Market Structure and Profit Sharing in Commuter Railway and Housing Development *

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1. Introduction

The development of large capacity public transit networks is widely considered as the most effective method to cope with transportation congestion problems in metropolitan areas. And it has two important advantages over automobile transportation: energy-efficiency and equity of mobility right for citizens. However, it must be recognized that in a developing country, cross regional equity may be greatly injured if national income is used for subsidizing large capacity public transit (in particular railways) networks in large cities. This is because a large part of railway investment is capitalized into land value. It is therefore important to design legal and economic schemes that make the profit yielded by investment on public transit railways to be returned back to the investors. A general treatment of this issue can be found in Hayashi (1989). In this paper we consider a case where a residential new town and a commuter railway connecting it to the CBD of the city is planned. A theoretical analysis for this case based on urban economics can be found in Kanemoto and Kiyono (1995). In the present paper several typical market structures that characterize the relationship of the railway firm and the residential developer are examined. It is hoped that by a comparison of the numerical results of these structures, useful insight could be obtained for designing practical policies on urban public transit development, especially for developing countries.

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2. The model

A transit line is planned to connect the CBD and a suburban area (new town), where the developer builds houses for sale (or rent), see Figure 1.

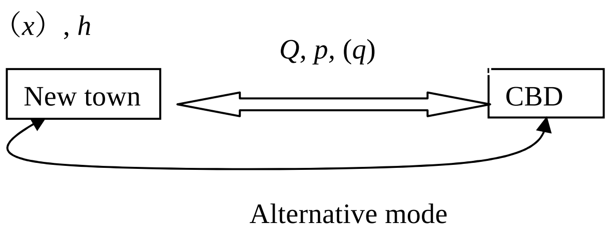


Figure 1. New town – transit – CBD model.

The variables q and x in parenthesis denote the volume of passengers using the transit and the population located in the new town, they are endogenously determined at equilibrium. The transit capacity Q, the transit fare p and house rent h are determined by the government, the transit firm and the developer, respectively.

Residents maximize their utility by choosing location and transport mode. In this paper *utility* is the negative of *disutility*, which is simply a generalization of transportation cost and housing cost measured in monetary term.

The demand for houses in the new town $x = x(Q, p, h)$ is determined by the following equilibrium conditions. Given x, the volume q using the transit is

$$q = \frac{x \exp(-\alpha C_t(q, Q, p))}{\exp(-\alpha C_t(q, Q, p)) + \exp(-\alpha C_A(x - q))} \quad (1)$$

where C_t and C_A are disutilities of using the transit and the alternative mode, respectively.

The utility regarding transport for residents in the new developed area (new town) is defined as

$$U_T = \frac{1}{\alpha} \ln(\exp(-\alpha C_t) + \exp(-\alpha C_A) \quad (2)$$

where α is a parameter.

Assume that transport is the single factor that determines the behavior of location selection in this example. Other factors such as environment characteristics are given fixed. Let ε be a vector denoting these factors, $f(\varepsilon)$ its contribution to the utility of locating in the new town.

The utility of locating at the new town is given by $U = U_T - \gamma h + f(\varepsilon)$.

γ is a parameter denoting the weight of house rent contributing to the disutility of householder locating in the new town. The utility of locating in other areas of the city is assumed to be

$$U_o = U_0 + U_1 (x / N)^2,$$

where U_0 and U_1 are constants, U_1 >0, the term $U_1(x/N)^2$ represents the improvement of utility by reduction of transportation cost in the other areas, due to a shift of population to the new town.

Suppose that the total population of the city is N and that the city is closed. The demand function for houses in the new town has the form

$$x = N \big/ [1 + \exp(\beta(U_o - U_T))] \quad (3)$$

where β is a parameter.

Given N, Q, p and h, U_T is a function of q and x, therefore equations (1) and (3) can be solved to find q and x simultaneously.

Implication of the above model will be explored by a numerical example with the following function forms and parameters.

$$C_t = a / Q + b(q / Q)^2 + p$$
$$C_A = c + d(x - q)^4$$

$$C_T = eQ^2 + vq$$
$$C_H = l_0 + l_1 x + l_2 x^2$$

$a = 20000, b = 20, c = 10, d = 0.001;$
$e = 0.04, v = 200;$
$l_0 = 10000, l_1 = 200, l_2 = 0.02;$
$\alpha = 0.1, \beta = 0.01, \gamma = 1;$
$f(\varepsilon) = 0.$

3. Market structures and numerical results

Suppose that the government determines the capacity Q of the commuter railway. The resulting population x in the new town, profits of the railway and housing sectors under various market structure will be investigated for given values of Q.

3.1 Duopoly (non-cooperative game)

This is a game similar to a conventional duopoly in structure but with the distinction that the goods the two firms produce are complements. In the game the transit firm determines fare *p* and the developer determines house price *h* to maximize their profits respectively.

$$\max_p \pi_T = pq - C_T(Q, q) \quad (4)$$

$$\max_h \pi_H = hx - C_H(x) \quad (5)$$

For a given Q, *p* and *h* are the two parameters (control variables) in the location/mode choice equilibrium. For a fixed *h*, *p* is decided so that the transit firm's profit is maximized - this determines a reaction curve of the transit firm to the behavior of the developer; the reaction curve of the developer to the transit firm is given inversely. Note that these reaction curves are derived from equilibrium conditions.

3.2 Cooperative game

If the transit firm and the developer form a coalition so that their total profit is maximized and divide it by a bargaining game (J. Nash, "Two-person cooperative games", *Econometrica*, **21**, pp.128-140). Let

$$\pi = \max_{(p,h)}\{pq + hx - C_T(Q,q) - C_H(x)\}, \quad (6)$$

subject to equilibrium equations.

Let PC_T and PC_H denote the profits that the transit firm and the house developer receive in the bargaining game, which are obtained by

$\max(PC_T - \pi_T)(PC_H - \pi_H)$

subject to $PC_T + PC_H = \pi$,

where π_T and π_H are profits in the duopoly case.

3.3 Competitive housing sector

The price (or rent) of house in the new town usually increases with the betterment of transit service provided by the transit firm. The extra profit caused by the house rent price increase should be properly returned to the transit firm, or to the government if the transit firm is subsided. A legal scheme that may achieve this is to let the developers bid for the right of residential development in the new town. The government may use this revenue from transferring the development right to subsidize the public transit firm if it embraces a deficit. Assume that the rail firm is a monopoly who maximizes its profit, and that the housing market is competitive so that the developers earn zero profit. A possible scheme for realizing this is to set the amount of houses to be constructed, and transfer the right of house construction to developers who agree to sell the houses at lowest price. This scheme seems difficult to be implemented in practice, because the government has to know correctly the demand for the houses, and the developers have to know correctly the demand function for housing. However, in a "matured" stage of urbanization, both the government, the rail firms and the developers have sufficient experience and knowledge about the residential and transport market, this scheme may be of practical significance.

3.4 Competitive transit and housing sectors

In some realistic cases the public transit sector may also be competitive, then it is reasonable to assume that both the transit firm and the housing developer break even.

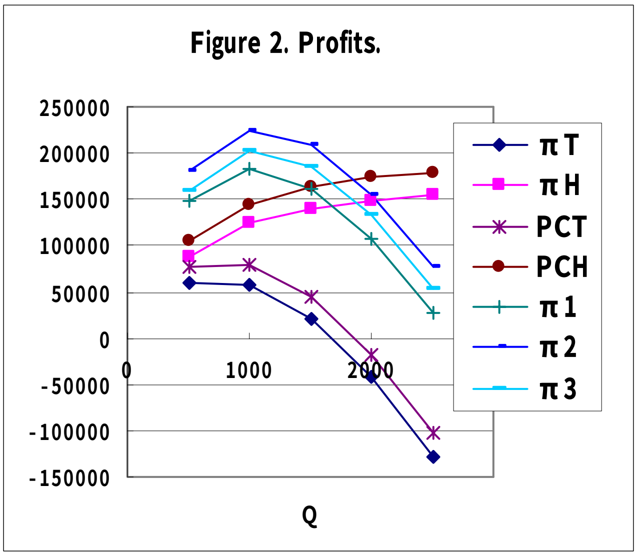
3.5 Competitive transit/housing monopoly

Another possible scheme for the government to capture the profit of constructing the rail line and the new town is to let the rail firms and developers bid for the right of constructing and operating the railway and developing houses as an integrated project. A developer may be an independent real estate developer or a development section owned by a rail firm. In any case, as the right of rail construction/management and new town development is transferred as a whole, the cooperative action of the rail management and house development should yield the same result. In our numerical example the following assumption is made.

Assumption: The competitiveness in the transit/housing bundle market implies that the transit fare and house rent are set so that the population in the new town is maximized, with the constraint that the total profit in the two sectors is zero.

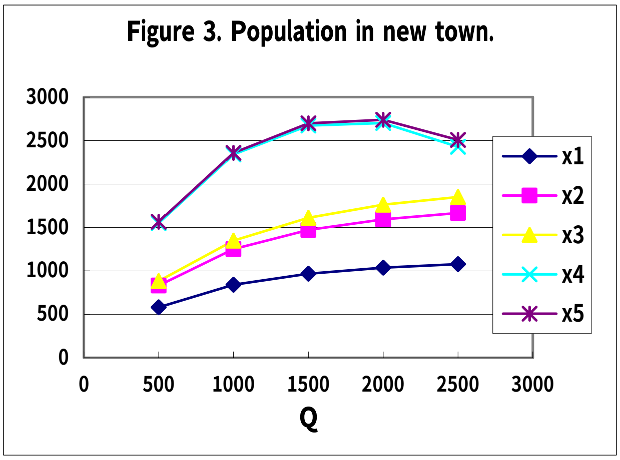
4. Discussion on the numerical results

(i) If the improvement of total profit of the transportation and the housing sectors by cooperative action is small, then there is only a small improvement of revenue for the transportation sector if the total profit increase is divided by a bargaining game rule. This fact is illustrated in Figure 2, where π 1 and π 2 denote the total profits in the duopoly and cooperation schemes, the improvement of profits of the transit firm and the developer are $PC_T - \pi_T$ and $PC_H - \pi_H$, respectively. In both schemes, the transit sector runs into deficit when transit capacity is large, cooperation reduces only very little of the deficit. Although the setting of our example is rather arbitrary, the above observation holds in general.



By the three competitive schemes described in Section 3.3, 3.4 and 3.5, the benefit that the house developer would have received, were it admitted to have the right of using the land without sharing transit line construction cost, can be returned to the investors of the railway. In our numerical example the transit firm has a profit π 3 when only the housing sector is competitive.

(ii) In our model these competitive schemes also yield large population in the new town. This result is shown in Figure 3, where *x1*, *x2*, *x3*, *x4* and *x5* denote the population in schemes described in Section 3.1, 3.2, 3.3, 3.4 and 3.5, respectively.



(iii) In the competitive schemes, there is an optimal transit capacity where the population in the new town is maximized. This is because if the transit capacity is too large, the residents have to share a large amount of cost which hinders the growth of the new town.

Finally, note that our model is simply a nested logit model of residential location and transport mode choices. A more general model based on urban economic theory is worth studying in future. And various cost functions used in the model also need to be identified by empirical studies.

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