use categories: industrial facilities, service retail buildings, shopping retail buildings, general retail buildings and office buildings. Therefore, we estimated specifications of each property category individually and an overall pooled model.

We estimated models with spatial correlation, spatial correlation and lag terms, and then with spatial correlation and heteroskedasticity. The spatial lag coefficient was insignificant and small in all specifications and the estimated coefficients were similar to the models with spatial correlation alone. We also employed a Bayesian approach for allowing heteroskedasticity (LeSage (1999)). There is evidence of significant heteroskedasticity, but these specifications have very similar coefficients and standard errors to the specifications with spatial correlation alone. Because the spatial correlation control appears to generate similar results as the other spatial models we tested and is less complicated, we present the spatial correlation results. Table 6 reports the coefficient estimates. In addition, the table shows the values of the various test statistics and their corresponding z-values values in parenthesis.

[36] Personal communication with Andy Youngs, California-Nevada Cement Council, 7/06/07.

The high adjusted-R^2 value (i.e. 0.83) is a favorable result for the model. The office, general retail and industrial equations each explain over 79% of the variation in sales prices within each of their respective categories.

The marginal effects of the property attributes are of the expected sign and generally highly significant in the pooled model (all property types). Sales prices are higher for buildings with greater property area. The coefficient on property area (*lpcsqft*) is positive and significant at the 1% level. The coefficient on age (*lage*) is negative and significant at the 1%, as expected. This robust negative effect of age suggests that newness, reflecting quality, is a characteristic also valued in the non-residential market. The coefficients on each of the nearby parking measures (*lpksup and lpkgarg*) are significant as expected and positive at the 1% level. Also, the coefficient on *lDQprice* is significant and positive at the 1% level, again as expected. Finally, the *ldens* coefficient is positive and significant at the 1% level, indicating that, as expected, denser areas have higher property prices. The coefficients are generally consistent across the individual property-type regressions.

The coefficients on *logpark, logbldg,* and *logparkxlogbldg* need to be understood jointly since we are interested in the marginal effect of parking and building, and not so much the individual coefficients. The coefficients on *logpark* and *logbldg* are each negative and significant at the 1% level. However, the marginal effect of parking area and building area are positive over the range of the data because the interaction term *logparkxlogbldg* has a positive coefficient (significant at the 1% level). It is key to include this interaction term because the analytical section predicts that parking should have a higher marginal value the larger the building floor area, ceteris paribus, and the positive coefficient on the interaction term supports this hypothesis.

Parking Regulation Direct Test

For the overall sample the mean ratio of actual to required spaces is .97, indicating that building usually have slightly less parking than required. The 95% confidence interval is [.92, 1]. This is evidence that developers are not building more than the required spaces. However, it does seem curious that they are building less than the required spaces. Shoup (2005) notes that parking regulations spread widely after WWII, so it is possible that the low ratio reflects legacy buildings. Also, more recent buildings are more likely to be under current parking regulations. Therefore, we looked at buildings less than 30 years old. This sub-sample has a ratio of .97 with a 95% confidence interval of [.93, 1.0]. This seems consistent with a binding parking requirement.[37] However, the limited dataset and the various problems with matching current parking requirements to older properties make these results suggestive rather than definitive.

Parking Regulation Indirect Test

Table 7 presents the results for our indirect test. The results suggest that parking requirements are binding for the majority of properties in all of the property classes. We define MPRs as binding for a given property when the estimated value of the left-hand-side (LHS) of Equation (24) is significantly greater than the right-hand-side (RHS) of Equation (24) at the 5% level (two-sided). For all properties (row 1) approximately 88% of properties appear to have binding MPRs. However, this masks significant variation. Industrial properties are estimated to have binding MPRs in about 80% of the cases, while service retail properties have binding MPRs for 99% of the properties.

The scale of the social loss from MPRs is related to the difference between the RHS and LHS of Equation (24), not just whether MPRs bind. The mismatch between the costs and the marginal willingness to pay for parking area suggests that too many resources are being allocated towards the construction of parking spaces. The last two columns of Table 7 give a sense of this mismatch. For all properties, parcel area plus construction costs are approximately \$20/ ft^2 more than the value of parking area. Again, there is significant variation in this difference across property types. For service retail, parcel area is worth approximately \$47/ft^2 more than parking space area. This suggests that the social loss from MPRs in the service retail category is quite large (per area). In contrast, for industrial areas, parcel area is only worth approximately \$5/ ft^2 more than parking space area, which implies that MPRs have comparatively low social cost per area for industrial properties. Our results, thus suggest that reducing parking standards for general retail, service retail and office uses will be a successful strategy in encouraging new development to provide fewer parking space on average. In contrast, a strategy will be less successful for shopping retail and industrial uses, which seem to either have lower standards relative to demand or be less sensitive to minimum parking standards.[38]

The estimated mean marginal land values used to calculate parking costs are somewhat lower than the per square foot land values in the Los Angeles area for vacant land. An analysis (Cutter

[37] However, many buildings have many fewer than the required number of spaces in current regulation. The 25th percentile of actual to required spaces is .72, so 25% of properties have less than 72% of the required spaces. This could either be the result of not having the exact parking requirements at the time of construction or widespread variances allowing less than the MPR. Investigating this anomaly is beyond the scope of the current paper but should be a subject for future research.
[38] For instance big shopping retail tends to want a lot of spaces to deal with the Christmas Rush.

(2008)) shows the value of vacant land zone industrial averaged \$38 ft^2 and vacant land zoned commercial averaged \$98/ ft^2. Because vacant land may not be representative of land values overall, we do not expect the marginal value of land to exactly equal the value of vacant land. However, the analysis of vacant land prices suggests that our land values are conservative and therefore our indirect test of whether MPRs bind is conservative.[39]

If minimum parking requirements force developers to supply parking beyond what the market is willing to pay for, then profit-maximizing developers will try to mitigate the negative effect from parking provisions on profits by economizing for example in space with more compact spots, narrower aisles, and other measures to minimize paved area. In this setting, the 350 ft^2 parking size estimate would be too large for some property types. Therefore, we have also re-estimated the models and simulations using a 300 ft^2 estimate to test the robustness of the results. This is a low-end estimate of the total area per parking space that could be achieved with Los Angeles area parking regulations. In general, the difference between the total parking costs and parking values narrows but not substantially. The estimated percentage of properties where the MPRs bind fall by three percentage points to 85 percent for all properties. Even in this very low parking space size scenario it appears that MPRs bind for a large majority of properties.

Discussion

The statistical results are consistent with parking constraints having a strong effect on land-use decision. It appears that in some property categories, such as service and general retail, individual properties are placing quite a bit more than the profit-maximizing amount of parking. It is nevertheless beyond the scope of this paper to estimate the effect of MPRs on the overall commercial property and parking equilibriums.

The ranking of the marginal value differences is similar to the ranking of the ITE (1985) maximum parking generation rates by property category we discussed in Section 4. The ITE (1985) maximum parking generation rate with by far the highest average value (service retail) is also the property category with the lowest marking parking use value and the greatest difference. This is evidence that the differences in marginal values are related to MPRs.

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[39] One curious result from these regressions is the negative marginal value accorded to parking area in the service retail category. A negative marginal value is plausible if the MPRs are so high that additional parking area adds no value to the lot and there are significant expenses for cleaning, maintenance, and occasional replacement of the parking lot. The negative \$8.69/ ft^2 marginal value could be accounted for by a maintenance and upkeep cost of \$.77/ ft^2 per year. This is plausible since asphalt must be replaced every 10-15 years at a cost of \$2-\$3/ ft^2, and also needs periodic maintenance and cleaning.

We can also test our finding by comparing the direct and indirect tests of whether MPRs bind for office properties. Our direct measure finds that about 72 % of properties are at or below the current MPR for their city. The indirect measure estimates that between 78% and 83% of office properties have binding MPRs. The sample for the direct test is slightly different and includes more properties in built out areas where MPRs are likely binding. However, the comparison suggests that the results reinforce each other. Thus, if the goal of minimum parking requirements is to prevent parking spillover and traffic congestion associated with cruising for on-street parking, our results suggest that MPRs are a blunt and inefficient form of parking management. Other forms of parking pricing that accounts for social externalities can be a superior parking management (Small (1992), Shoup (2004, 2005), Arnott et al. (2005)). For example, Arnott et al. (2005) show that an efficient on-street parking pricing scheme can produce travel time savings from reducing traffic congestion and wasteful cruising-for-parking activity and at the same time raise government revenues which can be used to reduce distortionary taxation.[40]

7. Conclusion

Minimum parking regulation is a pervasive feature of United States land-use practices. Davidson and Dolnick (2002) state that parking planning questions are among the top five queries for the American planning service each year. Authors such as Shoup (1999) and Davidson and Dolnick (2002) have suggested that parking regulation forces developers to place far more parking spots than necessary on their lot. Arnold and Gibbons (1996) detail the destructive environmental effects of excessive impermeable surfaces. Shoup (1999) also suggest that parking regulations may have a dynamic effect where the design requirements of large parking areas render new development pedestrian unfriendly so that more individuals are forced to travel by car.

However, to our knowledge, the evidence that parking requirements increase the amount of parking spaces built is limited to a few case studies. This paper seeks to remedy that by examining whether there is evidence of a parking regulation effect for sold properties in Los

[40] Arnott et al. (2005) also emphasize the need to examine policies that might complement congestion pricing, such as appropriately pricing freight and mass transit; staggering work hours for government employees; encouraging biking and walking; and improving the design of roads and intersections to improve traffic flow. Small (1992) discusses the design of a package of congestion charges and revenue uses that may be more politically feasible and thus, look attractive to most people. The author also discusses the potential amounts and uses of money raised by congestion pricing on all congested freeways and arterials in the five-county Los Angeles region. His numerical calculations of the effects of this package on various individuals confirm that such a package can create net benefits for a wide spectrum of individuals and interest groups.

Angeles. A simple theoretical model of optimal development of a parcel implies that the marginal value of parking should be less (equal) to the marginal value of land for a parcel plus the construction cost of parking in the presence (absence) of binding minimum parking regulations. We test this proposition for a multi-year dataset of sales and for six different property types using a spatial error model. We find that for the majority of properties a null hypothesis of equality between marginal parking and marginal land plus construction costs is rejected at a 5% significance level. This supports the idea that minimum parking requirements significantly affect the amount of parking on a parcel. A direct comparison of required and actual parking spaces for a subset of office properties where we could obtain approximate parking requirements also indicates that parking requirements bind for a majority of properties.

The magnitudes of the differences in the marginal quantities suggest that parking minimum requirements have large effects on the distribution of parcel space between various uses. Further research should examine the quantitative impact of parking minimums on the aggregate amount of parking and impervious space.

This research provides further evidence for the arguments of Shoup (1999) and Willson (1995) that parking minimums significantly distort land-use decisions. In addition, the evidence that, in some cases, parking use value is a small fraction of parcel land value suggests that the efficiency losses from parking minimums may be quite large. However, a full consideration of the optimal level of off-street parking would have to consider the congestion externalities due to lower requirements as well as the environmental benefits of less parking.

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Appendix

Table 1: Kuhn-Tucker conditions for problem (12)

	$\lambda_1 = 0$
$\lambda_2 = 0$	$B(N_u^*, \overline{q}, A)\dfrac{\partial h(S^*)}{\partial S} = p_k + \dfrac{\partial C_u(N_u^*, S^*)}{\partial S}$ $\dfrac{\partial B(N_u^*, \overline{q}, A)}{\partial N_u} h(S^*) = \dfrac{\partial C_u(N_u^*, S^*)}{\partial N_u}$
$\lambda_2 > 0$	$B(N_u^{mpr}, \overline{q}, A)\dfrac{\partial h(S^{mpr})}{\partial S} = p_k + \dfrac{\partial C_u(N_u^{mpr}, S^{mpr})}{\partial S} + \dfrac{\lambda_2^{mpr}}{N_u^{mpr}}\dfrac{\partial h(S^{mpr})}{\partial S}$ $\dfrac{\partial B(N_u^{mpr}, \overline{q}, A)}{\partial N_u} h(S^{mpr}) - \dfrac{\partial C_u(N_u^{mpr}, S^{mpr})}{\partial N_u} = -\lambda_2^{mpr}\dfrac{h(S^{mpr})}{(N_u^{mpr})^2}$ $N_u^{mpr} = ah(S^{mpr})$
	$\lambda_1 > 0$
$\lambda_2 = 0$	$B(N_u^{FAR}, \overline{q}, A)\dfrac{\partial h(\hat{S})}{\partial S} = p_k + \dfrac{\partial C_u(N_u, \hat{S})}{\partial S} + \lambda_1^{FAR}\dfrac{\partial h(\hat{S})}{\partial S}$ $\dfrac{\partial B(N_u^{FAR}, \overline{q}, A)}{\partial N_u} h(\hat{S}) - \dfrac{\partial C_u(N_u^{FAR}, \hat{S})}{\partial N_u} = 0$ $S^{FAR} = \hat{S}$
$\lambda_2 > 0$	$B(N_u^{**}, \overline{q}, A)\dfrac{\partial h(S^{**})}{\partial S} = p_k + \dfrac{\partial C_u(N_u^{**}, S^{**})}{\partial S} + (\dfrac{\lambda_2^{**}}{N_u^{**}} + \lambda_1^{**})\dfrac{\partial h(S^{**})}{\partial S}$ $\dfrac{\partial B(N_u^{**}, \overline{q}, A)}{\partial N_u} h(S^{**}) - \dfrac{\partial C_u(N_u^{**}, S^{**})}{\partial N_u} = -\lambda_2^{**}\dfrac{h(S^{**})}{(N_u^{**})^2}$ $N_u^{**} = ah(S^{**})$ $S^{**} = \hat{S}$

Table 2: Kuhn-Tucker conditions for problem (13)

	$\lambda_1 = 0$
$\lambda_2 = 0$	$B(N_S^*, \bar{q}, A)\dfrac{\partial h(S^*)}{\partial S} = p_k$ $\dfrac{\partial B(N_S^*, \bar{q}, A)}{\partial N_S} h(S^*) = \dfrac{p_l \bar{l} + p_k \overline{K}}{L}$
$\lambda_2 > 0$	$B(N_S^{mpr}, \bar{q}, A)\dfrac{\partial h(S^{mpr})}{\partial S} = p_k + \dfrac{\lambda_2^{mpr}}{N_S^{mpr}} \dfrac{\partial h(S^{mpr})}{\partial S}$ $\dfrac{\partial B(N_S^{mpr}, \bar{q}, A)}{\partial N_S} h(S^{mpr}) - \dfrac{p_l \bar{l} + p_k \overline{K}}{L} = -\lambda_2^{mpr} \dfrac{h(S^{mpr})}{(N_S^{mpr})^2}$ $N_S^{mpr} = ah(S^{mpr})$

Table 3: Property Type Summary.

Property Code	Obs(1997-2005)
Industrial	3,636
Service retail	1,547
Shopping retail	996
General Retail	1,101
Office	1,999
Total	9,279

Table 4: Variable Definitions

Variable name	Definition
Dependent Variable	
lprice	Log of sale price
Neighborhood Characteristics	
pkgarg	Area in publicly accessible parking - one-third mile radius (square feet)
pksup	Area in private parking per square foot land area - one-third mile radius (square feet)
dens	Total non-residential building floor area per square foot land area - one-third mile radius.
DQprice	Median house value in zip code and year of sale.
Property Characteristics	
pcsqft	Property area (square feet)
park	Parking area (square feet)
bldg	Building floor area (square feet)
age	Age of main building on property
cnloc	Corner location
Construction indicators	Categories are: concrete (dropped), brick, frame, mixed, other, missing
Condition indicators	Condition categories: A (dropped),E,F,G,P, missing.
Property categories	indicators for industrial (dropped), three retail types and office, for pooled specification only
Year dummies	Indicators for each year of sale (year1997-year2005)
Area dummies	Indicators for Southwest Los Angeles (dropped), West and East San Fernando Valley, and San Gabriel Valley
ltind	Indicator for light industrial (industrial property specification only)
looff	Low rise office indicator (office properties specification only)
offres	Office-residential dual use indicator (office properties specification only)

Table 5: Summary Statistics

Variable name	Mean	Max	Min	Sd	N
price	1,268,376	22,900,000	25,000	1,334,679	9279
pkgarg	176,470	4,291,031	0.00	228,832	9,279
pksup	0.75	7.80	0.25	0.41	9,279
dens	0.13	1.50	0.00	0.12	9,279
DQprice	282,155	2,950,000	41,500	163,276	9,279
pcsqft	29,970	152,896	2,161	27,713	9,279
park	9,536	115,500	350	10,590	9,279
bldg	12,893	207,745	98	14,350	9,279
age	37.00	176.00	1.00	19.86	9,279
cnloc	0.371	1	0	0.483	9,279
ltind	0.008	1	0	0.087	3,636
looff	0.680	1	0	0.466	1,999
offres	0.054	1	0	0.226	1,999
Construction indicators					
concrete	0.449	1	0	0.497	9,279
brick	0.120	1	0	0.325	9,279
frame	0.322	1	0	0.467	9,279
mixed	0.055	1	0	0.228	9,279
other	0.035	1	0	0.184	9,279
missing	0.018	1	0	0.134	9,279
Condition indicators					
A	0.449	1	0	0.497	9,279
E	0.120	1	0	0.325	9,279
F	0.322	1	0	0.467	9,279
G	0.055	1	0	0.228	9,279
P	0.035	1	0	0.184	9,279
missing	0.018	1	0	0.134	9,279
Area dummies					
Southwest Los Angeles	0.607	1	0	0.489	9,279
West San Fernando	0.085	1	0	0.278	9,279
San Gabriel	0.289	1	0	0.453	9,279
East San Fernando	0.020	1	0	0.140	9,279

* Before any variable transformation or rescaling.

Table 6: Spatial Error Regressions, Pooled and by Property Code.

Variable	Definition	All Properties	Industrial	Service retail	Shopping retail	General retail	Office
	Dependent Variable: Log (Sale Price)						
	Adj R2	0.83	0.88	0.70	0.81	0.79	0.87
lpkgarg	log(pkgarg)	0.03	0.03	0.02	0.06	0.01	0.01
		(4.63)***	(3.37)***	(1.03)	(2.45)**	(0.66)	(0.85)
lpksup	log(pksup)	0.07	0.08	0.10	0.01	0.14	0.06
		(4.08)***	(3.24)***	(2.15)**	(0.17)	(2.63)***	(1.63)
ldens	log(dens)	0.31	0.25	0.35	0.23	0.39	0.32
		(17.08)***	(10)***	(7.87)***	(4.08)***	(8.47)***	(9.27)***
lpcsqft	log(pcsqft)	0.40	0.35	0.53	0.34	0.35	0.25
		(40.36)***	(26.27)***	(19.75)***	(8.01)***	(11.06)***	(11.24)***
logpark	log(park)	-0.52	-0.30	-0.24	-0.18	-0.81	-0.73
		(28.68)***	(16.01)***	(6.08)***	(4.36)***	(10.87)***	(16.36)***
logbldg	log(bldg)	-0.23	0.06	-0.05	0.12	-0.55	-0.33
		(13.91)***	(3.67)***	(1.43)	(3.43)***	(7.52)***	(7.76)***
lage	log(age)	-0.14	-0.10	-0.14	-0.17	-0.14	-0.13
		(24.21)***	(12.94)***	(8.75)***	(9.52)***	(8.26)***	(9.06)***
logDQprice	log(DQprice)	0.41	0.33	0.43	0.39	0.55	0.38
		(28.91)***	(15.69)***	(12.06)***	(8.92)***	(15.55)***	(14.77)***
logparkxlogbldg	log(park)*log(bldg)	0.06	0.04	0.03	0.03	0.10	0.09
		(33.18)***	(19.78)***	(5.18)***	(6.79)***	(12.25)***	(19.61)***
	Constant	6.96	5.64	4.65	4.09	8.82	9.97
		(58.73)***	(28.39)***	(7.57)***	(6.02)***	(24.63)***	(77.45)***
	Rho (spatial correlation)	0.52	0.56	0.34	0.45	0.46	0.53
		(122.4)***	(89.2)***	(26.41)***	(36.2)***	(33.41)***	(53.18)***
	Observations	9,279	3,636	1,547	996	1,101	1,999

Absolute value of z statistics in parentheses.
*** Significant at 1% ** Significant at 5% * Significant at 1%
a The controls not listed are: year dummies, region dummies, building material dummies,
building condition dummies, corner location dummy, light industrial dummy, and low rise office dummy.

Table 7: Parking Value Appears Less than Parking Cost for Many Properties.

Parking Space =350 Square Feet***	Percent of Properties with Binding MPRs*	Average Marginal Parking Value per square foot	Average Marginal Parking Cost (Land + Parking Construction**) per square foot	Difference (Column 5-Column 4) per square foot	N
All	88%	7.94	28.37	20.43	9,279
industrial	80%	12.28	16.99	4.72	3,636
service retail	99%	-8.54	38.95	47.49	1,547
shopping retail	91%	19.18	29.11	9.93	996
retail	88%	8.53	33.08	24.55	1,101
office	84%	8.03	23.71	15.68	1,999
Parking Space =300 Square Feet****					
All	85%	9.23	28.33	19.1	9,279
industrial	75%	14.33	16.97	2.64	3,636
service retail	99%	-10.04	38.88	48.92	1,547
shopping retail	83%	22.95	28.73	5.77	996
retail	85%	9.13	33.42	24.29	1,101
office	78%	9.88	23.43	13.55	1,999

* Percentage of properties that reject parking value equals parking cost at a 5% significance level.
** Land cost is estimated from the hedonic model. Parking construction cost is placed at the cost of asphalt construction.
*** Each parking space is assumed to entail 350 square feet of parking surface, including all lanes and medians.
**** Each parking space is assumed to entail 300 square feet of parking surface, including all lanes and medians.