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Akiyoshi Furukawa

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Abstract

We analyze whether population affects spending on local public goods through economies of scale. The analysis examines two contiguous regions and two types of public goods: those that regional government "delivers" to residents (e.g., fire protection) and those that residents must travel to access (e.g., public libraries). In the former case, government's per capita local public expenditures might increase with regional population. In the latter case, they decline with population through scale economies. With carriage costs considered, however, the total cost of local public goods does not decline through economies of scale.

JEL classification: R51, H72, H76, R53

Keywords: spatial distance; carriage costs; regional population; local public expenditure

*School of Economics, Chukyo University 101-2 Yagoto Honmachi, Showa-ku, Nagoya, 466-8666, Japan Tel.: +81-52-835-7111 Fax: +81-52-835-7197 e-mail:ecockawa@mecl.chukyo-u.ac.jp

1 Introduction

The literature of local public finance expects economies of scale to reduce local public spending in more populous jurisdictions, as Alesina and Spolaore (1997) posit theoretically. Moreover, municipal mergers that enlarge population are presumed to reduce local public spending in Blume and Blume (2007), Dur and Staal (2008), Edwards (2011), and Durst (2014). Yokomichi (2007), Hirota and Yunoue (2017), Miyazaki (2014, 2018), and Nakagawa (2016) analyze municipal mergers in Japan.

Conversely, however, Buettner and Hadulla (2013) show that more populous regions spend more per capita on local public goods because of greater demand for them. Regional studies consider that consuming local public goods entails carriage costs (Fujita and Thisse, 2002; Berliant, Peng, and Wang, 2006; Braid, 2014). If regional population increases, total public expenditures might increase because of carriage costs.

Following Nakamura, Mukai and Tahira (2007), we analyze two types of local public goods: those that regional government "delivers" to residents (e.g., police and fire protection, garbage collection) and those that residents must travel to acquire (libraries, parks). Our research differentiates public goods by these costs to deliver and acquire, respectively. Following Buettner and Hadulla (2013) and Braid (2014), we analyze whether this differentiation affects relations between regional population and regional public expenditures.

Section 2 explains our model. Section 3 discusses the relation between regional population and local public expenditures. Section 4 concludes.

2 Model

Consider a one-dimensional space represented by linear segment $[0, N]$. Residents are evenly distributed over this segment, the density of which equals 1 . The segment has total population N in two regions (Region 1 and Region 2). Region 1 occupies $[0, n_1]$ and Region 2 $[n_1, N]$. n_1 is the endogenous boundary between them. The population of Region 1 is n_1 and that of Region 2 is $n_2 = N - n_1$. Each resident supplies one unit of labor. Therefore, region i 's labor supply equals n_i $(i = 1, 2)$.

Each region has one regional government that provides local public goods. Governments in Region 1 and 2 are located at the both ends of the segment. Government in Region 1 (Region 2) is located at 0 (N). Further, ${g_i}^\gamma$ units of private goods are needed to produce g_i units of local public goods. Consumption of local public good in Region i ($i = 1, 2$) is $z_i = {n_i}^{-\delta} g_i$ where δ denotes elasticity of population congestion. The cost function of a local public good $C(z_i, n_i)$ is ${z_i}^\gamma {n_i}^{\gamma\delta}$.

In accord with the literature of regional studies, we assume public goods entail carriage costs. Regional governments in effect "deliver" some public goods directly to residents (e.g., fire protection) at cost m per unit of distance. We call these *Type* 1 *goods* and the cost of providing them *delivery cost*. However, residents must convey themselves to locations where some public goods are available (libraries, parks). We call these *Type* 2 *goods* and the cost of consuming them *acquisition cost*. When Regional Government 1 provides Type 1 goods to residents located at $r \in [0, n_1]$, the round-trip distance is $2r$. Therefore, its aggregate travel distance to provide Type 1 goods is

$$ATD = \int_0^{n_1} 2r dr = {n_1}^2$$

Therefore, aggregate delivery costs for Type 1 goods in Region 1 are $m{n_1}^2$, and in Region 2 they are $m{n_2}^2 = m(N - n_1)^2$.

There is only one private good produced in each region. The private good is the numeraire good. Residents consume it. Moreover, it is used to produce local public goods. We evaluate costs of Type 1 and Type 2 goods with respect to the private good, which is produced using labor. In Region i, one unit of labor can produce β_i units of the private good. We assume Region 1 is the more productive. Therefore, $\beta_1 > \beta_2$ holds.

The resource constraint for the entire two-region economy is

$$\beta_1 n_1 + \beta_2 n_2 = n_1 x_1 + n_2 x_2 + C(z_1, n_1) + m{n_1}^2 + C(z_2, n_2) + m{n_2}^2$$

where x_i is the one resident's consumption of private goods in Region i. Residents in region i face this utility function:

$$U_i = \log x_i + \log z_i$$

When utility (u) and quantity consumed of the local public good (z_i) are given, the quantity of the private good x_i is $x_i = e^u/z_i$. From this fact and the model specification, the resource constraint is

$$\beta_1 n_1 + \beta_2 n_2 = n_1 \frac{e^u}{z_1} + n_2 \frac{e^u}{z_2} + {z_1}^\gamma {n_1}^{\gamma\delta} + m n_1^2 + {z_2}^\gamma {n_2}^{\gamma\delta} + m n_2^2$$

3 Regional Population and Delivery Cost of Type 1 Goods

Section 3 examines regional population and delivery cost of Type 1 goods that are efficiently allocated by a central planner. The planner maximizes the representative resident's utility when he equalizes all residents' utility.

The planner's Lagrangean is

$$
\begin{aligned}
L &\equiv u \\
&+ \lambda\Big[\beta_1 n_1 + \beta_2(N-n_1) - n_1\frac{e^u}{z_1} - (N-n_1)\frac{e^u}{z_2} \\
&- {z_1}^{\gamma}{n_1}^{\gamma\delta} - m{n_1}^2 - {z_2}^{\gamma}(N-n_1)^{\gamma\delta} - m(N-n_1)^2\Big]
\end{aligned}
$$

First-order conditions for z_1, z_2, n_1, and H_1 are

$$
\begin{aligned}
\beta_1 - \beta_2 &- \gamma\delta {z_1}^{\gamma}{n_1}^{\gamma\delta-1} + \gamma\delta {z_2}^{\gamma}(N-n_1)^{\gamma\delta-1} \\
&\quad -2mn_1 + 2m(N-n_1) = 0 \qquad (1)\\
\frac{n_1 e^u}{{z_1}^2} &- \gamma {z_1}^{\gamma-1}{n_1}^{\gamma\delta} = 0 \qquad (2)\\
\frac{(N-n_1)e^u}{{z_2}^2} &- \gamma {z_2}^{\gamma-1}(N-n_1)^{\gamma\delta} = 0 \qquad (3)
\end{aligned}
$$

Equation (1) shows the optimal distribution of population, which determines the boundary between Region 1 and 2. Equations (2) and (3) indicate the optimal provision of Type 1 goods.

First, we analyze the efficient distribution of population from the stated first-order conditions

$$\beta_1 - \beta_2 - \gamma\delta \left[\frac{e^u}{\gamma}\right]^{\frac{\gamma}{\gamma+1}} \left[n_1^{\frac{\gamma\delta-1}{\gamma+1}} - (N-n_1)^{\frac{\gamma\delta-1}{\gamma+1}}\right] + 2m(N-2n_1) = 0 \qquad (4)$$

The optimal population size ${n_1}^*$ is derived from this condition. ${n_1}^* > N/2$ holds for this population. That is, the population of Region 1 exceeds Region 2.

To capture the effect of delivery costs we examine the case $m = 0$. From the above condition, the optimal population in Region 1 exceeds (is smaller than) population in Region 2 when $\gamma\delta > 1$ (when $\gamma\delta < 1$). In short, delivery costs promote population agglomeration in Region 1.

Second, we analyze the efficient allocation of Type 1 goods. From first-order conditions,

$$z_i = \left(\frac{e^u}{\gamma}\right)^{\frac{1}{\gamma+1}} {n_i}^{\frac{1-\gamma\delta}{\gamma+1}} \qquad (5)$$

The efficient distribution of population between two regions is ${n_1}^* > {n_2}^* = N - {n_1}^*$. Therefore, when $\gamma\delta > 1$ - when per capita cost of Type 1 goods increases with population - Region 1 features less of the Type 1 good than Region 2. When $\gamma\delta < 1$, Region 1 features more Type 1 goods than Region

2.

When scale economies to produce Type 1 goods are greater and the congestion effect smaller, $\gamma\delta < 1$ holds and the more populous region provides more such goods. This means that demand for Type 1 goods increases with population (and decreases with population when $\gamma\delta > 1$).

Under efficient allocation, per capita local public expenditures on public goods that do not entail carriage costs are:

$$\frac{C(z_i, n_i)}{n_i} = \left(\frac{e^u}{\gamma}\right)^{\frac{\gamma}{\gamma+1}} {n_i}^{\frac{\gamma\delta-1}{\gamma+1}} \tag{6}$$

The optimal population in Region 1 exceeds that in Region 2. If $\gamma\delta < 1$, per capita local public expenditures are less in Region 1. Moreover, more of the Type 1 good is available in Region 1. That is, if regional population increases, per capita expenditures fall and quantity of the good increases through scale effects, a desirable condition from the perspective of public finance.

Per capita local public expenditures with carriage costs are

$$\frac{C(z_i, n_i) + m{n_i}^2}{n_i} = \left(\frac{e^u}{\gamma}\right)^{\frac{\gamma}{\gamma+1}} {n_i}^{\frac{\gamma\delta-1}{\gamma+1}} + mn_i \tag{7}$$

These expenditures rise with population if $\gamma\delta > 1$. If $\gamma\delta < 1$, when

$$\frac{\partial}{\partial n_i}\left[\frac{C(z_i, n_i) + m{n_i}^2}{n_i}\right] = \left(\frac{e^u}{\gamma}\right)^{\frac{\gamma}{\gamma+1}} \frac{\gamma\delta - 1}{\gamma + 1} {n_i}^{\frac{\gamma\delta-1}{\gamma+1}-1} + m > 0 \tag{8}$$

then expenditures rise with population. This condition holds if carriage costs per unit of distance (m) are large. Only when m is sufficiently small will expenditures fall with population. Therefore, Proposition 1 holds:

> **Proposition 1** Consider that reginal government bears costs of delivering the local public good. Under the optimal population distribution when carriage costs are not negligible, increases in population are not accompanied by lower per capita public expenditures.

Proposition 1 asserts that rising regional population does not reduce expenditures, although quantity of the local public goods may increase. If $\gamma\delta < 1$ without carriage costs, regional government in the more populous region can provide more of the Type 1 good and reduce per capita expenditures. Given carriage costs, however, it is impossible to reduce per capita expenditures through economies of scale.

4 Acquisition Cost of Type 2 Goods

Section 3 showed that per capita expenditures on Type 1 goods are higher in the more populous region when regional government bore delivery costs. Section 4 analyzes that situation by considering acquisition cost for Type 2 goods.

Regional government sets public facilities (e.g., parks and libraries) at the location where the government locates. Its cost is

$$E(z_i, n_i, F) = {z_i}^{\gamma} {n_i}^{\gamma\delta} + F \tag{9}$$

where F is the fixed construction cost.

Residents must travel to the facility, i.e., pay the cost of acquiring Type 2 goods. Like Section 3, m is their cost per unit of distance traveled. In Region 1, the round-trip distance is $2r$ for the resident located at $r \in [0, n_1]$. Aggregate travel distance for all residents (ATD_r) is:

$$ATD_r = \int_0^{n_1} 2r dr = {n_1}^2$$

Therefore, aggregate carriage costs are $m{n_1}^2$. Like Region 1, they are $m{n_2}^2 = m(N - n_1)^2$ in Region 2. Assuming equal distribution among residents, per capita carriage costs in Region i are $m{n_i}^2/n_i = mn_i$. In this setting, the resource constraint is

$$\beta_1 n_1 + \beta_2 n_2 = n_1 \frac{e^u}{z_1} + n_2 \frac{e^u}{z_2} + {z_1}^{\gamma}{n_1}^{\gamma\delta} + F + mn_1^2 + {z_2}^{\gamma}{n_2}^{\gamma\delta} + F + mn_2^2$$

The central planner maximizes the representative resident's utility subject to that resource constraint. Like Section 3, first-order conditions for n_1, z_1, z_2 are

$$\begin{aligned} \beta_1 - \beta_2 \quad &- \quad \gamma\delta {z_1}^{\gamma}{n_1}^{\gamma\delta-1} + \gamma\delta {z_2}^{\gamma}(N-n_1)^{\gamma\delta-1} \\ &\quad -2mn_1 + 2m(N-n_1) = 0 \qquad (10) \\ \frac{n_1 e^u}{{z_1}^2} \quad &- \quad \gamma {z_1}^{\gamma-1}{n_1}^{\gamma\delta} = 0 \qquad (11) \\ \frac{(N-n_1)e^u}{{z_2}^2} \quad &- \quad \gamma {z_2}^{\gamma-1}(N-n_1)^{\gamma\delta} = 0 \qquad (12) \end{aligned}$$

These equations are identical to the case involving Type 1 goods. Therefore, equations (4) and (5) are derived from these equations. As in Section 3, the optimally distributed population of Region 1 (${n_1}^{**}$) exceeds that of Region 2. When $\gamma\delta > 1$ (when $\gamma\delta < 1$), the quantitiy of Type 1 goods in Region 1 is less (larger) than in Region 2.

Under efficient allocation, per capita local public expenditures are

$$\frac{E(z_i, n_i, F)}{n_i} = \left(\frac{e^u}{\gamma}\right)^{\frac{\gamma}{\gamma+1}} n_i^{\frac{\gamma\delta-1}{\gamma+1}} + \frac{F}{n_i} \tag{13}$$

This expenditure declines with population without the case that $\gamma\delta > 1$, n_i is sufficiently large and F is sufficiently small. In many cases the increment in regional population prompts the reduction of per capita local public expenditures through economies of scale. The following analysis assumes that condition pertains.

Residents in effect bear government's cost plus their own cost to acquire Type 2 goods. Therefore, per capita total public expenditure is

$$\frac{E(z_i, n_i, F) + m{n_i}^2}{n_i} = \left(\frac{e^u}{\gamma}\right)^{\frac{\gamma}{\gamma+1}} n_i^{\frac{\gamma\delta-1}{\gamma+1}} + \frac{F}{n_i} + mn_i \tag{14}$$

If carriage costs per unit of distance m and population n_i are larger (smaller), public expenditures rise (fall) with population. Proposition 2 holds.

Proposition 2 Consider that residents incur costs to acquire the local public good. Under the optimal allocation, if carriage costs are not small, a larger regional population does not occasion lower per capita public expenditure even if regional government expenditures enjoy scale economies.

Here, the regional population epitomizes intra-regional travel distances. When it is larger, so are carriage costs. Proposition 2 asserts that costs residents incur do not diminish through economies of scale even if regional government expenditures enjoy scale economies. Regional governments will find it desirable to attract residents because doing so likely reduces public spending and improves financial efficiencies through economies of scale. However, attracting more residents exacerbates residents' burden via carriage costs.

5 Conclusion

We have analyzed regional public expenditures to provide local public services after considering carriage costs. Earlier studies indicate that per capita local public expenditures decline through scale economies when regional population rises, but those studies disregard intra-regional carriage costs. When consuming local public goods entails travel, regional population may increase the total public expenditure.

We found that per capita local public expenditures can increase with population if regional government must deliver a local public good. Regional government's per capita expenditures decline with population through scale economies if residents convey themselves to public facilities. Including carriage costs, however, public expenditures do not decline with regional population, and economies of scale have no effect.

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