Central place system, transportation policy, and regional welfare function

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Abstract This paper focuses on regions where local population constantly falls, and these areas are necessary to optimize the spatial economic structure and to improve the regional welfare level. A regional model is introduced in the main part of the paper which applies the established notion of the social welfare function in a spatial term together with parts of agglomeration economies, named as regional externalities. The outcome of the investigation shows that an adjustment of the hierarchical central place system of goods and services by means of structural changes on transportation network may manage to keep the regional system at a sustainable level of local population and economic activity. The methodology of the change in a transportation network employs the idea of an interregional coordination, which would be remarkably important to apply in these regions.

Keywords: Central place theory, transportation costs, agglomeration economies, social welfare function
JEL Classifications: D62, I31, O18, R12

Executive summary

Many countries, particularly, developed nations, now commonly face declines of total population. Following the methodological framework of the hierarchical central place system (Lösch, 1944 [1954]), upper hierarchical-ordered regions, such as the capital city, experience fewer problems of severe problematic issues on declines on local population and economic activity than lower hierarchical-ordered regions or rural areas. The worst scenario can be illustrated that local market system does not work sufficiently including publicly operated services such as the local transportation system due to a shortage of demand. A weaker market system may lose an attractiveness of a region that can cause more declines of local population itself. In order to avoid such problems, a sustainable regional economic management may play an important role. Regional economic management includes the optimization of spatial economic structure that may improve the regional welfare level.

The welfare level can be examined with the conceptual framework on Pigou (1932), although its theoretical approach has not been proceeded due to the presence of impossibility theorem (Arrow, 1950; Arrow and Scitovsky, 1969), for instance. Later, further investigations were made by Sen (1970) etc. In any cases, studies to measure a welfare level are remarkably important and some attempts can be made by providing certain assumptions. To be concrete, the analysis of individual utility may not be applicable to group preference that describe social welfare function. That is the fundamental idea of Arrow's impossibly theorem.

In order to avoid this problem, our analysis solely supply a condition that it is apparently better to have a good accessibility to the market so that more variety of goods and services may be available and that brings beneficial things both to the individual and to the society. The framework of welfare from the field of Regional Science was given by Isard (1975) in his topic of conflict resolutions based on location model analysis such as Isard (1956). This paper initially introduces a simple regional model, which employs the notion of social welfare function in a spatial term. In addition, regional agglomeration economies which are "external to the firm and the industry but internal to the region" will take into account to the analysis. These are extensive framework of conventional agglomeration economies which were classified by Parr (2002), and might have some similarities of the notion of "regional externalities" in Parr (2015).

The examination of our paper attempts to reveal locational forces which may work together with them such as hierarchical central place system and transportation costs partly employing the concept of location triangle model of Weber (1909 [1928]). Under overall considerations, we demonstrate an optimal regional system from the standpoint of spatial economy. Here, the optimal regional system implies that there are sufficient local population and

economic activity boosted by affiliating with neighbor regions under an appropriate regional public transportation policy.

Regional economic model

In this section, a regional model is examined for a representative household's utility maximization under a given budget constraint as indicated in Eqs. (1) and (2).

$$\max \quad U = U(x, A) \tag{1}$$

$$\text{s.t.} \quad M = \frac{1}{t}px + \frac{1}{t}\rho A \tag{2}$$

where his utility level U is determined by quantity demanded of composite good x $(x > 0)$ and an indicator of his living environment, A $(A > 0)$. The indicator A is related to non-market things such as access to clean air, water, quiet space, and so on but it costs distant trip to obtain them. This is also the same as composite good, x, and there is a parameter, t $(0 < t \leq 1)$ which represents unit transportation rate converted by an indicator that means that more efficient transportation approaches its value to 1. In other words, the parameter t approaches 1 as the physical accessibility is well-organized. A remaining parameter, ρ $(0 < \rho < 1)$, denotes the weight (share) on A against x. The parameter ρ approaches 1 as this representative individual is more interested in A than x.

From equations above, it is clear that less efficient transportation causes much tighter budget constraint in Eq. (2), which brings less utility level in Eq. (1). Here, we may assume that less efficient transportation can be less convenient access to the destination. For instance, lower frequency of public transportation is one of examples. Frequency of public transportation depends on the level of transportation demand. Transportation demand relies on unit transportation cost which includes not only monetary expenses as "fare to passengers" but also time and the extent of inconvenience to use public transportation system etc.

Figure 1 illustrates a simple transportation model, and shows a transportation route between two regions, S_1 and S_2. Here, there are two different and separate cities, which have centers, S_1 and S_2, respectively. Two cities are assumed to have the same scale regarding local population and economic activity, while some goods and services as well as types of job are different. Distance between each center of two cities is $d_{12}(= d_{21})$.

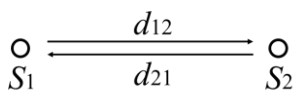

Fig. 1 Two locations

If two cities, S_1 and S_2, have no pre-arrangement on distributing goods and services, a variety of goods and services may be limited to the local economic scale within S_1 or S_2due to the presence of transportation costs.

As long as individuals traveling to other regions are limited, public transportation demand is kept at a minimum. For households, fare and frequency of transportation are more important factors than others, and if these are improved, they can access another region and utility level becomes much higher under the notion of "a love of variety" (See Dixit and Stiglitz, 1979; Ethier, 1982). For operators of transportation, their decision-making of frequency may depend on a combination of fare and quantity demanded is more important as well as their operating costs. Hence, it is necessary to consider operator's economic behavior.

It is apparent that less populated areas face more difficulties to supply more frequent services. Now, we examine how more frequent services may be available in less populated area for operators. Here, it should be noted that physical transportation network such as the road infrastructure has already been established for reasons of simplicity.

If the existing transportation system is not possible to sustain, an alternative transportation network needs to coordinate. One of alternatives is illustrated in Fig. 2, and this system involves an additional neighbor region. Now, there are three regions and quantity demanded on public transportation increases by the emergence of the additional region.

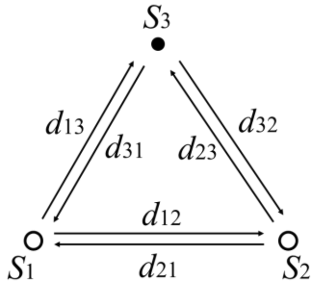

Fig. 2 Three locations

<u>Hypothetical analysis</u>

Hitherto, it is apparent that public transportation system plays an important role for a sustainable regional economy, while the system heavily relies on economic behavior of local households and transportation operators with several given constraints. This section demonstrates regional transportation policy within the framework of central place theory under hierarchical spatial structure. There are four different types of hypothetical scenarios which are shown below.

Case 1: $S_1 = S_2 = S_3$

The first case illustrates a situation which all three centers are equivalent hierarchical orders. On this scenario, an alternative center S_0 in Fig. 3 can be established if

$$d_{12} + d_{23} + d_{31} > d_{01} + d_{02} + d_{03} + \frac{F_{S0}}{2tq}$$

The above expression shows total transportation in the left-hand side shows total transportation costs of the alternative situation together with its establishment cost (= fixed cost), $F_{S0}0$ on the right-hand side. Note that q $(q > 0)$ = aggregate quantity traded.

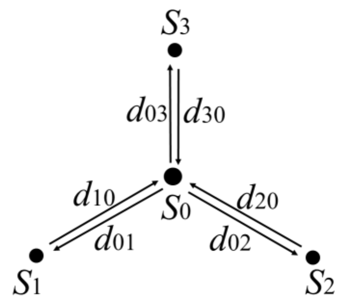

Fig. 3 A case of the same hierarchical order

Case 2: $(S_1 = S_2) > S_3$

This scenario has two higher hierarchical-ordered centers S_1 and S_2 than a remaining center S_3. Hence, that may have a transportation network between S_1 and S_2 via S_3 as illustrated in Fig. 4.

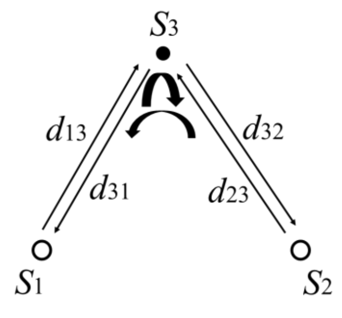

Fig. 4 A case of two larger hierarchical orders

Case 3: $(S_1 = S_2) < S_3$

The third case shows a fact of relatively higher hierarchical order of S_3 than others, S_1 and S_2. This specific scenario only requires transportation network between S_1 and S_3 as well as between S_2 and S_3 as shown in Fig. 5. Here, note that $g_{12} > g_{31}$ and $g_{23} > g_{32}$, if the transportation is provided for distributing goods and services. This is because the physical volume of distributing commodity is much larger than that of S_1 or S_2. Hence, there are disequilibria of transportation demand and supply between outbound and inbound.

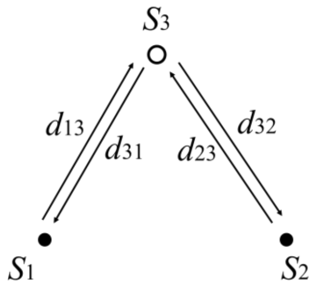

Fig. 5 A case of two smaller hierarchical orders

Case 4: $S_1 > S_2 > S_3$

The final case illustrates a situation which hierarchical orders are the largest at S_1, intermediate at S_2, and the smallest at S_3, respectively. On this scenario, the transportation network can be integrated into a one-way structure as depicted in Fig. 6. Detailed investigations should refer to Nakamura (2018).

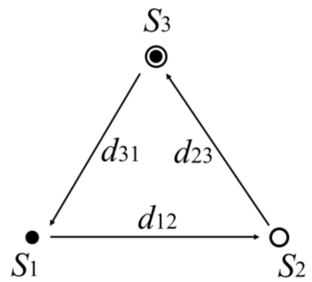

Fig. 6 A case of different hierarchical order

Any those listed scenarios require interregional coordination and negotiation between S_1, S_2, and S_3. The following section argues its feasibility in a real circumstance.

Further research

This analysis should be expanded to solve the following socio-economic problem. When regional population declines, accessibility to goods and services diminishes as the transportation supply exceeds its demand level. In addition, the tendency of ageing society limits a usage of public finance, and subsidiary payments to local transportation would be more restricted. These would leave more people outside the region, and local retailers and service providers gradually exit from the area. The vicious circle apparently diminishes the social welfare level of those areas.

To avoid such vicious circle causation, a restructure of public transportation system may have an important role with a framework of well-organized interregional transportation. An advanced system would make economic agents be feasible to merge their locations into a single representative site or their retail stores and services. As long as these locations are easily accessible from the transportation network, a sustainable regional economic growth in rural areas can coordinate. Although the physical scale or area has not been precisely defined, this is a fundamental idea of regional agglomeration economies. Perhaps, these can be methodologically connected with "regional externalities" in Parr (2015) by means of arguing regional development in Parr (1970).

While the interregional coordination increases the cost burden of each economic agent in the area in the short run, a proper policy will improve the level of social welfare in the long run.

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