JOURNAL OF URBAN ECONOMICS **44,** 43–58 (1998)
ARTICLE NO. UE972059

Parking, Transit, and Employment in a Central Business District*

Richard Voith

Research Department, Federal Reserve Bank of Philadelphia, 10 Independence Mall, Philadelphia, Pennsylvania 19106-1574

Received August 21, 1995; revised June 10, 1997

In this paper we present a general equilibrium model to examine the role of parking and transit subsidy policy on the size of a central business district (CBD), CBD land values, and the market shares of cars and transit. The three main features of the model are: (1) agglomeration economies increase continuously with labor market size; (2) congestion arises from auto use only; transit is noncongestible; and (3) locational equilibrium is maintained in the sense that firms and individuals cannot reduce costs or increase utility by moving, given equilibrium prices and city size. We derive the conditions under which parking taxes can be levied and used to subsidize transit and increase equilibrium CBD size and land values. We compute an optimal parking tax that maximizes CBD size and land values and derive relationships among parking taxes, transit use, and congestion. We find nonmonotonic relationships among parking taxes, land values, and transit use. © 1998 Academic Press

I. INTRODUCTION

Urban economists have long held that agglomeration economies associated with higher concentrations of employment give rise to cities and that the growth of cities stops when commuting, congestion, and other costs associated with size offset the benefits of agglomeration. The shift in employment patterns—from compact, transit-oriented central business districts (CBDs) to scattered, sprawling, auto-oriented employment centers spread throughout metropolitan areas—suggests that agglomeration economies have diminished and that many of the remaining benefits of agglomeration can be realized in less centralized settings. Despite the rise of suburban employment, however, many CBDs still have dense employ-

* Julie Northcott-Wilson provided excellent research assistance. The author wishes to thank the editor and two anonymous referees for their helpful comments. The views expressed here are solely those of the author and do not necessarily represent the views of the Federal Reserve Bank of Philadelphia or of the Federal Reserve System.

0094-1190/98 $25.00

ment concentrations, suggesting that agglomeration economies are still important in some markets.[1]

Traditional CBDs differ substantially from their suburban counterparts, primarily in their density of activity and modes of commuting. The high density of activity in CBDs, which facilitates face-to-face interaction and information flows, is one of the primary comparative advantages of CBDs. The dense concentration of activity is possible because CBDs typically are accessible by public transportation as well as by car. Public transport systems deliver larger numbers of people to small geographic areas than is possible by car, the predominant mode in suburban economic centers. The value of public transit–supported CBD agglomeration economies is counterbalanced by the costs of public transportation, congestion costs associated with cars in compact spaces, and high parking costs associated with the high intensity of land use.

Transportation policies influencing transit and parking prices play an important role in the relative competitiveness of the CBD, directly and through their effects on agglomeration and congestion. Agglomeration economies and externalities associated with auto congestion may justify policies that increase the price of parking and lower the price of transit. On the other hand, policies that increase parking costs place the CBDs at a competitive disadvantage when compared to suburban locations offering free parking and, hence, may lower potential agglomeration economies. Choosing parking and transit policies that maximize the value of CBD land involves weighing the tradeoff between auto congestion, transit costs, and parking costs for businesses and consumers.

Congestion has been extensively analyzed in the context of monocentric urban models by Mills [8], Solow [12], Oron *et al.* [9], Henderson [6], Arnott and MacKinnon [2], Sullivan [13], and Yinger [17]. These papers provide rich detail on the effects of congestion on the steepness of the rent gradient, the equilibrium size of the city, and the amount of land devoted to roads. However, most of these models have only a single commuting mode and exogenous agglomeration economies so they cannot be directly used to evaluate the effects of transit and parking policy on CBD agglomerations and CBD intrametropolitan competitiveness.[2]

[1] Reliable data on CBD employment trends are difficult to obtain, as most employment data are collected on the basis of the entire city jurisdiction. One exception is the data collected by Summers and Linneman [14]. They assembled employment data for CBDs for 60 cities for 1976, 1980, and 1986. During this period, they found that CBDs tended to perform significantly better in terms of employment growth than did the remainder of the central city.

[2] Some monocentric urban models allow more than one mode. Sasaki [11] examines a model with two transportation modes and examines the effects of improvement in one of the modes (which can be thought of as a reduction in congestion). The paper by Sullivan [13] allows for agglomeration economies that are a function of city size.

In this paper we present a general equilibrium model to examine the role of parking and transit subsidy policy on CBD size, CBD land values, and the market shares of cars and transit. The model follows in the tradition of the equilibrium location models with endogenous community size like that of Blomquist *et al.* [3] and Roback [10]. While these models lack the spatial detail of the monocentric models, they easily allow investigation of the role of parking and transit policy on equilibrium community size, land values, and mode shares in the presence of endogenous congestion and agglomeration. The three main features of the model are: (1) agglomeration economies increase continuously with labor market size; (2) congestion arises from auto use only; transit is noncongestible; and (3) equilibrium is maintained in the sense that firms and individuals cannot reduce costs or increase utility by moving, given equilibrium prices and city size. We derive the conditions under which parking taxes can be levied and used to subsidize transit to increase equilibrium CBD size and land values.

There are several key implications of the model. First, in the simplest version of the model, with land used for production fixed exogenously, we can find an optimal parking tax that maximizes CBD size and land values. Tax rates that lie below this rate result in excessive congestion from high auto use, reducing community size and land values. Taxes in excess of the optimal rate yield lower congestion but also have smaller communities and lower land values than would be obtained at the optimal tax and subsidy program. In the full model, with endogenously determined land use, the tax rate that maximizes land values is less than the rate that maximizes community size. Second, for cities with parking tax rates below the optimal rate, increases in parking taxes raise land values and parking prices while reducing the amount of land devoted to parking. Thus, contrary to what is commonly expected, parking taxes that are too low may actually reduce the value of land owned by parking providers. Third, public transit use is not monotonically related to changes in tax rates on auto use because excessively high auto tax rates reduce community size and eventually total subsidies for transit. Finally, the adverse consequences of underpricing congestion, that is, choosing parking taxes that are too low, increase with the strength of agglomeration economies.

The plan of the paper is as follows. Section II presents the basic theoretical model. Section III examines the comparative statics of the basic model. Section IV extends the analysis to include parking supply, with the use of land—for production or parking—endogenously determined. Section V concludes.

II. BASIC MODEL

Consider an economy that produces a single, nationally traded commodity, x, at many locations. We will focus on production of this commodity at one location that has the attributes of a central business district. In particular, there are agglomeration economies associated with increasing local CBD employment, N; the district has a fixed supply of land that is used for production, L^0; and workers have two modes of access to the CBD: automobile and transit.[3] The distinguishing characteristic of the transportation system is that the automotive system is subject to congestion, while the transit system is not.[4] We specify the behavior of producers and consumers below.

Producers

Firms produce the consumption good using land, l, and labor, n, with a constant return to scale technology. The corresponding prices of land and labor are r and w, respectively. Agglomeration economies result in increasing output per unit of input as aggregate labor market size increases. The production function, which is assumed to be separable in N, is given by $x = f(n, l, N)$. The corresponding unit cost function is $c(w, r, N)$. Equilibrium in the product market requires that the price of x, which is normalized to 1, must be equal to unit costs:

$$c(w, r, N) = 1 \tag{1}$$

with $C_w, C_r > 0$ and $C_N < 0$. Using Shephard's lemma, the relative share of labor to land in production is given by $n/l = c_w/c_r$. Given the land available for production L^0, aggregate labor demand is $N = L^0 c_w/c_r$. Because the production function is separable in N, the labor demand is a function only of w, r, and L^0:

$$N = N(w, r, L^0). \tag{2}$$

The concavity of the cost function with respect to w and r, in conjunction with a restriction on the cross partial derivative ($C_{wr} \geq 0$), implies that $N_w < 0$ and $N_r > 0$. $N_L > 0$ as well.

Consumers and Commuting

Consumers each supply a single unit of labor and receive w, which is used to purchase the consumption good and transportation. All consumers derive identical utility from consuming x. Consumers reside outside the CBD and commute to work by either car or train.[5] The cost of auto

[3]All land in the CBD is of equal value for production.

[4]A recent paper by Tabuchi [15] examining bottleneck congestion in a two-mode setting makes similar assumptions regarding congestibility of cars and transit. Tabuchi finds that it may be welfare-enhancing to subsidize the noncongestible transportation mode.

[5]We abstract from issues of commuting distance and fixed costs associated with auto ownership.

commuting includes only a parking tax, τ, and congestion cost $g(N^a)$, which, because highway capacity is assumed fixed, is an increasing function of the total number of people driving, N^a.[6] Commuting by train incurs no congestion and costs p^t. Given w, p^t, τ, and N^a, consumers choose their transportation mode to minimize transport costs and, hence, maximize consumption of x. Consumers can achieve net-of-commuting wage, q, outside the region; locational and modal equilibria require that consumers cannot attain higher net wages by moving or changing mode. Thus, for drivers,

$$w - \tau - g(N^a) = q \tag{3}$$

and, for transit riders,

$$w - p^t = q. \tag{4}$$

All consumers either take the train or drive so that

$$N = N^t + N^a, \tag{5}$$

where N^t is the number of people using the train. Revenues from the parking tax, τN^a, are used to subsidize train commuting, which is provided at a constant cost per passenger, D.[7] Total transit costs, therefore, are proportional to the number of passengers, N^t. The price of train commutation is set such that the revenue from passengers plus revenues from subsidies equal costs.[8] Thus $p^t N^t + \tau N^a = DN^t$, which yields

$$p^t = D - \tau N^a / N^t. \tag{6}$$

Equations (1)–(6) constitute a system of equations that determine w, r, p^t, N^a, N^t, and N. The exogenous variables are L^0 and D. The policy variable of interest is τ, the choice of which affects the split between auto and transit, which, in turn, determines equilibrium commuting costs, wages, and land values.

[6] We consider the case in which parking price and supply are endogenously determined in Section IV. We can think of the basic model as a case where there is an unlimited supply of parking on the periphery of the CBD, and hence, the cost of parking is just the parking tax.

[7] Because of their high fixed costs, the cost per passenger of train service is likely to decline as the number of users increases. These scale economies reinforce the effects of agglomeration in production. To focus on the role of policy on agglomeration and congestion, we have assumed constant per-passenger costs. Allowing for declining costs would not qualitatively change our findings.

[8] We do not address the issues arising from rent seeking on the part of transit providers. Given subsidy revenues, transit providers are assumed to maximize ridership, which requires that all commuters receive the same subsidy.

The six-equation system can be simplified considerably. Equations (3) and (4) imply that auto and transit users' commuting costs must be equal so $\tau + g(N^a) = p^t$. Substituting (5) and (6) into this expression, we obtain N^a as a function of τ, N, and D:

$$\tau + g(N^a) = D - \tau N^a/(N - N^a). \tag{7}$$

We can rewrite (7) as

$$N^a = N^a(\tau, N, D). \tag{8}$$

By totally differentiating (8), it is easy to show that $N^a_\tau < 0$, $N^a_N > 0$, and $N^a_D > 0$. Thus auto use is decreasing in parking taxes, increasing in CBD size, and increasing in train costs.

We can further redefine the congestion cost function, $g(N^a(\tau, N, D))$, as $G(\tau, N, D)$, where $G_\tau < 0$, $G_N > 0$, and $G_D > 0$ since $g_{N^a} > 0$. Finally, we can use (2) to substitute for N to redefine the congestion cost function as $G(\tau, N(w, r, L^0), D) = H(\tau, w, r, L^0, D)$, where $H_\tau < 0$ and $H_D > 0$ and, since $G_N > 0$, $H_w < 0$, $H_r > 0$, and $H^0_L > 0$. Substituting the congestion cost function $H(\cdot)$ in Eq. (3), we obtain

$$w - \tau - H(\tau, w, r, L^0, D) = q, \tag{9}$$

which, in conjunction with (1) and (2), yields a three-equation system with endogenous variables w, r, and N, and exogenous variables L^0, D and the policy variable τ.

III. COMPARATIVE STATICS

We can analyze the effects of parking tax and transit subsidy policy either by totally differentiating (1)–(6) and solving for changes in employment, land use, mode split, transportation prices, wages, and land rents with respect to changes in parking taxes, or by evaluating the comparative statics of the model based on Eqs. (1), (2), and (9), which yields simpler expressions. Totally differentiating (1)–(6) yields

$$C_w\, dw + C_r\, dr + C_N\, dN = 0, \tag{10}$$

$$dN = N_w\, dw + N_r\, dr, \tag{11}$$

$$dw - d\tau - g_{N^a}\, dN^a = 0, \tag{12}$$

$$dw - dp^t = 0, \tag{13}$$

$$dN = dN^t + dN^a, \tag{14}$$

$$dp^t = \big((D - p^t)\, dN^t - \tau\, dN^a - N^a\, d\tau\big)/N^t. \tag{15}$$

We also totally differentiate (9):

$$dw - d\tau - H_\tau\, d\tau - H_w\, dw - H_r\, dr = 0. \tag{16}$$

Wages

Because most of the following comparative statics effects depend on the sign of $dw/d\tau$, we first consider the effects of taxes on wages. Given fixed interregional utility, q, the utility effects of changing wages must be offset by changes in congestion, taxes, and transit prices. By rearranging terms in Eq. (12), we have $dw/d\tau = 1 + g_{N^a}\, dN^a/d\tau$; since $dN^a/d\tau$ will be shown to be negative, the sign of $dw/d\tau$ is ambiguous. Using Eqs. (10), (11), and (16) and solving for $dw/d\tau$, we obtain

$$\frac{dw}{d\tau} = \frac{1 + H_\tau}{1 - H_w + (c_w + c_N N_w)/(C_r + C_N N_r)}. \tag{17}$$

Recall that H_w, C_N, and $N_w < 0$ and C_w, C_r, and $N_r > 0$, so as long as $C_r > -C_N N_r$, the denominator of (17) is positive. As is shown in Appendix 1, this condition implies that the demand for labor is always downward sloping. Intuitively, this condition says that the costs associated with an increase in rent are greater than the savings associated with increased agglomeration economies resulting from a shift in inputs from land to labor. The numerator of (17) can be either positive or negative. When the reduction in congestion associated with an increase in taxes is large, the increasing taxes will lower wages.

We can establish several facts about the relationship between wages and parking taxes. First note that $dw/d\tau < 1$ always.[9] After all, if $dw/d\tau > 1$, then the costs of taxation would be more than offset by wage increases. Second, Eq. (4) indicates that wages for $\tau = 0$ must be equal to the wages for $\tau \geq \tau^m$, where τ^m is the tax rate at which no one chooses to drive. With $\tau = 0$ or $\tau \geq \tau^m$ there is no subsidy for transit, so p^t is the same in either case, so wages must be the same as well. Third, note that, for $0 < \tau < \tau^m$, Eq. (6) implies $p^t < (p^t \mid \tau = 0)$, which, in conjunction with (4), indicates $w < (w \mid \tau = 0)$, so wages must decline as taxes are first imposed, and as taxes rise to τ^m, wages must return to the level prevailing when $\tau = 0$. Without further structure on the model, we cannot determine the exact path of wages as τ changes, but for Cobb–Douglas production technology and a linear congestion function, simulation shows that the

[9] To see that $dw/d\tau < 1$, note that, in the numerator of (17), $H_\tau < 0$ always, so $1 + H_\tau < 1$, and because $H_w < 0$ and $(C_w + C_N N_w)/(C_r + C_N N_r) > 0$, the denominator, $1 - H_w + (C_w + C_N N_w)/(C_r + C_N N_r) > 1$ always. Thus $dw/d\tau < 1$.

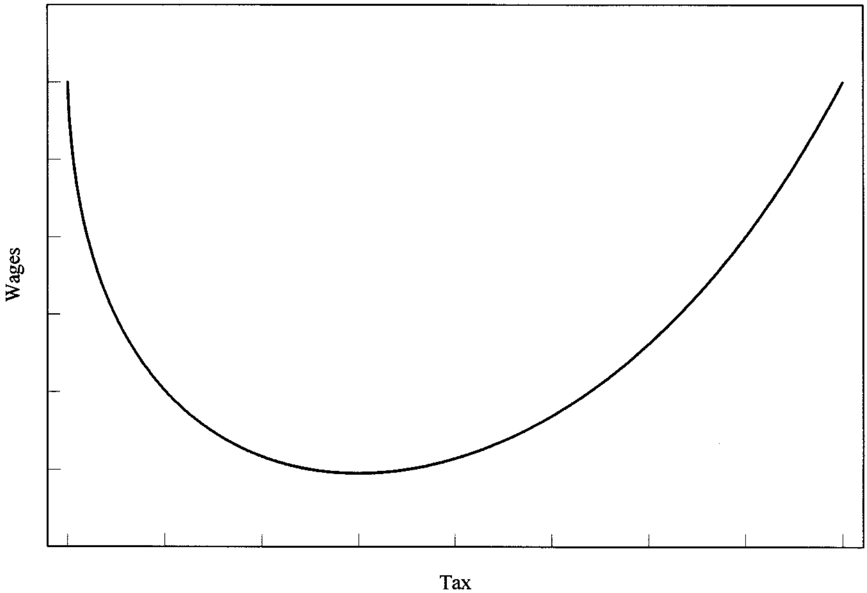

FIG. 1. Wages.

relationship between w and τ takes on the U-shaped pattern shown in Fig. 1.[10]

Rents

Using Eqs. (10), (11), and (16), we can compute $dr/d\tau$:

$$\frac{dr}{d\tau} = -\frac{C_w + C_N N_w}{C_r + C_N N_r}\frac{dw}{d\tau} < 0 \quad \text{if } \frac{dw}{d\tau} > 0$$
$$\geq 0 \quad \text{if } \frac{dw}{d\tau} \leq 0. \tag{18}$$

Rent increases with increases in τ if the increase in τ reduces wages.

[10] To examine the path of wages as τ changes analytically, we need to evaluate the second derivatives of the system, which is impossible without additional structure, and, even with the assumption of relatively simple technology, becomes analytically intractable. It is, however, relatively straightforward to simulate. We need only assume production and congestion technology. We examined Cobb–Douglas production technology: $x = An^{\alpha}l^{(1-\alpha)}N^{\beta}$ and congestion of the form $g(N^a) = \delta(N^a)^{\gamma}$. As one would expect, extensive simulation of the model using these technologies yields the U-shaped pattern shown in Fig. 1 for parameters satisfying conditions assuring downward sloping demand for labor and $\tau^m > 0$. Details of the simulation are available on request.

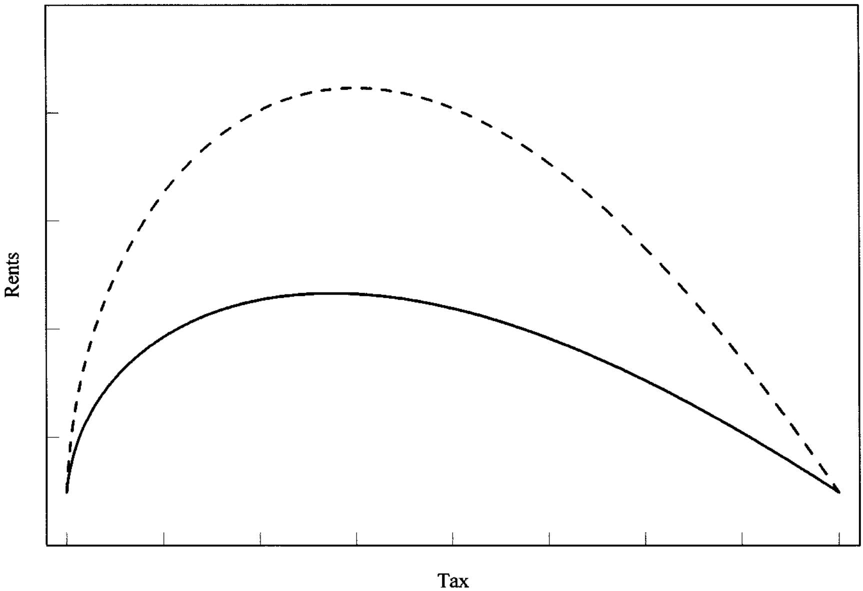

FIG. 2. Rents.

Falling wages imply that, in equilibrium, firms are willing to pay higher rents to be in the region.

Simulation of the model using Cobb−Douglas technology and linear congestion shows that the strength of agglomeration economies plays a role in the effects of τ on rents. Figure 2 shows two simulations with identical assumptions regarding technology and congestion except that the parameter reflecting agglomeration economies (β in footnote 10) is -0.1 in the base case and -0.2 in the high agglomeration case. Note that rents rise faster to a higher peak when agglomeration economies are stronger. Thus the adverse effects of choosing $\tau \neq \tau^*$ are larger when agglomeration economies are stronger. Additional simulation exercises show that this finding holds for more general assumptions with regard to the form of agglomeration.

Transit Prices

Following immediately from Eq. (13), the effects of a change in τ on transit prices is identical to that on wages:

$$\frac{dp^t}{d\tau} = \frac{dw}{d\tau} < 0 \qquad \text{if } \frac{dw}{d\tau} < 0$$

$$\geq 0 \qquad \text{if } \frac{dw}{d\tau} \geq 0. \tag{19}$$

Note that, since $dw/d\tau > 0$ implies $dp^t/d\tau > 0$, an increase in tax rates must result in lower, not higher, subsidies for transit. In this case tax revenues fall and subsidies fall because many fewer people find it attractive to use automobiles, and fewer people use transit.

Community Size

The effects of τ on community size can be readily calculated using Eqs. (10), (11), and (16) as well:

$$\frac{dN}{d\tau} = \frac{N_w C_r - N_r C_w}{C_r + C_N N_r} \frac{dw}{d\tau} < 0 \qquad \text{if } \frac{dw}{d\tau} > 0$$

$$\geq 0 \qquad \text{if } \frac{dw}{d\tau} \leq 0. \tag{20}$$

The numerator of (20) is always negative, and if labor demand is downward sloping ($C_r > -C_N N_r$), the denominator is always positive, so that increases in τ increase N if an increase in τ also results in lower wages. Community size increases with τ up to the point where $dw/d\tau = 0$ because lower wages improve firms' competitive positions, increasing the demand for labor. This finding is consistent with most previous research suggesting that tolling regimes can increase the equilibrium size of a city. Again, simulation reveals that the importance of choosing the correct tax rate increases with the strength of agglomeration economies. When agglomeration economies are strong, community size increases faster to a higher peak as τ approaches τ^* from below than would be the case with lower agglomeration economies. Conversely, community size falls faster as τ exceeds τ^* when agglomeration economies are higher.

Automobile Commuting

The number of people commuting by car follows directly from Eq. (11):

$$\frac{dN^a}{d\tau} = \frac{1}{g_{N^a}} \left(\frac{dw}{d\tau} - 1 \right) < 0. \tag{21}$$

According to Eq. (21), increasing the tax rate will always reduce auto travel, since $dw/d\tau < 1$. As τ increases while $dw/d\tau < 0$, the gains associated with declining congestion offset the additional tax cost and decline in wages for those continuing to drive.

Transit Commuting

There are two effects of increasing τ on transit use. Increasing τ increases the subsidy each driver pays for transit. On the other hand, increasing τ reduces the number of people choosing to drive and hence pay the subsidy. Knowing $dN/d\tau$ and $dN^a/d\tau$, Eq. (15) immediately gives the effects of changing tax rates on transit commuting, $dN_t/d\tau$:

$$\frac{dN^t}{d\tau} = \left(\frac{N_w C_r - N_r C_w}{C_r + N_r C_N} - \frac{1}{g_{N^a}} \right) \frac{dw}{d\tau} + \frac{1}{g_{N^a}} > 0 \qquad \text{if } \frac{dw}{d\tau} \leq 0. \quad (22)$$

As long as $dw/d\tau < 0$, a tax increase raises equilibrium community size. Basically, when $dw/d\tau < 0$, transit prices are falling, reflecting the fact that total subsidy growth is sufficient to increase the equilibrium subsidy per transit user. Note that there is a range in which $dN^t/d\tau > 0$, even though $dw/d\tau$ and $dp^t/d\tau > 0$. This corresponds to a range in which a tax increase reduces both N^a and N, but N^t increases. When $dw/d\tau = 0$, $dN^t/d\tau > 0$, since the second term is positive.

The relationships among N^a, N^t, N, and τ are shown in Fig. 3. N^a is continuously declining until it reaches 0 at τ^m. N^t first rises until it reaches its peak at τ^{Nt}, which is greater than τ^*. N^t then falls, but not all the way to its level at $\tau = 0$. N rises to a peak at τ^*, which corresponds to the point at which $dw/d\tau = 0$. N then falls until $\tau = \tau^m$ where $N^t = N$. From the point of view of maximizing community size or maximizing rental values, the optimal tax is τ^*.

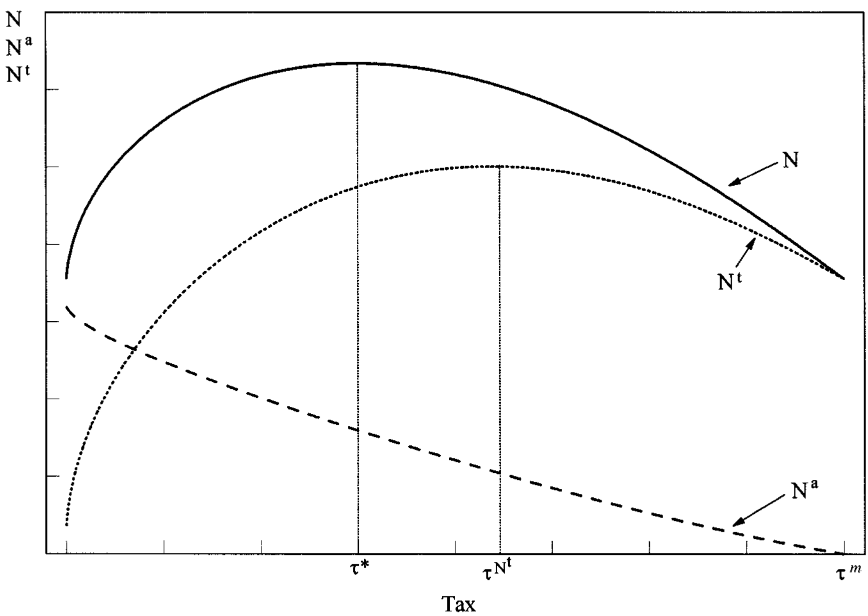

FIG. 3. Total labor, car users, and transit users.

The key empirical implication of the simple model is that the relationship between parking taxes and transit use, land rents, and community size is not monotonic. There is essentially a Laffer curve for parking tax revenues; the effects of changing τ depend largely on where a city lies on the Laffer curve.[11] For cities with high congestion and low τ, we should observe positive relationships between tax changes and transit use, land rents, and community size. The reverse should be true for cities that already have high taxes and low congestion. Thus, while disaggregate empirical studies of the effects of parking (see Gillen [4] and Wilson [16], for example) find a strong positive relationship between parking prices and an individual's transit use, one could observe a negative relationship between parking prices and transit use if parking taxes are too high.

We have not explicitly discussed the role of a change in transit costs except with respect to their effects on $dw/d\tau$. It is easy to show, however, that lower costs result in lower equilibrium wages, transit prices, and auto use, but higher rent, transit use, and employment. Simulation further shows that the adverse consequences of high transit costs increase with the strength of agglomeration.

IV. ENDOGENOUS LAND USE: PARKING SUPPLY AND PRICE

We can extend the basic model to determine the amount of CBD land used for production and the amount used for parking. Let L be the total amount of CBD land and L^s be the amount of land used for parking. L^0 and L^s are determined endogenously and parking operators must pay the market rent to bid land away from business. All land is used either for production or for parking so that

$$L^s + L^0 = L. \tag{23}$$

Parking is produced using a fixed amount of land per space, s.[12] In equilibrium, parking unit costs must equal the parking price so parking prices are $p^a = sr$. The total amount of land required for parking is simply s times the number of people choosing to drive:

$$L^s = sN^a. \tag{24}$$

One other change in the model is needed; eq. (3), which gives net of commuting wages for drivers, must also include the price of parking so (3)

[11] Inman [7] estimates "revenue hills" or "Laffer curves" for various taxes, including wage, income, and business taxes, for the city of Philadelphia and finds that the city is near the peak of the revenue hill in each of these taxes so the idea that a parking tax increase may not generate additional revenues in the long run may not be far-fetched.

[12] This is obviously a simplification. As the price of land increases, multistory garages can be built, reducing the land input per space.

becomes

$$w - \tau - p^a - g(N^a) = q. \tag{25}$$

Most of the comparative statics results are qualitatively similar to those found for the simple model, but the expressions are more complex and less useful expositionally. We focus here only on the differences from the simple model and new insights from the full model (the complete comparative statics results are available upon request). In particular, we reexamine the effects of τ on rent and community size and provide new information on the equilibrium auto use, parking price, and land use.

As in the simple model, most of the comparative statics results turn on the sign of $dw/d\tau$. While the expression for $dw/d\tau$ is considerably more complicated, its sign is determined by the same considerations as in the simple model; $dw/d\tau$ is more likely to be negative if congestion is high, auto use is high, and costs are low. Similar to the simple model, $dr/d\tau$, $dN/d\tau$, and $dN^t/d\tau$ all are greater than 0 if $dw/d\tau < 0$. Unlike the simple model, however, $dr/d\tau$ and $dN/d\tau$ both can take on positive values for part of the range of $dw/d\tau$ within the interval $[0, 1]$. But as $dw/d\tau$ gets larger, $dr/d\tau$, $dN/d\tau$, and $dN^t/d\tau$ all become negative. One can also show that, as $dw/d\tau$ gets larger, $dr/d\tau$ turns negative before $dN/d\tau$, which implies that the tax that maximizes land values is less than the tax that maximizes community size. Finally, just as in the simple model, $dN^a/d\tau < 0$ always. The relative values of the taxes maximizing transit ridership (τ^t), community size (τ^N), land values (τ^r), and minimizing wages (τ^w) are shown in Fig. 4.

Parking Prices and Land Use

Extending the simple model to include parking prices and land use is, in some ways, trivial, but nevertheless yields important insights on the relationships among τ, p^a, L^s, and L^0. Given the assumptions about parking production, changes in rents are directly reflected in parking prices, so $dp^a/d\tau = dr/d\tau$. This finding is analogous to the results of monocentric city models, which find that too much land is devoted to roads because excessive congestion lowers the equilibrium rent. Further, changes in auto use are directly related to land used for parking: $dL^s = -dL^0 = s\,dN^a$. These facts imply that the sign of the relationship between parking prices and auto use depends on the magnitude of $dw/d\tau$. As shown in Fig. 4, increasing parking prices are associated with lower parking use if $\tau < \tau^r$ (the level of τ that maximizes rents) but parking prices and auto use are positively related if $\tau > \tau^r$. Thus, if τ is too high, reducing taxes will increase N^a and increase parking prices. On the other hand, taxes that are too low will result in low parking prices and low values for land, including the land held by parking lot owners.

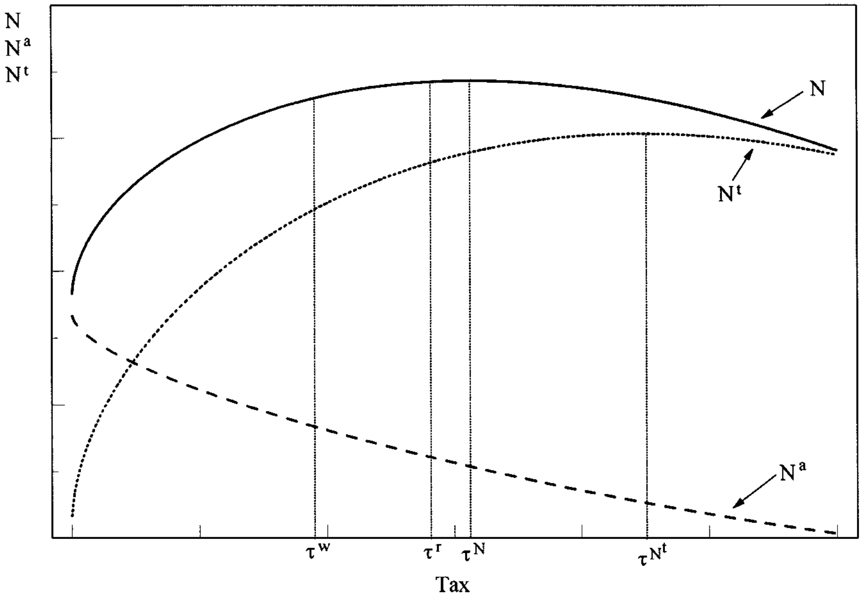

FIG. 4. Total labor, car users, and transit users.

V. CONCLUSION

In this paper we have developed an equilibrium model to directly evaluate the consequences of parking taxes and transit subsidies for equilibrium community size, land values, and modal share. While the model lacks the rich spatial detail of monocentric city models with congestion or the precise modeling of congestion in bottleneck literature, the model highlights the tradeoffs that CBDs face in setting parking taxes and transit subsidies. Like virtually all models examining congestion in urban areas, we find that parking taxes can result in higher land values and larger communities. This work differs from earlier work except that of Tabuchi [15] in that we explicitly consider a congestible mode (auto) and a noncongestible mode (train). Tabuchi presents a clear analysis of the conditions under which cities should employ the rail mode and provide subsidies to the rail rider. While we do not explicitly address these issues, we allow the number of people working in the CBD to be determined endogenously, so that the number of people making the choice between car and train varies with parking tax policy. Thus there is less of a margin to tax auto commuters through parking fees because workers can choose other work locations as fees become too high. Surprisingly, most papers that have considered using parking fees as a substitute for tolls (Arnott *et al.* [1] and

Glazer and Niskanen [5], for example) do not consider the effects of the fees on the long-term location of employment.

In a similar vein, even though most spatial models of congestion explicitly consider the effects of congestion on city size, this is accomplished within a framework in which the CBD is the only employment center. Modern metropolitan areas are polycentric, with CBDs competing within the region for employment. If cities attempt to extract too high a fee from auto commuters, commuters will choose to leave the CBD rather than changes modes. Auto congestion will fall, but at the expense of agglomeration economies. To the extent that the comparative advantage of CBDs depends on a high density of economic activity, the degree of success with which it manages congestion is crucial. As we have seen, the negative consequences of choosing policies that set inappropriately low parking taxes and transit subsidies are greater when agglomeration economies are large.

There are a host of directions in which this research could be extended. One obvious extension is to introduce a more sophisticated spatial framework; another obvious extension would be to incorporate the detailed analysis of congestion found in the literature. A more fruitful innovation, however, would be to examine the role of transit subsidy in the overall tax and fiscal package of a city, since parking taxes are but one factor affecting the overall competitiveness of the CBD and may not be directly linked to the net subsidies from drivers to transit users.

APPENDIX 1

The assumption needed to sign the denominator of (17), which is the expression for $dw/d\tau$, is $C_r > -C_N N_r$. This assumption implies that firms' agglomeration benefits of labor/land substitution associated with a rent increase are not greater than the cost of higher rent. This can be easily seen by examining the firms' costs in wage and rent space. Substituting Eq. (11) into Eq. (10), we find that in equilibrium:

$$\frac{dw}{dr} = -\frac{C_r + C_N N_r}{C_w + C_N N_w}.$$

Since C_w, C_r, and $N_r > 0$ and C_n and $N_w < 0$, the assumption of $C_r > -C_N N_r$ assures $dw/dr < 0$. Thus, for firms to produce at unit cost equal to 1, which is required at equilibrium, increases in rents must always be accompanied by a reduction in wages.

This condition also implies that the demand for labor, N^d, is downward sloping. Using Eqs. (10) and (11) to solve for labor demand:

$$\frac{dN^d}{dw} = \frac{N_w C_r - N_r C_w}{C_r + C_N N_r}.$$

This is negative as long as $C_r > -C_N N_r$ so increases in wages always result in lower employment.

REFERENCES

1. R. J. Arnott, A. de Palma, and R. Lindsey, A temporal and spatial equilibrium analysis of commuter parking, *Journal of Public Economics*, **45**, 301–335 (1992).
2. R. J. Arnott and J. J. MacKinnon, Market and shadow land rents with congestion, *American Economic Review*, **68**, 588–600 (1978).
3. G. C. Blomquist, M. C. Berger, and J. P. Hoehn, New estimates of the quality of life in urban areas, *American Economic Review*, **78**, 91–107 (1988).
4. D. W. Gillen, Estimation and specification of the effects of parking costs on urban transport choice, *Journal of Urban Economics*, **4**, 187–199 (1977).
5. A. Glazer and E. Niskanen, Parking fees and congestion, *Regional Science and Urban Economics*, **22**, 123–132 (1992).
6. J. V. Henderson, Congestion and optimum city size, *Journal of Urban Economics*, **2**, 48–62 (1975).
7. R. P. Inman, Can Philadelphia escape its fiscal crisis with another tax increase? *Business Review*, Federal Reserve Bank of Philadelphia, September–October, 3–20 (1992).
8. E. S. Mills, "Studies in the Structure of the Urban Economy," Johns Hopkins Univ. Press, Baltimore (1972).
9. Y. Oron, D. Pines, and E. Sheshinski, Optimum vs. equilibrium land use pattern and congestion toll, *Bell Journal of Economics and Management Science*, **4**, 619–636 (1973).
10. J. Roback, Wages, rents and the quality of life, *Journal of Political Economy*, **90**, 1257–1278 (1982).
11. K. Sasaki, Income class, modal choice, and urban spatial structure, *Journal of Urban Economics*, **27**, 322–343 (1990).
12. R. M. Solow, Congestion cost and the use of land for streets, *Bell Journal of Economics and Management Science*, **4**, 602–618 (1973).
13. A. M. Sullivan, The general equilibrium effects of congestion externalities, *Journal of Urban Economics*, **14**, 80–104 (1983).
14. A. A. Summers and P. D. Linneman, Patterns and processes of urban employment decentralization in the U.S., Wharton Real Estate Center Working Paper, Univ. of Pennsylvania (1990).
15. T. Tabuchi, Bottleneck congestion and modal split, *Journal of Urban Economics*, **34**, 414–431 (1993).
16. R. W. Willson, Estimating the travel and parking demand effects of employer-paid parking, *Regional Science and Urban Economics*, **22**, 133–145 (1992).
17. J. Yinger, Bumper to bumper: A new approach to congestion in an urban model, *Journal of Urban Economics*, **34**, 249–274 (1993).