Policies Compacting the City Size Subject to the Urban Fiscal Constraint

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We examine the cost-benefit analysis for road investment in a city with a spatially variable property tax, FAR regulations and a congestion tax considering MCPF (the marginal cost of public funds). Many previous studies have shown that it would be optimal to implement a congestion tax and use the tax revenue to fund road capacity expansion. However, in the real world, it is difficult to implement a congestion tax in all cities. In addition, since the congestion tax cannot be introduced on roads that are not congested, other means of raising funds are needed to improve all roads in a city. Therefore, we focus on the floor-area ratio regulations used to achieve compact cities and the equivalent effect of property taxes. Our study explores the efficiency and income distribution, road capacity of property tax and floor-area ratio regulations with explicitly considering a government budget constraint. Our results of quantitative analysis can be summarized as follows. A congestion tax is the first best. FAR regulation is the second best. Regime 3 is the least efficient because the financial constraint additionally generates deadweight losses in the floor market. Spatially variable rate of property tax is less efficient than Regime 4. But land rent is always positive in Spatially variable rate of property tax, while land rent can be negative in FAR regulation. When land rent is negative, landowners do not provide land. In this respect, spatially variable rate of property tax has an advantage.

Key words: *location-dependent property tax, FAR regulation, MCPF, road investment, efficiency*

1. Introduction

Most cities suffer from congestion. Expansion of road capacity is often used to reduce congestion. In addition to expanding the capacity of congested roads, other roads must also be maintained and managed, which requires large amounts of money. Therefore, efficient financing is required to maximize social welfare. In addition, capacity expansion alone does not maximize social welfare because the effects of capacity expansion are offset by induced traffic when traffic demand is highly elastic. Mohring and Harwitz (1962) has shown that it would be optimal to introduce a congestion tax and use the tax revenue to fund capacity expansion. Social welfare is maximized because the congestion tax acts on the distribution of urban population, which in turn optimizes capacity. Realistically, however, it is difficult to implement a congestion tax in all cities. In addition, since the congestion tax cannot be introduced on roads that are not congested, other means of raising funds are needed to improve all roads in a city. Therefore, a policy including a congestion tax should be considered to optimize the population distribution, optimize the capacity of congested roads, and raise financial resources to perform road maintenance within the city. It should be noted that when raising financial resources other than through congestion taxation, dead load generally occurs, and therefore, MCPF (the marginal cost of public funds) needs to be considered.

Kono, Pines and Yokoi (2019) examines a spatially variable property tax as a policy to optimize population distribution and reduce congestion. But in this previous study, all roads have fixed capacities. Kono and Joshi (2019) examines the cost-benefit analysis for road investment in a city with FAR regulation. But MCPF is not considered in this study.

This study examines the cost-benefit analysis for road investment in a city with a spatially variable property tax, FAR regulations and a congestion tax considering MCPF.

2. Model

We use the setup that modifies Kono, Pines and Yokoi (2019). We use both static and dynamic

models for traffic congestion. The city's geography in both two models is represented by the location of a center at some point in space and the exogenous supply of land around it, which is potentially available for housing production. In dynamic model, a river exists at distance x from the center, surrounding the center, with a bridge that serves as a traffic bottleneck. The latter is represented by a function $\bar{\phi}[x]$, which is the length of the arc for residential area at distance *x* from the center where, $x \in [0, b, \bar{J}]$, $\bar{\phi}[0] = 0$, b is the most distant location from the city center where land is used for residence, and $\bar{J}$ is the jurisdiction's radius (by assumption, $\bar{J} \geq b$). In static model, the length of the arc for residential area at distance *x* from the center is represented by $(1 - \rho[x])\bar{\phi}[x]$, where $\bar{\phi}[x]$ is total residential area and roads, and $\rho[x]$ is the ratio of roads.

The city accommodates $\bar{N}$ identical households. The utility function of a household who lives *x* miles from the center is given as $u[z[x], h[x]]$, where $z[x]$ is the consumption of a composite good, which is also the numeraire, and $h[x]$ is the consumption of housing at x. The initial endowment of a representative household is I units of a composite good and an equal share in the housing-producing firm which entitles them to an equal share in the aggregate firms' profit.

The spatial distribution of the $\bar{N}$ identical households is represented by a function $N[x]$, the population residing between x and the boundary where $x \in [0, b]$.

A round trip between x and the city center, where all the workplaces are located, costs $T[x]$ units of the composite good. $T[x]$ is

- Static model

$$T[x] = \int_0^x t\big[N[s]\big]ds \text{ at } \forall x \in [0, b],$$

where $t[N[s]]$is the marginal transportation cost with respect to distance from the city center as a function of the traffic volume at s.

- Dynamic model

$$T[x] = \eta x \text{ at } \forall x \in [0, x_B),$$
$$T[x] = \eta x + \xi \frac{N[x_B]}{a[x_B]} \text{at } \forall x \in [\text{at } \forall x \in (x_B, b]$$

where $a[x]$ is the road capacity at x.
The city has multiple congested radial roads and infinite circumferential roads on which travelling is costless. A flat km charge τ_T may be imposed on commuting where $x \in [0, J]$.

Housing is supplied by numerous price-taking firms. The available urban land is used to produce housing, along with composite goods. Let $c_H\big[H[x]\big]$ units of the composite good be required per unit of land to produce $H[x]$ units of housing per unit of land area. Then, if housing is supplied at a positive level, profit maximization requires that

$$\tau_H\,[x] = \frac{q[x] - c_H'[H[x]]}{q[x]} \text{ at } \forall x \in [0, b],$$

where $\tau_H\,[x]$ is the ad valorem tax on housing.

The net profit $\Pi[x]$ from housing production per unit of land is:

$$\Pi[x] = H[x]q[x](1 - \tau_H[x]) - \big(c_H\big[H[x]\big] + \bar{r}\big)\text{at } \forall x \in [0, b].$$

A viable city requires a variable quantity of local public goods for the road investment. A planner finances the road investment cost by the optimal set of tax instruments available. Although our main concern is financing the road investment cost with an optimal structure of excise tax on housing (property tax, hereafter), we begin our discussion by considering alternative tax regimes, each representing a distinct combination of taxes, road pricing and subsidies. Accordingly, we define four regimes:

Regime 1 (a). The common rate of property tax and a flat km charge.
Regime 1 (b). The common rate of property tax.
Regime 2 (a). Spatially variable rate of property tax and a flat km charge.
Regime 2 (b). Spatially variable rate of property tax.
Regime 3 (a). FAR regulation, the common rate of property tax and a flat km charge.
Regime 3 (b). FAR regulation and the common rate of property tax.

We define the budget constraint of the planner in general terms. Accordingly:

- Static model

$$\int_0^b \rho[x]\bar{\phi}[x]\,(R[x] + \overline{c_M})dx = \int_0^b (1 - \rho[x])\bar{\phi}[x]H[x]q[x]\tau_H[x]\,dx + \int_0^b N[x]\tau_T dx + \bar{S}$$

- Dynamic model

$$a[x_B](\overline{c_{BC}} + \overline{c_{BM}}) + \int_0^b (R[x] + \overline{c_{RM}})a[x]dx = \int_0^b \bar{\phi}[x]H[x]q[x]\tau_H[x]\,dx + \int_0^b N[x]\tau_T dx + \bar{S}$$

where $\bar{S}$ is a subsidy from a higher-level government.

3. Numerical Simulations

We divide the city into five discrete rings with a different width (1.0-3.0km). The rings are indexed by $i \in \{1, \ldots, 5\}$, where $i = 1$ at the zone adjacent to the CBD edge.

We consider a hypothetical city with $\bar{N} = 500{,}000$. The expenditure function is specified as $E = u + \frac{\alpha}{1-\varepsilon} p^{1-\varepsilon}$, where α is set up for a hypothetical city in Japan. We consider a city with the price elasticity of housing demand $\varepsilon = 0.2$. We set the household income as $\bar{I} = 5$ (million yen). The floor production function is specified as $c(H) = \left(\frac{H}{0.0028}\right)^{1/0.75}$, where the parameters are estimated from 112 samples of Japanese buildings.

Table 1 shows the social welfare and income distribution by regime. Regime 0 (congestion tax and a head tax) is included in Table 1. Comparing to Regime 1 (b), we can show how much efficiency has been increased by property tax and FAR regulation.

Comparing Regimes 2 (b) and 3 (b), we can find the welfare improvement ratio against Regime 0 are about 24% and 28% in Regime 2 (b) and Regime 3 (b), respectively. So, Regime 3 (b) is better. But highlighted cell in Table 1 shows a negative value of landowner's profit in Regime 4, so landowners do not provide land. The landowner's profit in Regime 3 cannot be negative, which can be theoretically proved. From these points, Regime 2 (b) can be a promising policy for congestion externalities.

Figure 1 shows the land rent at each location by regime. The land rent near the CBD in Regime 3 (b) is negative value.

Finally, the characteristics of each regime are summarized as follows. Regime 2 (b) is less efficient than Regime 3 (b). But land rent is always positive in Regime 2 (b), while land rent can be negative depending on the locations and the economic situations in Regime 3 (b). When land rent is negative, the landowner does not provide land. In this sense, Regime 2 (b) is feasible, while Regime 3 (b) can be infeasible due to negative land rent.

Table1: Social welfare and income distribution

Regime	Bottleneck capacity (10^4car/h)	Landowners' profit (10^{12}yen)	Residents utility (10^{12}yen)	Social welfare (10^{12}yen)	Welfare improvement ratio (%)
0	28.4	0.03	2.27	2.30	100.0
1 (b)	35.3	0.02	2.24	2.26	
2 (b)	29.2	0.03	2.24	2.27	23.7
3 (b)	29.7	-0.02	2.29	2.27	28.0

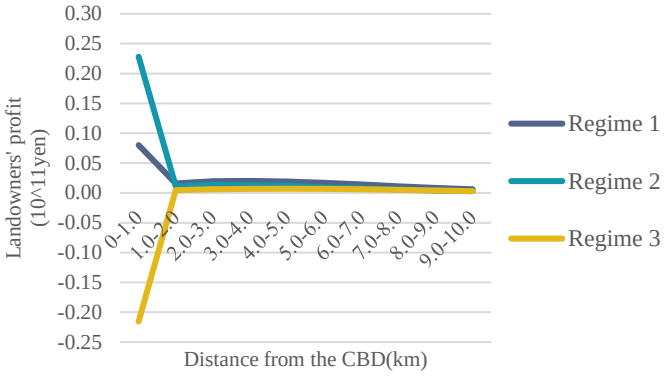


Figure 1: Land rent by location

4. Concluding Comments

This study examines the cost-benefit analysis for road investment in a city with a spatially variable property tax, FAR regulations and a congestion tax considering MCPF through quantitative analysis.

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References

1) Mohring, H., & Harwitz, M. (1962). Highway benefits: An analytical framework.
2) Kono, T., Pines, D., & Yokoi, T. (2019). Spatially-variable property tax and optimal tax composition in congested monocentric cities: George, Pigou, Ramsey and Strotz unified. Journal of Urban Economics, 112, 122-132.
3) Kono, T., & Joshi, K. K. (2019). Traffic Congestion and Land Use Regulations: Theory and Policy Analysis. Elsevier.