ELSEVIER Regional Science and Urban Economics 25 (1995) 395–410

regional SCIENCE & urban ECONOMICS

Optimal transportation policy with strategic locational choice

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Received August 1994; revised version received October 1994

Abstract

This paper presents a model of strategic locational choice by duopolistic firms in an urban area where consumer locations are endogenous and where a public facility is exogenously fixed. A welfare analysis taking their strategic behavior into account is conducted. It is shown that the firms' equilibrium locations often differ from the optimal locations which, in contrast to standard location theory, are not at the quartiles of the urban area. Corrective transportation taxes or subsidies can be used to support an optimal locational structure. Changes in transportation costs require unit-for-unit offsetting changes in transportation taxes or subsidies.

Keywords: Transportation policy; Spatial equilibrium; Public facilities

JEL classification: R00; H00

1. Introduction

Both private and public facilities combine to shape the landscape of modern cities. Large private firms, whether in the manufacturing, retailing, or service sectors exert a major influence on consumers' residential choices. Similarly, many public facilities such as schools, hospitals, and major transportation nodes affect the locational choices of both households and

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SSDI 0166-0462(95)02092-6

firms. Clearly, transportation costs are also crucial determinants of urban structure.

The role of transportation costs is central to received theories of urban economics (see, for example, Fujita, 1989). There are as yet, however, very few attempts to integrate both private and public facilities in urban economic models. While it is commonplace to assume that firms operate competitively and are located a priori in a given central business district, it is somewhat unnatural to model large urban firms as perfect competitors, since spatial differentiation often creates a situation in which firms have some market power. Competitive models of urban structure can be used to show how the spatial distribution of public services can affect private sector locational decisions (see, for example, Kanemoto, 1980). However, in a small-number setting, strategic interactions among firms are crucial. Furthermore, these interactions may themselves be affected by public facilities or other distinctive geographical features.[1]

The purpose of this paper is to study spatial structure in a simple model that incorporates a single public facility and duopolistic private firms. We begin by analyzing the nature of the optimal spatial configuration of firms and households. We then consider the equilibrium spatial configuration and find that equilibrium outcomes are often suboptimal despite the absence of congestion or other technological or consumption externalities. In the present model, market failure can be traced to the strategic externalities arising between firms. Having identified the source of the market failure, we are then able to identify possible corrective policies. In particular, taxes or subsidies on transportation can be used to support an efficient locational pattern. We also discuss how the optimal tax must adjust to changes in the economic environment, resulting, for example, from technological improvements or other factors that alter transportation costs. Our results differ significantly from those encountered in transportation economics where optimal location analyses typically ignore strategic considerations.

2. The model

The basic model to be used here is developed in detail in Thisse and Wildasin (1992) (hereafter TW). In this section, we outline the structure and assumptions of the model and recapitulate some results on the characterization of equilibria that are relevant for the purposes of the present study.

[1] While most research in urban economics has abstracted from strategic considerations, there are, nevertheless, a few studies that incorporate strategic elements in the analysis of urban location and transportation. See, for example, de Palma (1992), Fujita and Thisse (1986, 1991), Stahl (1987), and Thisse and Wildasin (1992) and references therein.

One distinctive feature of the model compared with previous ones is that it allows for the presence of both private firms and public facilities. More precisely, we assume there are two private firms (as in Fujita and Thisse, 1986) and, in addition, a single public facility. The location of the public facility is exogenously determined, while the locations of the firms are determined within the model. We assume that there is a continuum of households who must locate in the urban area. The size of the population is fixed at N, and each household resides on a lot of a given size, the same for all households. We normalize this common lot size at one. Households travel both to the public facility, for example, to take advantage of some necessary public service, and to one of the private firms at which some private consumption commodity can be purchased. Each household is assumed to make just one trip to each, and these trips are carried out independently, so that the total transportation cost borne by each consumer is the sum of the costs he incurs in travelling to a private firm and to the public facility. In equilibrium, households will compete for locations which are favorably situated, while firms will compete for locations which are profitable; an equilibrium occurs when land prices clear the land market and when no agent has any incentive to change locations. We now describe this framework in more detail.

The underlying spatial framework of the model is linear. We suppose that the public facility is located at the point $N/2$, and households and firms may locate anywhere along the real line.[2] However, we know from the analysis in TW that all households will, in equilibrium, be located symmetrically around the public facility, and will thus cover the interval $[0, N]$, to which we restrict our attention henceforth. Locations and distance will therefore be measured by distance from 0, the left endpoint of the urban area.

Each consumer has an exogenously-given income, Y, which it uses to purchase the consumption good from one of the private firms, to pay land rents, and to cover the cost of transportation to the private firms and to the public facility. We assume that the travel cost is a fixed amount, t, per unit of distance (regardless of the quantity of the consumption good purchased). We assume that the price of the consumption good is the same for both firms and is set equal to one, while the marginal cost of production is constant and equal to c for both firms.[3] Let $R(\xi)$ denote the land rent at location ξ, and

[2] Alternatively, the point $N/2$ can be reinterpreted as a CBD where pre-existing firms are established, pay to the households a wage equal to Y, and earn zero profits. Our results would remain the same in this context.

[3] This assumption focuses attention on the locational interdependence of firms and households when firms price above marginal cost, but does not itself address the issue of price competition between firms. However, the divergence between price and marginal cost, $1 - c$, in effect parameterizes the intensity of price competition. Furthermore, it is argued in the conclusion that our results would essentially be the same in any extended model incorporating price competition, if that model would (as one would expect) give rise to symmetric equilibria.

let x_1 and x_2 denote the locations of the two firms, with $x_1 \leq x_2$. A household located at point ξ will purchase the private good from the firm i that is nearest, that is, for which $|x_i - \xi|$ is smallest. Letting $z(\xi)$ denote the consumption of the private good for this household, the household's budget constraint implies that

$$z(\xi) = Y - t|x_i - \xi| - t\left|\frac{N}{2} - \xi\right| - R(\xi) . \tag{1}$$

Since households have identical endowments, they must have identical utility levels in equilibrium, which implies that they all consume the same amount of the consumption good. Let z^* denote this common level of consumption. Households will compete for more favorable locations, and rents there will be bid up sufficiently to offset any gains that residents there might receive from lower transportation costs. The land rent gradient will thus mirror the structure of transportation costs, as is typical in urban economics models. We assume for simplicity that the opportunity cost of land is zero, so that land rent at the extremities of the urban area will be zero as well. It follows from this fact and from (1) that the consumption of the household located at 0, which is the same as the consumption of all other households in equilibrium, is given by

$$z^* = Y - t\left(x_1 + \frac{N}{2}\right), \tag{2}$$

recalling that firm 1 is assumed to be the nearest one to the consumer located at point 0 and is therefore patronized by this consumer.

Firms are assumed to choose simultaneously their locations, anticipating the reaction of consumers to their decisions. In other words, as indicated in the introduction, locational choices are modeled as a two-stage game in which firms move first and households second.[4] The sales of each firm are given by the size of its market area times the consumption expenditure of each household. Its profit is, therefore, equal to $1 - c$ times its sales. When a given firm unilaterally changes its location, it affects both the size of its market area and the common level of consumption, z^*. The former will be referred to as the *market area effect*, while the latter is called the *consumption effect*. As discussed in Fujita and Thisse (1986), the market area effect tends to draw the firms together, as each gets some benefit from encroaching on the other's territory. On the other hand, this may lead to increases in transportation costs, which, in turn, reduce the level of consumption, z^*. In equilibrium, firms must balance these effects against one another in such a

[4] This is in accordance with general equilibrium models involving agents with market power. See, for example, Bonanno (1990) for a recent survey.

way as to maximize profits. We assume that firms choose their locations non-cooperatively.

In TW (Theorem 1), we have shown the existence of a unique Nash equilibrium under the following conditions:[5]

(i) if $t \leqslant 2(Y/N) \leqslant 3t$, then the firms will locate at the endpoints of the urban area, with

$$x_1^e = 0 \quad \text{and} \quad x_2^e = N ; \tag{3a}$$

(ii) if $3t \leqslant 2(Y/N) \leqslant 4t$, then the firms will locate symmetrically about the public facility with locations given by

$$x_1^e = \frac{N}{2} + \frac{Y}{t} - 2N \quad \text{and} \quad x_2^e = \frac{N}{2} - \frac{Y}{t} + 2N ; \tag{3b}$$

(iii) if $4t \leqslant 2(Y/N)$, then the firms agglomerate at the urban center, i.e.

$$x_1^e = x_2^e = N/2 . \tag{3c}$$

The fact that firms seek maximum geographical differentiation when the travel cost is high, and minimum differentiation when it is low, may come as a surprise. As stated above, there are two effects at work in this model, i.e. the market area effect and the consumption effect. For t sufficiently large, any unilateral move by a firm toward the center strongly reduces the quantity consumed so that the latter effect overcomes the former. In other words, it never pays for firms to deviate from the endpoints where they enjoy spatial monopoly power. On the other hand, when t is low enough, the quantity consumed is almost unaffected by a firm's move toward the market center. This case is reminiscent of Hotelling's model with fixed and equal prices. So, the market area effect now predominates and the two firms choose to locate together at the urban center. A priori, one might think that location no longer matters when transportation costs are low, thus implying that dispersion is the typical equilibrium configuration. This intuition turns out to be wrong. There is a tendency toward central agglomeration when t is small, precisely because firms are, in this case, able to attract consumers from the whole area without facing a sharp decrease in local demands. (This tendency is robust against alternative demand systems, market structure, and equilibrium concept, as discussed in Fujita and Krugman, 1994, and Thisse, 1993.)

For an equilibrium to exist, the individual income Y must be larger than the minimum (across firm locations) of the maximum travel cost that any

[5] In TW, it is assumed that $c = 0$. The characterization of the equilibrium locations of the firms remains valid when $c > 0$, since, in either case, the profit-maximizing firm seeks to maximize its sales volume.

individual has to incur to consume both the private and public goods. This condition is given by $Y \geqslant tN/2$ (see (i) above), which can be viewed as a basic resource adequacy constraint for the economy. When the value of t is relatively high, the firms locate at the endpoints of the urban center in a 'fully dispersed' equilibrium; as the value of t falls, the firms move to a symmetric 'partially dispersed' equilibrium, and eventually to an 'agglomerated' equilibrium. Note that this model *allows* agglomeration to occur in equilibrium, but that agglomeration is not imposed as an exogenous structural feature of the model as is often the case in urban economics.

3. Optimal urban structure

Having derived a theory of equilibrium urban structure, it is natural to ask whether that structure is optimal according to some appropriate economic criterion. Within the context of the above model, there are three groups of agents with whose welfare we should be concerned. First, there are the consumers, who derive utility from the consumption of the private good provided by the firms. As we have already seen, the level of consumption of this good is the same for all consumers in equilibrium and is given by z^*. This provides a simple measure of welfare for each individual consumer. The aggregate real income of all consumers taken together is just Nz^*. A second group whose welfare is determined within the model is the landowners to whom the rents on land accrue. Their aggregate real income is the total land rent in the urban area, which is given by the expression

$$TLR = \int_0^N R(\xi)\,\mathrm{d}\xi\ . \tag{4}$$

Finally, the profits of the firms are part of the real income of their owners. Since equilibria are symmetric, each firm serves half of the market and earns a profit equal to $(1-c)Nz^*/2$; that is, the profit margin times the volume sold; the total profit accruing to both firms is therefore $(1-c)Nz^*$.

The aggregate real income of consumers, landowners, and profit recipients provides a natural social welfare indicator for this model. Of course, this suppresses issues relating to the distribution of income among and within these groups. If the government had lump-sum redistributive instruments at its disposal, these could be used to equalize the social value of income among all agents. In this case, distributional objectives are fully met and social welfare is maximized when aggregate income is maximized. Since we are not primarily concerned with distributional issues in this paper, we shall use aggregate income as our social welfare indicator. However, it should be noted that if ideal redistributive instruments are not available, the distribution of income can be important for social welfare. Therefore, in analyzing alternative locational patterns and policies, we shall also describe their impact on the distribution of income among consumers, landlords, and the owners of firms. Aggregate social welfare or real income is given by

$$W = (2 - c)Nz^* + TLR . \tag{5}$$

It will be convenient to have a more explicit expression for total land rent. Assuming that the firms are symmetrically located, the land rent gradient is depicted in Fig. 1. Since consumers located between firms 1 and 2 must visit one of these firms as well as the public facility located at the center, all of the locations between firms 1 and 2 are equally favorable, which is reflected in the fact that the equilibrium land rent is constant in the interval $[x_1, x_2]$. Outside this interval, land rent declines at the rate $2t$ with distance from the center, since each additional unit of distance entails an increase in the travel cost to both the public facility and to the nearest firm. Total land rent is given by the area under the curve in Fig. 1, i.e.

$$TLR = 2t(Nx_1 - x_1^2) . \tag{6}$$

3.1. Characterization of optimal locations

We begin our welfare analysis by determining the optimal locations for firms. Imagine that firm locations could be directly controlled by a planner, but that markets function freely conditional on the locations thus de-

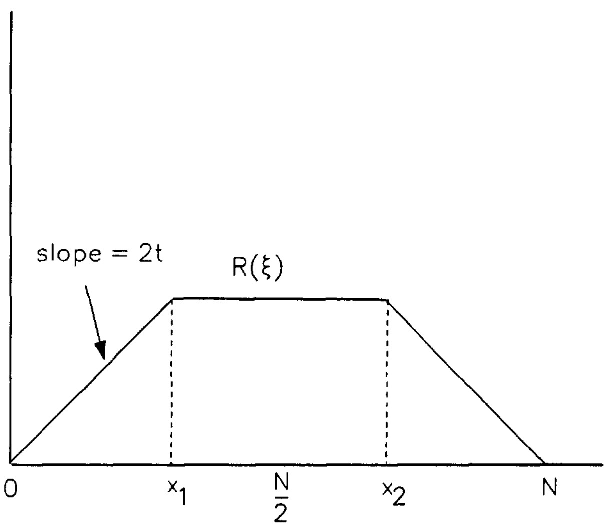

Fig. 1. Equilibrium land rents.

termined. Clearly, we can restrict attention to symmetric configurations. Substituting (2) and (6) into (5) yields

$$W = (2-c)NY - \frac{2-c}{2}tN^2 + cNtx_1 - 2tx_1^2\,, \tag{7}$$

which is strictly concave in x_1. The first-order condition shows that the optimal configuration is given by

$$x_1^{\circ} = \frac{cN}{4} \quad \text{and} \quad x_2^{\circ} = N - \frac{cN}{4}\,. \tag{8}$$

That is, *optimality requires that the firms locate between the edges and the quartiles of the urban area.*

Our result that the optimal locations of the firms are generally outside the quartiles of the urban area, or possibly at its endpoints, is in sharp contrast to standard results in location theory, according to which firms should be located at the first and third quartiles in order to minimize total transportation cost, given by $tN^2/2 - tNx_1 + 2tx_1^2$. The difference in results is attributable to the fact that the profits of private firms are included in the social welfare criterion. Indeed, neglecting those profits would yield a social welfare criterion given by

$$\begin{aligned}\hat{W} &= Nz^* + TLR \\ &= NY - N^2\frac{t}{2} + tNx_1 - 2tx_1^2\,, \quad \text{by (2) and (6)}\,,\end{aligned}$$

which is again strictly concave in x_1. Applying the first-order condition shows that the corresponding optimal locations are given by $x_1 = N/4$ and $x_2 = 3N/4$ – that is, the quartile result. This follows from the fact that the welfare criterion $\hat{W}$ is actually equal to total income NY minus total transportation costs, so that welfare maximization is equivalent to minimization of transportation costs.

When firms are located at the endpoints of the urban area, consumption per household, z^*, attains its maximum value. Since profits are given by $(1-c)Nz^*$, this configuration also maximizes the profits of firms. Landlords, however, are adversely affected by this arrangement. As can be seen from (6), total land rent is always reduced as the firms move away from the urban center and is reduced to zero when the firms are fully dispersed. Thus, attainment of the optimal locational structure entails a trade-off among the interests of the consumers and firms, on the one hand, and landowners on the other. Since the price of the consumption good has been normalized to one, $1-c$ is the Lerner index of firms' market power. When only aggregate income matters for social welfare, and when this index takes its maximal value ($c=0$), the interests of consumers and firms completely dominate those of the landowners and the firms optimally locate at the endpoints of the urban area. As c increases from 0 to 1, this index decreases and the optimal locations move continuously from the endpoints to the quartiles. Note that both firms and consumers become worse off, while landowners become better off. This apparently surprising result arises because the interests of firms and consumers are opposed to those of landowners. In this model, a lower Lerner index decreases the importance of profits in aggregate income, so that a planner facing a reduction in the market power of firms attaches less importance to the common interests of consumers and firms and more to those of landowners.

Since the difference between our welfare criterion W, as given in (5), and $\hat{W}$ is just the profits of the duopolistic firms, we should re-emphasize that the existence of non-zero profits in our model is attributable to the assumption that output is sold at a price in excess of marginal cost. Thus, determining optimal locations by taking firm profits into account (i.e. using W in (5) as the social welfare criterion) is inherently a second-best exercise. It yields the *conditionally* optimal firm locations, taking the noncompetitive industry structure and associated absence of marginal-cost pricing as given. If marginal-cost pricing could be enforced, the (variable) profits of the firms would equal zero and the welfare criterion would be $\hat{W} = Nz^* + TLR$ which, as we have seen, is just total income less transportation costs. At a first-best optimum, prices would indeed be set in this way and then the optimal firm locations would be at the quartiles. While this characterization of the first-best optimum is certainly worth noting, the following discussion focuses on the second-best optimal locations given by (8). The second-best optimum appears to be the more interesting one, given the underlying duopolistic structure of the model, unless one wishes to assume that policymakers can force firms to behave like perfect competitors.[6]

As an aside, it is interesting to consider what happens when the model is modified so that there are no private firms. More precisely, suppose that there are two types of public goods or services, one supplied at a centrally-located facility and the other provided by two facilities whose locations are variable. This framework is one in which no profits accrue to private firms, bringing the model much closer to those that are traditionally used to analyze optimal facility location. In this case, the social welfare criterion $\hat{W}$, defined above, is the appropriate one. As we have seen, optimality requires that the two facilities should be located at the quartiles, as in standard location models. This highlights again the role of private firms and of the inclusion of their profits in social welfare in our analysis.

[6] Note that if marginal-cost pricing could somehow be imposed, the profits of both firms would vanish. Each would then be indifferent both about its own location and about the location of its rival, and, as a consequence, equilibrium locations would be completely indeterminate.

3.2. The nature of market failure

Having characterized both the equilibrium and optimal locations of firms, as given by (3) and (8), we observe that they do not generally coincide. In some cases, the firms are too far apart, in other cases they are too close together, and, possibly, their locations may exactly coincide with the optimum. In the limiting case where $c = 0$, the optimal locations are at the endpoints of the urban area and firms choose to locate there, in equilibrium, when transportation costs are large enough (see (3a)); for lower values of t, the firms locate in the interior of the urban area and there is, therefore, insufficient dispersion. This market failure arises due to a *strategic externality* between the firms when choosing their locations; for t small enough, the market area effect dominates the consumption effect because z^* is not very sensitive to changes in a firm's location. Each firm, therefore, moves inward from the edges of the urban area in order to capture more of the market from its rival. When $c > 0$, it is no longer optimal for the firms to be located at the edges of the urban area, but the firms may still be insufficiently dispersed. For example, when t is very small (see (3c)), the firms are fully agglomerated, but this cannot be optimal for any value of c, since the firms are never located inside the quartiles at the optimum. Firms may also be *excessively* dispersed, however: for t relatively large (see, for example, (3a)), firms choose to locate far apart while, for c large enough, it is socially desirable for them to be closer together. In such cases, the consumption effect is 'too large' relative to the market area effect.

For $c > 0$, using (3b) and (8), the market equilibrium is optimal ($x_i^e = x_i^o$) when the transportation rate and the marginal production cost satisfy

$$\tilde{c} = \frac{4Y}{N}\frac{1}{t} - 6\,, \tag{9}$$

provided that $\hat{c}$ is positive. This condition is satisfied if and only if $3t < 2Y/N$, corresponding to (3b) and (3c). When $c > \hat{c}$, firms are too dispersed, while firms are insufficiently dispersed when $c < \hat{c}$. If $3t > 2Y/N$, corresponding to (3a), the firms are excessively dispersed for any positive value of c. Expression (9) can be used to define a partition of the (t, c) space as shown in Fig. 2, where the heavy line shows combinations of t and c for which the market equilibrium is optimal. Clearly, in almost all cases, *the market fails to support efficient configurations*.

Note, finally, that the failure of markets to produce efficient outcomes cannot be attributed to the fact that the firms in this model engage in non-competitive pricing. As c increases, the divergence between price and marginal cost, as measured by the Lerner index, diminishes. Yet the equilibrium locations do not necessarily get closer to the optimal locations as c rises, and, indeed, the divergence between equilibrium and optimal

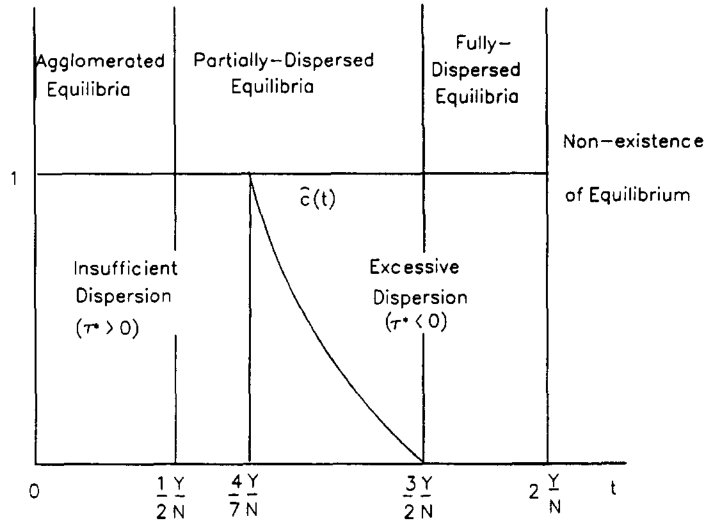

Fig. 2. Types and welfare properties of equilibria.

locations can become *larger*.[7] Market failure in this model is intrinsically locational in nature, and is not simply a consequence of the specification of pricing behavior.

3.3. Correction of market failure

Taxes and subsidies provide a means by which market failure due to strategic externalities can be corrected, much in the spirit of Pigou. Suppose that the government is able to impose a tax (or a subsidy, when negative) on transportation of τ per unit distance traveled. Gasoline taxes, public transportation pricing, or direct tolls provide practical examples of policy instruments that can alter (pecuniary) transportation costs. Suppose, further, that the proceeds of this transportation tax are paid back to consumers as uniform lump-sum transfers. (If transportation is subsidized, so that $\tau < 0$, then the lump-sum transfer is to be interpreted as a lump-sum tax.) Can the government improve the efficiency of the system through appropriate choice of the tax rate τ?

[7] An example will illustrate. Suppose that $t > (2/3)(Y/N)$, so that the equilibrium locations of the firms are at the endpoints of the urban area (see (3a)). Consider the optimal locations, as given by (8), for $c = 0$ and $c = 1/2$. In the first case, the equilibrium locations are optimal; in the second case, where the Lerner index has fallen from 1 to 1/2, the firms still choose to locate at the endpoints but the optimal locations are closer to the center of the urban area. Indeed, still higher values of c bring the optimal locations still closer together, further increasing the difference between equilibrium and optimal locations.

It is convenient to define some new notation for the model in which government taxes appear. Let $\bar{t} \equiv t + \tau$ denote unit transportation costs inclusive of tax. In view of (3), it follows that a tax acts as a separating force, causing the equilibrium locations of the firms to be further apart, while a subsidy acts as an attracting force, drawing the firms closer together. Denote by $\bar{z}^*$ and $\overline{TLR}$ the equilibrium pre-household consumption and total land rent in the presence of the tax τ. Since tax revenues are rebated to consumers,

$$\bar{z}^* = Y - \bar{t}\left(x_1 + \frac{N}{2}\right) + \frac{G}{N}, \tag{2'}$$

where G is total tax revenue, defined by

$$G = \tau \frac{N^2}{2} - \tau N x_1 + 2\tau x_1^2 . \tag{10}$$

The expression for total land rents in the presence of the tax is identical to that given in (6), except that t must be replaced by $\bar{t}$. Therefore, social welfare in the presence of the tax is given by

$$\bar{W} = (2 - c)N\bar{z}^* + \overline{TLR} .$$

We now show that the optimal value of τ is that which sustains the optimal locations given by (8). Since increasing τ leads to firms to disperse, there is, therefore, one value of τ for the two firms to be optimally located in equilibrium. The precise value of τ that does this is the value of τ for which $x_i^e = x_i^o$; from (3b) and (8), this is calculated to be

$$\tau^o = \frac{4}{6+c}\frac{Y}{N} - t . \tag{11}$$

Certain properties of the optimal tax rate τ^o are immediate from (11). The optimal tax rises with income and falls with population. It also falls, unit for unit, with the real (non-tax) transportation cost t. One implication of this is that if real transportation costs should fall in such a way that the firms would be drawn away from the optimal locations, the transportation tax should adjust upward so as to keep the total transportation cost $\bar{t}$ constant and thus preserve the optimal spatial configuration. If an optimal transportation policy is applied, it follows that *real reductions in transportation costs do not induce any change in the urban structure*, nor do travel patterns change for any consumer. However, *transportation improvements yield benefits in the form of higher consumption and higher profits*, as the real cost of travel falls for all consumers, while the taxes that preserve the optimal structure are redistributed to consumers so as not to reduce their real incomes. (In the event that it is optimal to subsidize transportation, reductions in t result in a reduction in the optimal subsidy rate, thus lowering the lump-sum taxes imposed on consumers.) Interestingly, technological improvements that lower production costs – or increase firms' market power as measured by the Lerner index – lead to a more dispersed optimal configuration, and should, therefore, be accompanied by an increase in the transportation tax.

Finally, let us compare these results with those obtained when there are no corrective policies. As in Theorem 4 in TW, it can be shown that social welfare is not monotonic in real transportation costs t (see Fig. 3). If fact, while marginal reductions in t do unambiguously raise welfare when firms are in fully-agglomerated and fully-dispersed equilibria, there is a range of intermediate values of t, supporting partially-dispersed equilibria, where welfare can actually increase as t rises. This is a paradoxical result that can be better understood in the light of the preceding analysis. Starting from a partially-dispersed equilibrium, an increase in t has two effects on welfare. On the one hand, an increase in t leads to more dispersed location patterns, which may raise welfare. On the other hand, an increase in t entails an increase in the real resource cost of travel, which tends to reduce welfare. The welfare effect of a marginal increase in t is therefore ambiguous. The (local) maximum of welfare shown in Fig. 3 occurs at $t^* = (2/\sqrt{11-c})(Y/N)$, at which these two effects just balance. However, as we now know from the above analysis, this is an imperfect outcome; ideally, a corrective tax should be used to sustain the optimal location pattern. When this is done, reductions in real transportation costs always increase welfare, which is in accordance with intuition.

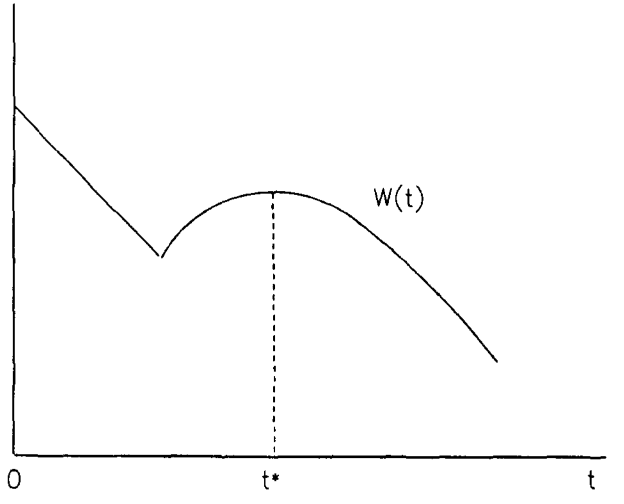

Fig. 3. Welfare and unit transportation cost.

4. Conclusion

The foregoing analysis has investigated optimal locational arrangements for firms in an urban area that also contains a fixed public facility. We have found, somewhat surprisingly, that firms do not optimally locate at the quartiles of the urban area, and that this is true regardless of the value of the transportation cost. Equilibrium locations often differ from the optimal ones due to the operation of the market area effect, first identified by Hotelling. We have also seen that the market failure arising from the strategic choice of locations by firms can be corrected through the imposition of a transportation tax or subsidy. Finally, decreases in transportation costs must be matched by increases in transportation taxes, or reductions in subsidies, in order to preserve an optimal spatial structure.

One limitation of the model is that it does not explicitly deal with price competition between firms. Within the present framework, it would seem reasonable to assume that firms choose their prices and locations before consumers move. Because of the symmetry of the model, one would presume that any equilibrium should be one in which the firms locate symmetrically and charge identical prices. So long as this is the case, our analysis remains essentially valid, since any changes in the identical prices charged by both firms only redistribute income between consumers and firms, leaving unchanged the locations of both consumers and firms. Hence, we expect that our results are robust to generalizations that allow for price competition; a formal proof of the existence of equilibrium with price competition would certainly be non-trivial, however, so our remarks here are somewhat speculative.

Another strong limitation of our model is that consumers make independent trips to the public and private facilities. Yet the existence of multipurpose trips is well documented and supported by many empirical studies (see, for example, Thill and Thomas, 1987). If consumers are allowed to do trip-chaining, it is then readily verified that both the equilibrium and the optimum coincide; the two firms locate with the public facility at the city center. This is because the consumption of the composite good is now independent of the firms' locations. Hence, only the market area effect matters and the agglomeration occurs as in the standard model of spatial competition. However, if multipurpose shopping is reasonable for some goods (you buy your newspaper on the way to the railway station), it is not for others (you do not buy shoes on the way to the hospital). Accordingly, one may expect some private facilities to be clustered at the city center because of trip-chaining, while others are dispersed because some goods are bought separately.

Our analysis has taken as given the attributes of the 'public facility,' such as its size, quality, and so forth. The model could be extended to incorporate the benefits of the facility explicitly in the utility function of households, and the sharing of the costs of provision of the facility through a tax system could be represented explicitly as a subtraction from the income of households. There are several related questions to explore in such a setting. The fundamental normative problem is to determine the optimal level of provision of the services of the facility (e.g. optimal size or quality). The fundamental positive problem is to understand how the level of provision of the facility's services may affect locational choices. These questions are closely related. If the provision of public services interacts with locational choices, normative evaluation of the level of provision requires that the locational impact of the policy be taken into account. This is necessary because equilibria in our model are not first-best efficient and the first-order welfare effects of public facility provision on locational decisions cannot be assumed to vanish. These issues go beyond the scope of the present paper. Here let us simply observe that the present model can be interpreted as one that takes the level of facility attributes as exogenously fixed, with the utility of the public facility to consumers and its cost of provision subsumed within the structure of preferences and endowments. Under this interpretation, our analysis investigates the efficiency of market equilibria *conditional* on whatever level of service provision has been selected. In one sense, our model is very general, since it permits but does not require public facility attributes to be fixed at their optimal values.

The analysis of transportation policy in an imperfectly competitive setting is still in its infancy. It would be inappropriate to use the preceding results as a guide to real policy. However, the results do show that policy evaluation that neglects strategic interactions in the location decision making of firms can be seriously misleading. These interactions introduce distortions into the economic environment that need to be taken into account if the real consequences of policy interventions are to be properly understood. Our results also show that public and private facilities play rather different roles in the analysis of equilibrium urban structure and in policy evaluation. Again, approaches that omit this distinction or that fail to take into account the existence of both types of facilities may lead to inappropriate conclusions concerning transportation policy. In order to put policy evaluation in urban areas on more solid foundations, it would be desirable to extend the present model in several directions. Among these, we would mention the existence of different types of private firms and public facilities, the role of multipurpose trips, the existence of several transportation modes, and the implications of urban congestion.

Acknowledgements

P. Jehiel, T. Kuroda, M. Fujita, Y. Papageorgiou, S.-K. Peng, K. Small, and an anonymous referee provided very helpful comments on an earlier version of this paper. The paper was presented at the Regional Science Association meetings (Houston) and at a conference on 'Decentralization and Economic Organization of Space' (Marseille). This work was carried out while the first author was a Fellow of the Institute for Advanced Study at Indiana University. The second author also thanks the Ministère de la Recherche (France) for its support.

References

Bonnano, G., 1990, General equilibrium theory with imperfect competition, Journal of Economic Surveys 4, 297–328.

de Palma, A., 1992, A game-theoretic approach to the analysis congested networks, American Economic Review (Papers and Proceedings) 82, 494–500.

Fujita, M., 1989, Urban economic theory (Cambridge University Press, Cambridge).

Fujita, M. and P. Krugman, 1994, When is the economy monocentric? Or von Thünen and Chamberlain unified, Regional Science and Urban Economics, in press.

Fujita, M. and J.-F. Thisse, 1986, Spatial competition with a land market: Hotelling and Von Thunen unified, Review of Economic Studies 53, 819–841.

Fujita, M. and J.-F. Thisse, 1991, Spatial duopoly and residential structure, Journal of Urban Economics 30, 27–47.

Kanemoto, Y., 1980, Theories of urban externalities (North-Holland, Amsterdam).

Stahl, K., 1987, Theories of urban business location, in: E.S. Mills, ed., Handbook of urban economics (North-Holland, Amsterdam), 759–820.

Thill J.-C. and I. Thomas, 1987, Toward conceptualizing trip-chaining behavior: A review, Geographical Analysis 19, 1 – 19.

Thisse, J.-F., 1993, Oligopoly and the polarization of space, European Economic Review 37, 299–307.

Thisse, J.-F. and D.E. Wildasin, 1992, Public facility location and urban spatial structure: Equilibrium and welfare analysis, Journal of Public Economics 48, 83–118.