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What are the Spatial Effects of Employer-Paid Parking at the CBD?

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Abstract

This paper exploits the theoretical connections between employer-paid parking at the CBD and city size, urban welfare, land rents and car commuting using a spatial general equilibrium model with two transportation modes and endogenous residential parking.

Our results show that employer-paid parking at the CBD is an ending parking subsidy that shifts a commuter's decision towards driving to work by changing the relative costs structure of transport modes. By shifting population densities from locations near downtown towards the suburbs, the subsidy also increases the share of workers driving to work and expands the city size. However, the net impact on residential parking land cannot be signed in general because the effects on housing units and parking spaces per dwelling at a particular location in the city run in opposite directions.

In addition, because employer-paid parking leads urban residents to prefer locations farther from the city core, residential land rent close to the downtown district decreases while, the value of residential land at central-suburban and in the suburbs increases. On the other hand, city residents as group generally benefit from employer-paid parking.

Key words: Employer-Paid Parking, Parking Subsidies, Urban Form, Modal Choice

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1. Introduction

According to the 2000 Census, around 75.6% of U.S. workers drove alone to work in 2000. After a decade of rising gas prices, billions spent on transit and huge media hype over shifts to public transportation, the big surprise out of the 2010 U.S. Census, has been the continued growth over the last decade in driving alone to work. Between 2000 and 2010, driving alone to work increased by 7.8 million out of a total of 8.7 million increase in total jobs, implying that this mode of transport reached 76.5% of the U.S. workers.

Parking subsidies such as employer-paid parking and parking requirements on zoning ordinances have long been criticized for greatly contributing to this type of behavior (Willson and Shoup 1990b; Shoup and Breinholt 1997; Shoup 2011). After all, when considering how to get to work, the availability of free parking can be a key factor. In particular, employer paid-parking is a form of matching grant whereby an employer offers to pay the cost of parking if employees are willing to pay all other cost of driving to work. As a result, employees have the incentive to drive alone to work because they are able to park for free (Shoup and Willson 1992a). Even in central areas such as downtown Los Angeles where parking is most expensive, many auto commuters who drive park free (Willson and Shoup 1990a, Shoup 2011).

Solo driving has nevertheless been shown to contribute to high levels of traffic congestion and air pollution in metropolitan areas (Shoup and Willson 1992b). Strategies such as cash-out programs have been advocated and implemented as an attempt to correct for the price distortion introduced by employer-paid parking and thus, reduce the number of car commuters. For example, the state of California has a parking cash-out law whereby employers who subsidize parking, transit or vanpool rides are required to give commuters the option of receiving taxable cash instead.

Yet, these commuting programs are seldom enforced and employee participation in these programs may be affected negatively if the cash subsidy is low and/or if the job site is located in an area with poor transit service.

One reason that has been pointed out for leading employers to provide subsidized free parking at work is the U.S. federal tax policy which exempts this subsidy from both income and payroll taxes, while cash is taxable (Shoup 2011). By distorting the employers' choices about transportation fringe benefits, the current tax code also distorts commuters' transportation decisions. Free or subsidized parking can also be used to attract and retain employees or enhance the availability of the employee to work extra hours. Moreover, free parking is a non-salary benefit that is easier to cut than salary.

Even though employer-paid parking is an important feature of workplace parking pricing and has been a hot topic in the policy arena over the last decade, there is remarkably little analytical work on the effects of this type of parking subsidy. To our knowledge, none of the existing theoretical studies on parking pricing examines simultaneously, within a reasonably realistic spatial general equilibrium model, the various effects of employer-paid parking. Such effects include switching between travel modes, changes in overall welfare, and changes in land area and structural densities. Most of the theoretical studies on parking pricing focus either on the efficiency of second-best pricing of parking spots in the absence of congestion tolls (Arnott et al. 1991; Arnott and Rowse 1999; Verhoef et al. 1995; Calthrop et al. 2000; Anderson and de Palma 2004) or on the effects of parking and transit subsidies on the CBD size (Voith 1998) or on the role of employer-paid parking for the desirability of congestion tax reform and for the relative efficiency of recycling instruments (De Borger and Wuyts 2009).

The goal of this paper is thus to develop a spatial general equilibrium model which allows one to deal with changes in modal choice, urban welfare and urban form of ending parking subsidies in a closed city.

The model is based on residential location and includes two competitive transport modes. Housing is portrayed as a commodity with two attributes, namely floor space and parking spaces, which are both choice variables of the housing developer. Residential parking is assumed to consume a fixed amount of land per parking space. All urban residents are car owners and commute to job sites in the downtown district either by public transit or car. It is also assumed that workers commuting by car do not pay the full resource cost of parking at the workplace because of (full or partially) employer-paid parking. Within this framework we examine the distributional and spatial effects of employer-paid parking at the CBD.

The results of this paper are highly intuitive and can be summarized as follows. Employer-paid parking at the CBD is an ending parking subsidy that shifts a commuter's decision towards driving to work by changing the relative costs structure of transport modes. We also show that by shifting population densities from locations near downtown towards the suburbs, this subsidy increases the share of workers driving to work as well as the city size. However, the net impact on residential parking land cannot be signed in general because the effects on housing units and parking spaces per dwelling at a particular location run in opposite directions.

Another finding is that employer-paid parking has non-homogenous spillover effects throughout the city. Since employer-paid parking leads urban residents to prefer locations farther from the city core, residential land rent close to the downtown district decreases while, the value of residential land at central-suburban and in the suburbs increases. On the other hand, city residents as group generally benefit from employer-paid parking. Workers in the auto part of the city experience an increase in their income net of transport costs, while workers in the transit part of the city benefit from lower housing rental prices. Thus, landowners in the transit part of the city (that is, in locations near the CBD) are the ones who actually lose from this type of commuting subsidy. And, workers commuting to work by public transit may actually like subsidies to suburban automobile users because this decreases the pressure on the housing market near the city core.

The remainder of the paper is organized as follows. In the next section, we develop our theoretical model and discuss the optimality conditions. Section 3 analyses the spatial behavior of choice variables, and section 4 discusses the urban equilibrium conditions. Section 5 then presents the market equilibrium comparative statics of a change in employer-paid parking. Finally, the last section offers conclusions.

2. Model

Suppose a linear city extending from a Central Business District (CBD), located at zero, to the urban fringe $\bar{x}$. The city consists in N urban residents who are assumed to be renters, car owners and to have identical tastes and income. Urban residents reside outside the CBD and commute to work either by car or public transit. All car commuters park at work. Let x denote distance from the place of residence to the CBD, N^c the total number of residents driving to work and N^b the number of residents using public transit. To the extent that all residents either take the public transit or drive to work in the CBD, the urban population satisfies the condition

$$N = N^b + N^c \tag{1}$$

Land is owned by absentee landowners and r_a is the exogenous rural land rent.

Transportation Costs

The cost of auto commuting includes a variable cost and parking costs and is represented by

$$[t_c + \theta_c y]x + f_c - s \tag{2}$$

where $t_c x$ denotes a part of cost varying proportionally with distance such as fuel costs, $\theta_c x$ is the time spent in car travel which is valued at the individual wage rate y, f_c represents parking cost at the CBD and s the employer subsidy for parking at the workplace.

On the other hand, commuting by public transit costs

$$f_b + \theta_b yx \tag{3}$$

where f_b denotes the fixed costs in the case of public transit such as fares and $\theta_b yx$ represents the time cost to an urban resident using public transit.

We assume that $\theta_b > \theta_c$ and $f_c > f_b$. Commuting to work by car is faster but entails a higher fixed cost. In addition we assume the variable cost of using the car is lower than that of using public transit, $t_c + \theta_c y < \theta_b y$.

Under the costs functions (2) and (3), an urban resident chooses between the two transport modes according to his location. That is, an urban resident located x miles from the CBD chooses commuting to work by public transit if

$$[t_c + \theta_c y]x + f_c - s > f_b + \theta_b yx \tag{4}$$

Therefore, there is a cutoff distance, denoted as modal boundary ($\hat{x}$), where urban residents, are indifferent between using the car and public transit and which satisfies the following conditions

$$\hat{x} = \frac{f_c - s - f_b}{\theta_b y - \theta_c y - t_c} \tag{5}$$

$$0 < \hat{x} < \bar{x} \tag{6}$$

Conditions (5) and (6) imply that both modes are used in the city and that close to the CBD urban residents will always commute by public transit.

Residential Bid Rent Functions

Residents' tastes are represented by $U(q,\alpha,m)=\omega(q)+\phi(\alpha)+m$ where m is consumption of a numeraire non-housing commodity, α is the number of parking spaces per dwelling and q is consumption of housing, measured in square feet of floor space. We assume that $\omega_q>0$, $\omega_{qq}<0$ and $\phi_\alpha>0$, $\phi_{\alpha\alpha}<0$.

While the price of the composite good is assumed to be the same everywhere in the city (taken to be unity for simplicity), the rental price per square foot of housing floor space, denoted R, varies with location.

Since urban residents are identical, the urban equilibrium must yield identical utility levels for all individuals. Spatial variation in R allows equal utilities throughout the city. In particular, the price per square foot of housing varies over space so that the highest utility level attainable at each location equals a constant level of utility $\overline{U}$. Given residents choice of transport modes implied by (5) and (6), the maximum amount an urban resident living at distance x from the CBD would be willing to pay for a dwelling of size q with α parking spaces at a given utility level and income level satisfies

$$R(x)=\begin{cases}\omega(q)+\phi(\alpha)-\overline{U}+y-f_b-\theta_b yx & for \quad 0\le x\le \hat{x}\\ \omega(q)+\phi(\alpha)-\overline{U}+y-f_c+s-[t_c+\theta_c y]x & for \quad \hat{x}<x\le \overline{x}\end{cases} \tag{7}$$

The bid function is increasing and concave in the housing attributes, and decreasing in the given level of utility.

The Costs of Residential Parking

For simplicity, we assume the only type of residential parking provided in the city is surface parking. The cost per residential parking space can be represented as

$$i\overline{K} + r\bar{l} \tag{8}$$

where r and i are the prices of land and 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. While the price of capital is assumed to be exogenous and uniform across space, the price of land is endogenously determined and varies over space.

Housing Developers

The amount of floor space in a developer's complex is given by $H(K,L)$, where K is the capital input and L is the amount of building land and H is a strictly concave and homogenous of degree one. 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 $h_S > 0$ and $h_{SS} < 0$. $h(S)$ represents residential total floor space per unit of building land. Since q is floor space per dwelling, it follows that the number of dwellings in a complex is given by $\dfrac{H(K,L)}{q}$, which can be written as $\dfrac{Lh(S)}{q}$.

Given the preceding discussion, the developer's profit equals

$$L\left\{\frac{h(S)}{q}\left[R(q,\alpha,x) - \alpha[r\bar{l} + i\bar{k}]\right] - iS - r\right\} \tag{9}$$

where the expression in brackets in (9), denoted π, is profit per acre of building land and $R(q,\alpha,x)$ is defined by (7). For fixed L, developers choose q, α and S to maximize (9) and competition bids up land rent r until maximized profit per acre equals zero. Since total profit is zero regardless of the value of L, the scale of the developer's building is indeterminate.

Assuming an interior solution, the first-order conditions for choice of structural density, dwelling size and parking spaces per dwelling that must be met are respectively[1]

$$\frac{\partial\pi}{\partial S} = \frac{h_S(S)}{q}[R(q,\alpha,x,\overline{U}) - \alpha[r\bar{l} + i\bar{k}]] - i = 0 \tag{10}$$

$$\frac{\partial\pi}{\partial q} = \frac{h(S)}{q}[R_q - \frac{R(q,\alpha,x,\overline{U}) - \alpha[r\bar{l} + i\bar{k}]}{q}] = 0 \tag{11}$$

$$\frac{\partial\pi}{\partial\alpha} = \frac{h(S)}{q}[R_\alpha - r\bar{l} - i\bar{k}] = 0 \tag{12}$$

and the zero profit condition is

$$\pi = \frac{h(S)}{q}\left[R(q,\alpha,x,\overline{U}) - \alpha[r\bar{l} + i\bar{k}]\right] - iS - r = 0 \tag{13}$$

Equation (10) says that structural density is expanded until the marginal increase in revenue per acre of building land equals the marginal increase in cost from the extra capital plus the marginal increase in parking land cost required to hold parking spaces per dwelling fixed.

Equation (11) says that dwelling size is expanded until the marginal decrease in revenue per acre of building land equals the marginal decrease in parking land cost from holding the number of parking spaces per dwelling fixed.

Finally, equation (12) says that the number of parking spaces per dwelling should be increased until the net increase in revenue per acre of building land equals zero.

The Hessian matrix of π evaluated at the solution to (10)-(12) may be written

[1] While the utility level $\overline{U}$ is ultimately endogenous, it is viewed as parametric at this stage in the analysis. Moreover, if we consider the case where surface parking spaces per dwelling equals zero (a corner solution), then condition (12) would be replaced by the following three Kuhn Tucker conditions: $\alpha \geq 0$, $\frac{h(S)}{q}[R - r\bar{l} - i\bar{k}] \leq 0$ and $\alpha\frac{h(S)}{q}[R_\alpha - r\bar{l} - i\bar{k}] = 0$.

$$D = \begin{bmatrix} \frac{h_{ss}}{q}[R-\alpha[r\bar{l}+i\bar{k}]] & 0 & 0 \\ 0 & \frac{h}{q}R_{qq} & 0 \\ 0 & 0 & \frac{h}{q}R_{\alpha\alpha} \end{bmatrix} \tag{14}$$

The negative definiteness of D required by the second-order condition is guaranteed by $h_{ss} < 0$ and the strict concavity of R, where $R_{qq} < 0$ and $R_{\alpha\alpha} < 0$. Thus, $|D_1| < 0$, $|D_2| > 0$ and $|D| = \frac{h_{ss}R_{qq}R_{\alpha\alpha}h^2}{q^3}[R-\alpha[r\bar{l}+i\bar{k}]] < 0$.

We now proceed to examine how the main endogenous variables vary over space.

3. Spatial Behavior of the Main Endogenous Variables

Spatial Behavior of S, q, α and $\bar{l}\alpha + q/h$

We now focus on the spatial behavior of structural density (S), dwelling size (q), parking spaces per dwelling (α) and land per dwelling ($\bar{l}\alpha + q/h$).

Differentiating (13) with respect to x while taking into account (7) and (10)-(12) yields, after some manipulations,

$$r_x = \begin{cases} \dfrac{-\theta_b y}{\bar{l}\alpha + \dfrac{q}{h(S)}} < 0 \quad for \quad x < \hat{x} \\ \dfrac{-[t_c + \theta_c y]}{\bar{l}\alpha + \dfrac{q}{h(S)}} < 0 \quad for \quad x > \hat{x} \end{cases} \tag{15}$$

According to (15) residential land rent decreases with distance from the CBD but exhibits a kink at the boundary between the two transport modes. At the modal boundary $\hat{x}$, structural density, dwelling size and the number of parking spaces per dwelling are the same regardless of which mode the urban resident selects since transportation costs are the same at $\hat{x}$. Note that $r(x)$ is not differentiable at $x = \hat{x}$ because $R(x)$ is not differentiable at $x = \hat{x}$, but left and right differentiable at that point. Equation (15) shows that the residential land rent associated with the automobile is less steep at $x = \hat{x}$.

Totally differentiating (10) - (12) taking account of the dependence of r on x and solving for S_x, q_x and α_x using Cramer's rule gives, after simplifying, the following results:

$$S_x = \frac{-h_s r_x q}{h_{ss} h[R - \alpha[r\bar{l} + i\bar{k}]]} < 0 \tag{16}$$

$$q_x = \frac{r_x}{hR_{qq}} > 0 \tag{17}$$

$$\alpha_x = \frac{\bar{l} r_x}{R_{\alpha\alpha}} > 0 \tag{18}$$

Let $\delta = \alpha\bar{l} + q/h$. Taking advantage of the results thus far, it is possible to derive the spatial behavior of the amount of land per dwelling in the following way:

$$\delta_x = \alpha_x \bar{l} + \frac{q_x h - h_x q}{q^2} > 0 \tag{19}$$

Moreover, the amount of land at location x is given by $N(x)\delta(x)$ where $N(x)$ is the number of dwellings. Thus, $\frac{N(x)}{N(x)\delta(x)} = \frac{1}{\delta(x)}$ represents population density at location x which, exhibits a the spatial behavior described by

$$\left(\frac{1}{\delta}\right)_x = -\frac{\delta_x}{\delta^2} < 0 \tag{20}$$

According to (16)-(18), buildings have fewer storeys farther from the CBD and dwellings are bigger closer to the edge of the city. Moreover, the number of residential parking spaces per dwelling increases with distance from the CBD, implying that bigger houses are bundled with more parking spaces. Equations (19) and (20) also reveal that urban residents consume more land as we move away from downtown (where land is typically more expensive) and population density decreases with distance from the CBD.

4. Urban Equilibrium Conditions

Next, we turn to the analysis of the urban equilibrium under the assumption of a closed city, where population (N) is viewed as fixed, while the urban utility level is determined within the system. The first spatial equilibrium condition requires that urban land rent at the edge of the city, $\bar{x}$, must equal the agricultural land rent

$$r(\bar{x},\overline{U},s) = r_a \tag{21}$$

The second equilibrium condition is that population must fit inside the city. The population condition must also reflect mode choice.[2]

$$\int_0^{\hat{x}} \frac{1}{\delta_b(x)}dx + \int_{\hat{x}}^{\bar{x}} \frac{1}{\delta_c(x)}dx = N \tag{22}$$

or[3]

$$r(\hat{x},\overline{U})[\theta_b y - \theta_c y - t_c] + r(0,\overline{U})[t_c + \theta_c y] = \theta_b y\big[N[t_c + \theta_c y] + r_a\big] \tag{23}$$

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[2] We define δ_i with $i = b,c$ as the total amount of land per dwelling under mode i .

[3] Recall that land size at location x is fixed and equal to 1. From (15) we get $\delta_b(x) = -\frac{r_{bx}}{\theta_b y}$ and $\delta_c(x) = -\frac{r_{cx}}{t_c + \theta_c y}$ which, we insert back into (22). Then, integrating while taking into account (21) and that $r_b(\hat{x}) = r_c(\hat{x})$ yields, after some manipulations, (23).

Since $1/\delta(x)$ represents population density and the city is linear with unit width, the integrals in (22) aggregate total residents out to the urban boundary and equate it to N. Finally, the number of workers commuting by car is determined as

$$N^c = \int_{\hat{x}}^{\bar{x}} \frac{1}{\delta(x)} dx = \frac{r(\hat{x}, \overline{U}) - r_a}{t_c + \theta_c y}. \tag{24}$$

Together (21), (23) and (24) constitute a system of equations that can be solved for the unknowns $\overline{U}$, $\bar{x}$ and N^c.

5. The Effects of Employer-Paid Parking

Within the above framework, we now examine the effects of a marginal increase in s on the optimal values of structural density, dwelling size, residential parking supply, commuting mode choice, city size and urban welfare.

Impacts on the Modal Boundary

Differentiating equation (5) with respect to s yields

$$\frac{d\hat{x}}{ds} = -\frac{1}{\theta_b y - \theta_c y - t_c} < 0 \tag{25}$$

Thus, since an increase in employer paid parking decreases the generalized costs of commuting to work by car, the modal boundary is shortened meaning that urban residents at the old modal boundary shift from transit to auto after an increase in the parking subsidy.

Impacts on Utility level and Residential Land Rent

Totally differentiating (23) with respect to s while substituting (25), yields the impact of a change in employer-paid parking on residents' welfare as

$$\frac{d\overline{U}}{ds} = \frac{\theta_b y \delta(0)}{\theta_b y \delta(0) + [\theta_c y + t_c][\delta(\hat{x}) - \delta(0)]} > 0 \tag{26}$$

On the other hand, the impacts of a change in employer-paid parking on residential landowners' welfare can be described by the change on the residential land rent profile.

$$\frac{dr(0)}{ds} = -\frac{1}{\delta(0)} \frac{d\overline{U}}{ds} < 0 \tag{27}$$

$$\begin{aligned} \frac{dr(\hat{x})}{ds} &= -\frac{1}{\delta(\hat{x})}\left[\frac{d\overline{U}}{ds} + \theta_b y \frac{d\hat{x}}{ds}\right] = \\ &= \frac{\theta_b y[\theta_c y + t_c]}{[\theta_b y - \theta_c y - t_c][\delta(0)[\theta_b y - \theta_c y - t_c] + \delta(\hat{x})[t_c + \theta_c y]]} > 0 \end{aligned} \tag{28}$$

The above comparative static analysis reveals city residents as group generally benefit from employer-paid parking. On the other hand the impact of an increase in employer-paid parking on landowners is not the same everywhere in the city. In particular, it is shown that residential land rent near the CBD decreases while residential land rent at locations farther from the business district increases.

Intuitively, when there is an increase in employer-paid parking, driving costs to work decrease because there is a reduction in parking costs at work, which eases suburban access. Because commuting by car is cheaper, some of the urban residents who originally were commuting by public transit will now use the car. Since they use the car, they are motivated to relocate to farther from the CBD. On the other hand, for those urban residents already using the automobile, the income net transport cost increases. These two effects together bids up housing bid rents in the area of the city where the car is the transportation mode to commute to work, while depressing housing bid rents near the CBD. Note that the attributes of public transit did not change and therefore, workers who keep commuting by public transit must now enjoy a higher utility because housing rents are lower everywhere in their residential area. This, in turn, results in lower residential land rents in central areas of the city.

Impact on the Number of Workers Commuting by Car

Totally differentiating (24) with respect to s and using (25) and (26), yields after simplifying

$$\frac{dN^c}{ds} = \frac{1}{[\theta_b y - \theta_c y - t_c][\delta(0)[\theta_b y - \theta_c y - t_c] + \delta(\hat{x})[t_c + \theta_c y]]} > 0 \tag{29}$$

Given the above discussion, it is not surprising the positive sign of (27), meaning employer-paid parking increases the number of workers driving to work. Further intuition can be gained by examining the impacts on city size and population densities.

Impact on the urban boundary

Totally differentiating (21) with respect to s while substituting (25) and (26) yields,

$$\begin{aligned}\frac{d\bar{x}}{ds} &= -\frac{1}{\theta_c y + t_c}\left[\frac{d\bar{U}}{ds} - 1\right] \\ &= \frac{\delta(\hat{x}) - \delta(0)}{\theta_b y \delta(0) + [\theta_c y + t_c][\delta(\hat{x}) - \delta(0)]} > 0\end{aligned} \tag{30}$$

since $\delta(\hat{x}) > \delta(0)$. Thus an increase in employer-paid parking expands the city boundary, whereby the size of the city gets larger. It is worth mentioning that this expansion in city size is larger, the biggest the difference between the highest amount of land per dwelling in the transit part of the city and the lowest amount of land per dwelling in the auto part of the city.

Impact on structural density, dwelling size and residential parking spaces per dwelling

Totally differentiating (12) with respect to s while taking into account the dependence of the land rent on s, yields

$$\frac{d\alpha(0)}{ds} = \frac{\bar{l}}{R_{\alpha\alpha}} \frac{dr(0)}{ds} > 0 \text{ and } \frac{d\alpha(\hat{x})}{ds} = \frac{\bar{l}}{R_{\alpha\alpha}} \frac{dr(\hat{x})}{ds} < 0 \tag{31}$$

given (27) and (28) and that $R_{\alpha\alpha} < 0$. According to (31), the number of parking spaces per dwelling increases in central locations and decreases at farther locations from the CBD. This suggests that employer-paid parking at the CBD influences market residential parking supply throughout the city, leading to more parking spaces per dwelling near the center than in the absence of the subsidy.

The impacts on structural density at the CBD and at the modal boundary can also be examined by first computing S_u and then using (26) and (28) to evaluate, yields[4]

$$\begin{aligned}\frac{dS(0)}{ds} &= S_u(0)\frac{d\overline{U}}{ds} = \\ &= \frac{h_s q}{h_{ss}\delta(0)h[R(0) - \alpha r\bar{l} - \alpha i\bar{k}]}\frac{d\overline{U}}{ds} < 0\end{aligned} \tag{32}$$

$$\begin{aligned}\frac{dS(\hat{x})}{ds} &= S_x(\hat{x})\frac{d\hat{x}}{ds} + S_u(\hat{x})\frac{d\overline{U}}{ds} = \\ &= -\frac{h_s q}{hh_{ss}[R(\hat{x}) - \alpha r\bar{l} - \alpha i\bar{k}]}\frac{dr(\hat{x})}{ds} > 0.\end{aligned} \tag{33}$$

By a similar method, we can find the effects on dwelling size at the city center and at the modal boundary by determining the sign of[5]

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[4]The partial effect of S_u was determined by totally differentiating the system of equations (10)-(12) evaluated at the initial equilibrium with respect to the exogenous parameter of interest while taking into account the dependence of r on $\overline{U}$ and then using Cramer's rule to find the result.

[5] The partial effect of q_u was determined by totally differentiating the system of equations (10)-(12) evaluated at the initial equilibrium with respect to the exogenous parameter of interest while taking into account the dependence of r on $\overline{U}$ and then using Cramer's rule to find the result.

$$\frac{dq(0)}{ds} = q_u \frac{d\overline{U}}{ds}$$
$$= -\frac{1}{h(0)\delta(0)R_{qq}} \frac{d\overline{U}}{ds} > 0 \tag{34}$$

$$\frac{dq(\hat{x})}{ds} = q_x \frac{d\hat{x}}{ds} + q_u \frac{d\overline{U}}{ds}$$
$$= -\frac{\theta_b y}{\delta(\hat{x})hR_{qq}} \frac{d\hat{x}}{ds} - \frac{1}{h\delta(\hat{x})R_{qq}} \frac{d\overline{U}}{ds}$$
$$= -\frac{1}{\delta(\hat{x})hR_{qq}} \left[\frac{d\overline{U}}{ds} + \theta_b y \frac{d\hat{x}}{ds} \right] \tag{35}$$
$$= \frac{1}{hR_{qq}} \frac{dr(\hat{x})}{ds} < 0$$

According to the above comparative statics, an increase in employer-paid parking also does not have the same effect in dwelling size and structural density everywhere in the city. After an increase in s, structural density decreases and dwelling size increases in central locations while the opposite effects occur as we move towards central-suburban and suburban locations. Given the above spatial impacts on the profile of dwelling sizes and structural densities, it is also the case that employer-paid parking at the CBD decreases population density near downtown while increasing population densities in suburban areas. Since there is a fixed number of workers that must be housed in the city, this can also explain the expansion of the city size after an increase in s. Thus, by concentrating residences in central-suburban and suburban areas, employer-paid parking increases the number of workers driving to work.

Impact on Residential Parking Land

Total parking land is $L^p = \bar{l}\int_0^{\bar{x}} N(x)\alpha(x)dx$. By differentiating L^p with respect to s yields

$$\frac{dL^p}{ds} = \bar{l} N(\bar{x}) \alpha(\bar{x}) \frac{d\bar{x}}{ds} + \bar{l} \int_0^{\bar{x}} \left[\frac{dN(x)}{ds} \alpha(x) + \frac{d\alpha(x)}{ds} N(x) \right] dx \tag{36}$$

While the first term on the right-hand-side of (36) is positive, the second term sign cannot be determined. The reason is because the effect of an increase in s on the number of dwellings and parking spaces per dwelling provided at a given location run in opposite directions.

Take for example what happens in locations near downtown. While the subsidy's depressing effect on the number of housing units provided reduces parking land, a countervailing effect from more parking spaces per dwelling may dominate, raising parking land in this part of the city. The same set of effects, but with opposite directions, also occur in suburban areas, where the number of housing units increase but the number of parking spaces per dwelling decreases after an increase in s. Thus, the net effect of an increase in employer-paid parking on the amount of land allocated to residential parking is ambiguous in general. Note, however, that if the number of parking spaces is held fixed, then the amount of residential parking land would decrease in central areas while increasing in the suburbs.

6. Conclusions

This paper exploits the theoretical connections between employer-paid parking and city size, urban welfare, land rents and car commuting. Using a spatial general equilibrium model with two competing transport modes and endogenous residential parking, the paper results are in line with those of Willson and Shoup (1990) and Shoup's (1997) case studies. Therefore, on the one hand this paper complements existing anecdotal literature on the effects of employer-paid parking. And on the other hand, by specifically modeling parking (an attribute of the house that consumes land) and the developers' behavior, it also adds to the existing theoretical literature on the effects of commuting subsidies on urban form and modal choice behavior (Sakasi 1989; Brueckner 2005; Su and DeSalvo 2008; Borck and Wrede 2008).

Overall, the results show that employer-paid parking is an ending parking subsidy that shifts a commuter's decision towards driving to work, increases the share of workers commuting to work by car and expands the urban boundary. To the extent that this subsidy increases the amount of parking demanded at the worksite, this parking subsidy may create an incentive for local governments requiring more parking in nonresidential areas. However, it has been shown that nonresidential parking requirements actually create an oversupply of parking (Cutter and Franco (2012)), which in turn would depress the cost of driving solo and create an incentive for auto commuting (Shoup 2005). Future research should explore the connections between employer-paid parking and local parking requirements and how these connections may exacerbate other urban problems such as traffic congestion and air pollution.

We also show that residential land rent close to the downtown district decreases while the value of residential land at central-suburban and in the suburbs increases, when this type of parking subsidy is in place. In contrast, urban residents as a group gain with this type of subsidy.

Another interesting finding is that employer-paid parking at the CBD influences the spatial supply of residential parking, leading central locations to supply more parking spaces per dwelling than in the absence of the subsidy. In addition, this parking subsidy also leads developers near the city core to provide fewer housing units than the market would have otherwise provided. Because the impacts on housing units and on parking spaces per dwelling run in opposite directions in both parts of the city, the net effect of employer-paid parking on residential parking land cannot be signed in general. Empirical work based on the current analysis would hence be useful avenue for future research.

There are nevertheless a couple of limitations to our analysis. In our analysis, we have abstracted from the possibility of workers been offered the option to cash-out their parking subsidies. Another type of incentive that has not been examined here, and that can be the topic of future research, is an employer-paid transit pass scheme. Under this commuting program, the employer pays the cost of employees' transit, converting the fixed cost for parking spaces into a variable cost for the public transportation subsidy. The effects of subsidies to public transit have nevertheless been analyzed in the monocentric city model with two transportation modes and no congestion. For example, Sasaki (1989) has shown that a decrease in either the basic fare or in the proportional part of the fare leads to contraction of the city and to a reduction of the rent in the suburban area. However, rent in central locations decreases also when there is a drop in the proportional part of the fare but it can increase if the subsidy is on the basic fare. Hence, it would be interesting to examine the distributional and efficiency effects of alternative commuting subsidies in the presence of traffic and parking congestion externalities.

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