Chapter 6
An Investigation of Hierarchical Central Place Systems and Optimal Spatial Structures for Improving Regional Welfare

Daisuke Nakamura

Abstract Central place theory, as used in market area analysis, explains how economic activity is spatially organised, and how the systematic organisation of such activity can optimise it. However, this work has devoted little attention to problematic issues in rural areas, which are nearly free of the diseconomies associated with urbanisation, such as pollution and congestion, but which often have difficulty accessing goods and services. This paper will demonstrate how an alternative spatial economic structure can be organised within the framework of central place theory and describe what sort of regional system is required to sustain the availability of goods and services in rural areas.

Keywords Central-place system · Market areas · Transportation costs · Cooperative behaviour · Regional development

6.1 Introduction

Hierarchical central place systems are a part of central place theory, which was originated by Christaller (1933 [1966]) and Lösch (1938, 1944 [1954]). Although they were first developed in the domain of geography and the location of economics, central place systems can also be used to classify financial and administrative

A preliminary version of this paper was presented at the 50th Anniversary Session of the 49th Annual Meeting of the Japan Section of the Regional Science Association International in Tokyo, October 2012. The author would express his thanks to H. Ohta, M. Ohta, K. Kourtit, and D. Plane for their valuable comments and suggestions for further development of the paper.

D. Nakamura (✉)
Faculty of Global Management, Chuo University, Tokyo, Japan
e-mail: dnakamura@tamacc.chuo-u.ac.jp

Y. Higano et al. (eds.), *New Frontiers of Policy Evaluation in Regional Science*,
New Frontiers in Regional Science: Asian Perspectives 52,
https://doi.org/10.1007/978-981-16-4501-3_6

systems (Parr 2008). In the theoretical work, these central place structures are typically associated with large metropolitan areas, including capital cities. Such centrality can result from a variety of spatial, historical, and economic factors, but it can also lead to problematic disparities when it comes to well-being and quality of life in rural regions. This paper examines how spatial economic organisation can be used to sustain regional welfare, by coordinating access to goods and services in ways that support local populations and their economic activity.

Regional welfare can be enhanced, at least in part, through the economies of agglomeration. These economies are referred to as externalities, with Baumol and Blinder (2016: 304) having categorised spatially unconstrained economies into those marked by beneficial externalities versus detrimental externalities. The difference between these types of economies turns on incidental costs that are borne by others who receive no compensation for any resulting damage to their well-being. Such costs are positive in cases of beneficial externality, but negative in cases of detrimental externality. Furthermore, Parr (2002) proposes a classification of spatially constrained economies that are external to the firm; he divides these into localisation economies, urbanisation economies, and activity-complex economies.

Although localisation and activity-complex economies are commonly linked with manufacturing industries, urbanisation economies are not necessarily connected with aspects of firms and industries. In addition, urbanisation economies also have detrimental externalities such as pollution and congestion, which are referred to as urbanisation diseconomies. These concepts need to be expanded to analyse issues of regional welfare in general and the welfare of rural areas in particular. As demonstrated by Nakamura (2010), rural areas tend to enjoy less availability of goods and services due to the profit-maximisation priorities of firms, which choose to maximise profits rather than revenues. This paper analyses how goods and services can nonetheless be more securely distributed in these areas, arguing that such well-organised distribution systems may partly contribute to improving regional welfare levels.

The economics of welfare was first formally investigated by Pigou (1932), though the limited scope of his analysis was criticised by Robbins (1938), Little (1957), and others. While successors of welfare economics such as Bergson (1938), Hicks (1939), Kaldor (1939), Scitovsky (1941), and Samuelson (1947) attempted to develop the conceptual framework further, this later work gave rise to theoretical contradictions and other problems (Arrow 1950; Arrow and Scitovsky 1969). Later, in a remarkable expansion of the approach, Sen (1974) managed to extend welfare analysis but without creating methodological difficulties, and Stiglitz et al. (2009) built on this work to provide an index of well-being that informed the better-life index of the Organisation for Economic Co-operation and Development (OECD) (see also Stiglitz et al. 2010). Relatedly, Sustainable Development Goals (SDGs) were proposed by the United Nations; these goals include several aspects of well-being in rural as well as urban areas.[1] Some of the goals involve quality of life (QOL), and economists have developed various approaches related to this subject of study. For example, Blomquist et al. (1988) and Glaeser et al. (2001) focused on the attractiveness of urban areas when it comes to QOL. Greenwood and Hunt (1989) explored how metropolitan migration has been shaped by considerations of employment and also amenities. For their part, Jensen and Leven (1997) compared and contrasted life in suburbs with life in central cities, and Ifcher and Zarghamee (2011) investigated quantitative metrics for well-being. These studies established that QOL is typically higher in urban areas, although those areas also have negative factors such as congestion and high crime rates.

More recently, Jackson et al. (2012) revealed the importance of cooperative behaviour in society, using the conceptual framework of social quilts and neighbour communication networks. Desmet and Rossi-Hansberg (2013) developed an index of welfare in urban areas that includes governments' budgetary constraints as well as externalities to amenities in those areas. Jones and Klenow (2016) provided another index of welfare using micro-data for several countries that could argue about existing studies which extend beyond GDP-based measurements.

With these previous studies mainly focusing on the evidence of the agglomeration forces of economic activity, the present paper explores what sort of economic system is required to create optimal regional welfare in rural areas. Here, the argument assumes that rural areas offer benefits that offset negative factors in urban areas, such as a rich environment of natural resources. Better access to goods and services is still required in rural areas, however especially necessary goods and services. Access to the market and inputs were studied by Weber (1909 [1928]) via a location triangle model. While the original study investigated the optimal plant location under the calculus of minimum transportation costs, which encompass a combination of two types of input and a single final product, this model can be generalised for an analysis of the optimal locations for the distribution of goods and services and those locations' corresponding transportation costs.

The paper is organised as follows. In Sect. 6.2, which draws on ideas from central place theory, a spatial model in a simple framework is introduced to examine regional welfare and rural spatial attributes of the central place system used in the model. Then, alternative spatial organisations, proposed via hypothetical analyses, are introduced in Sect. 6.3, and issues of regional sustainability are considered in Sect. 6.4. Section 6.5 indicates further possible expansions of the analysis, with Sect. 6.6 providing concluding comments.

[1] See the Division of Sustainable Development Goals of the United Nations at sustainabledevelopment.un.org/sdgs

6.2 A Spatial Model

In order to use the framework of central place theory to investigate regional welfare in rural areas from the standpoint of the availability of goods and services, it is first necessary to employ established market area analysis originating from Lösch (1944 [1954]) and Mills and Lav (1964) and summarised as follows by Nakamura (2007). First, the total revenue, TR, of a representative profit-maximising firm under a spatial monopoly with a regularly formed circular market area can be stated using the following expression:

$$\mathrm{TR} = \frac{1}{3} Dt\pi U^3 \left(a - btU\right), \tag{6.1}$$

where D ($D \geq 0$) = density of demand, t ($t \geq 0$) = unit distribution transportation cost, $\pi \approx 3.14159$, U ($U \geq 0$) = maximum market area radius, and a and b ($a \geq 0$, $b \geq 0$) = components of the given demand curve. Here, note that there is no demand beyond the maximum radius of the market area.

Second, the total cost, TC, can be expressed as:

$$\mathrm{TC}(q) = ckq^2 + F_{\mathrm{T}}, \tag{6.2}$$

where c ($c \geq 0$) = a unit cost to use as input for production, k ($k \geq 0$) = technological indicators for efficiency of production, q ($q \geq 0$) = quantity of output, and F_{T} ($F_{\mathrm{T}} \geq 0$) = the fixed or terminal cost for the distribution of goods and services. Regarding parameter k, as more efficient production becomes available, the indicator k approaches 0.

In order to solve the optimal market area radius of the representative firm, the marginal revenue and the marginal cost should be found under the spatial monopoly condition. The marginal revenue, MR, is immediately available from Eq. (6.1):

$$\mathrm{MR}(U) = \frac{1}{3} Dt\pi U^2 \left(3a - 4btU\right). \tag{6.3}$$

Meanwhile, the marginal cost can be derived from Eq. (6.2), which is replaced by a function of the market area radius u. The conversion uses the following equation for a circular spatial configuration with an additional variable μ ($\mu \geq 0$) representing a physical obstacle to accessibility between different locations:

$$q = \mu\pi u^2. \tag{6.4}$$

To sum up, the marginal cost, MC, as a function of the market area radius becomes:

$$\mathrm{MC}(u) = \partial \frac{ck^2\mu^2\pi^2u^4}{\partial u} 4u^3ck^2\mu^2\pi^2. \tag{6.5}$$

Since U in Eq. (6.3) can be treated as u, the optimal market area radius, u^*, can be specified by equalising Eq. (6.5) to Eq. (6.3):

$$u^* = \frac{3at}{4\left(bt^2 + 3k^2\mu^2\pi c\right)}. \tag{6.6}$$

Also,

$$\frac{\partial u^*}{\partial b}, \frac{\partial u^*}{\partial t}, \frac{\partial u^*}{\partial k}, \frac{\partial u^*}{\partial \mu}, \frac{\partial u^*}{\partial c} < 0 \quad \text{and} \quad \frac{\partial u^*}{\partial a} > 0. \tag{6.7}$$

In this way, producers determine the size of their market area. In other words, there are consumers who are not able to obtain goods and services in question beyond the optimal market area radius. Nakamura (2010) characterises this situation in spatial terms as "consumer exclusion." Such spatial consumer exclusion may cause households in the affected areas to accept lower availabilities of goods and services than households in large metropolitan areas.

While services necessary to the public can be supplied by local or municipal authorities in the form public services, those authorities' budget constraints are generally tighter in industrialised countries due to the ageing of the total population, for instance. Under such circumstances, it is necessary to develop a well-organised regional system for the distribution of goods and services. The system can be expected to reduce the level of consumer exclusion and increase regional welfare levels, even when the region in question involves rural areas with small-scale economies.

6.3 Hypothetical Analysis

This section demonstrates how to avoid creating spatial consumer exclusion, over the longer term, in rural areas. In Fig. 6.1, the origin O_1 is the centre of a large metropolitan area where many goods and services are available—based on the idea of central place theory. The horizontal axis shows the physical distance from the centre O_1. The maximum market area radius is point B, and there are still targeted households at this point. Beyond that point, households are able to obtain their goods and services from other central places, as indicated in Eq. (6.1). The vertical axis depicts price levels. As the distance increases from O_1, these price levels rise. Correspondingly, under the condition of a "freight on board" (f.o.b.) pricing system for market area analysis, actual spending in households increases due to transportation costs.

In Fig. 6.1, the price level p_m shows the maximum reserve price of households for a representative commodity or service. In that case, the commodity or service which has a price p_1 cannot be bought by households that are located beyond point A. As a result, as Fig. 6.1 illustrates, households located between point A and point

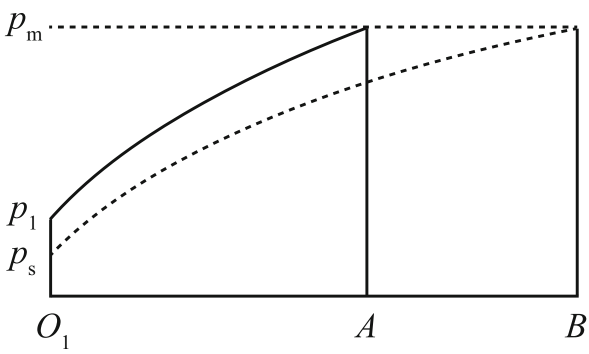

Fig. 6.1 Price and distance of goods and services

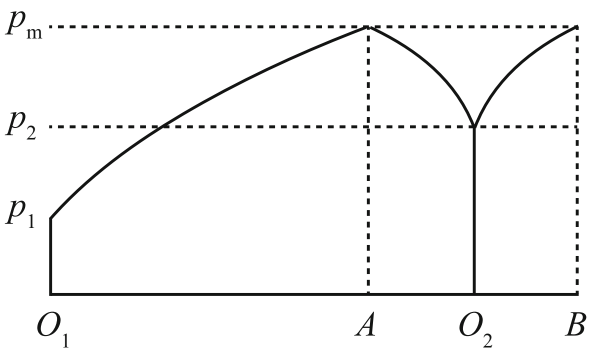

Fig. 6.2 Local lower hierarchical central place system

B face consumer exclusion unless mill price decreases to p_s and transportation costs for distribution also decrease.

An alternative framework is shown in Fig. 6.2. The figure has a centre O_2 which is a local hierarchical central place. The maximum market area radius may be $B - A$, where $AO_2 = BO_2$ on an economic plane without any physical obstacles. In this case, a high price p_2 is still acceptable, and the difference $p_2 - p_1$ can be devoted to the management of the local central place O_2. Management of this sort is needed because O_2 will be in a more inefficient situation, due to the limitations of large-scale economies, than the central place O_1.

A problem may appear where there is spatial market competition between the centre O_1 and the local centre O_2. As illustrated in Fig. 6.3, this can be observed when the price of O_1 declines to the level p_s or, perhaps, together with a reduction of distribution transportation costs from the centre O_1. The actual problem is that the local centre O_2 loses its territory $h - A + B - z$ within the market area radius. If the remaining market area, which is not a regularly formed circular market area, falls below the point where normal profit levels can be managed, a spatial structure of this sort is not sustainable for the distribution of goods and services from the local central place O_2.

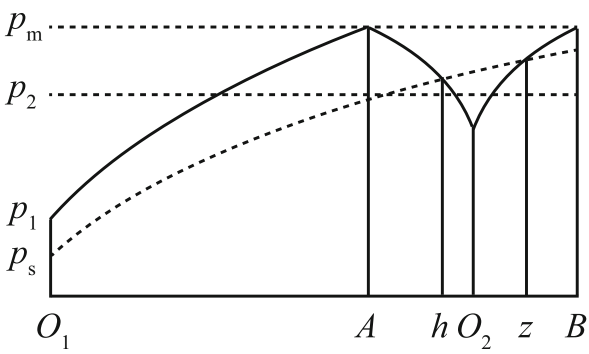

Fig. 6.3 Hierarchical central place system

This situation corresponds to a shrinking of the demand curve for O_2 that reduces the value a. Further, applying Eq. (6.7) to this situation shows that the optimal market area radius also decreases on average, due to the altered shape of the circular formation after that shift.

6.4 Regional Sustainability

The previous section demonstrated that spatial market competition under a hierarchical spatial structure may cause severe problems with regional sustainability when it comes to distributing goods and services. As depicted in Fig. 6.4, where the horizontal axis and the vertical axis, respectively, show the size of market area and the level of operating cost at the local central place O_2, a nonoverlapped market area situation satisfies bv (wider market area radius and less cost), while an overlapped market area gives rise to the area gw (narrower market area radius and more cost) for the local central place O_2.

Here, costs to distribute goods and services from the local centre O_2 become higher when the original market area is partly eroded by the centre O_1, since the economies of a larger scale on the centre O_1 may allow for a further reduction of costs by the narrowing of the market area of the local centre O_2. That pushes up the mill price and transportation costs for distribution from the local centre O_2. Eventually, more spatial consumer exclusion appears over the longer term, if the centre O_1 attempts to engage in spatial competition as a short-run entry deterrence behaviour. In that circumstance, regional coordination systems might be necessary to restore operational efficiency of the local central system O_2.

While online stores can be an alternative method for distributing goods and services, there may be more household utility in actual, face-to-face shopping, as long as maximum information and immediate use are key priorities for a given household. In addition, a competitive explicit price set by an online merchant, p_0 ($p_0 \geq 0$), should theoretically satisfy $p_0 \leq p_m$ where p_m represents the maximum

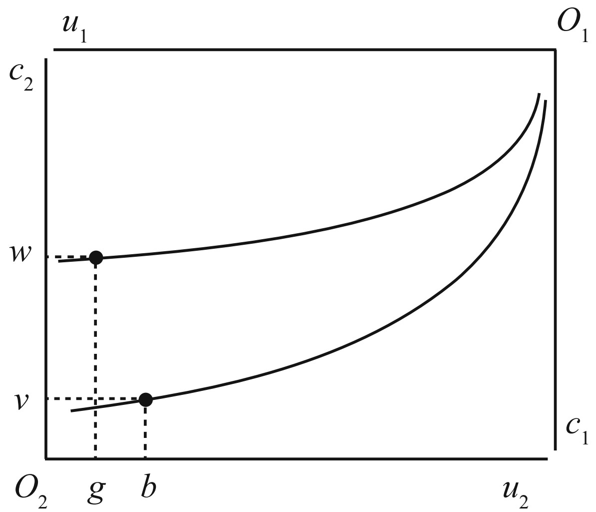

Fig. 6.4 Territorial overlaps

reserve price of households mentioned earlier. Since online stores generally involve longer waiting periods after purchases and also less complete product information than actual, brick-and-mortar shopping, those aspects of online shopping can be added as implicit costs. Such costs can be expressed by $\sigma(\sigma \geq 0)$, with the actual price then being $p_0 + \sigma$. Hence, the sufficient condition for online stores to prevail over physical stores would be $p_0 + \sigma \leq p_{\mathrm{m}}$. As long as such firms are not directly related to a given region, when it becomes apparent that the distribution of goods and services to that region is unprofitable, their decision to cease business operations may be reached much faster than the decision of locally oriented firms that use the local central place system O_2.

Highly ranked central places, such as capital cities and financial centres of the country, commonly face heavy spatial concentration. These are reasons why many countries enact decentralisation policies as part of top-down, national land-planning, and policy-making initiatives. However, such measures may not work well in the long run if they involve only cost-saving opportunities such as taxation rewards in rural areas. Above and beyond such opportunities, firms must remain in place once they have migrated to those regions. In other words, it is necessary to provide a secure environment for economic activity over the longer term, to ensure that every economic agent can maintain a satisfactory level of utility or profit.

However, the provision of a secure economic environment of this kind should not be expected under the condition where each individual or firm's sole aim is to maximise its utility or profit level. Instead, a bottom-up approach is needed to maximise regional welfare. To be concrete, when households purchase goods and services at lower prices, their doing so may naturally expand the market share of the larger central places outside the region. It would be ideal if these market areas would

Table 6.1 Pay-offs among different selections

A/*B*	Together	Individual
Together	A_{11}, B_{11}	A_{12}, B_{12}
Individual	A_{21}, B_{21}	A_{22}, B_{22}

then steadily and reliably have goods and services distributed to them. Otherwise, rural areas will face a severe spatial consumer exclusion.

A simple two-player normal-representative form in Table 6.1 can describe the situation at issue. The table shows that there are two local households, person *A* and person *B*. Each player can either choose strategy 'together' or 'individual'. Here, 'together' implies that the player purchases items always via the local central place system, while 'individual' represents the player who pursues only individual utility maximisation, by purchasing from the lower-price market (O_1). Also, note that $A_{12} \approx A_{21} > A_{11} > A_{22}>$ and $B_{12} \approx B_{21} > B_{11} > B_{22}$. In the long run, it is apparent that the combination (A_{11}, B_{11}) is the best solution for all, ensuring that regional welfare in terms of availability of goods and services is maximised. However, the players' actual selection is a different combination, (A_{22}, B_{22}), which results in much lower payoffs for all than the combination (A_{11}, B_{11}). The reason for this selection derives from other potential patterns—namely, (A_{12}, B_{12}) and (A_{21}, B_{21})—since a player who selects 'individual' can earn a larger payoff in a non-cooperative game.

However, a regional system might be able to consider organising a cooperative game rather than a non-cooperative one in this connection. If there is a referee (i.e., regional planners) and if that referee offers the possibility for cooperative behaviour by providing sufficient information (i.e., informing players about the payoff matrix that results from sustaining the local central place system O_2 versus continuing to select an 'individual' node), an infinitely repeated game may lead local households to select 'together' unless others deviate from the triggering strategy. To minimise any risk of deviation, beneficial externality across the region needs to be arranged by substantially increasing its attractiveness.

6.5 Further Avenues for Inquiry

The framework outlined in this paper may also be applicable to local firms that obtain inputs either via a local central place system or from somewhere else outside the region. Once all relevant economic agents, including those in the governmental sector, are included in the model framework, the impact of utilising the local central place system on the regional economy can be evaluated by input-output analysis. Thus, in an expanded version of the approach sketched here, a regional econometric input-output model (REIM) can provide regional economic forecasting, in the manner originally established by Israilevich et al. (1997). This analysis can then be connected with community-level central place theory through the economic-based approach proposed by Parr et al. (1975), the lower-hierarchical forecasting model developed by Chalmers et al. (1978), and the economic-based approach, involving linkage between different hierarchical sectors, developed by Mulligan (1979). Likewise, the analysis will be able to address Robinson's (1997) model of problematic factors in household economies, by attempting to establish a direct link between the input-output model and central place system proposed by Sonis and Hewings (2003). It can factor in, too, the Löschian market area analysis via input-output analysis presented in Sonis (2007).

To sum up, the sustainable local central place would become necessary, and its sustainability guaranteed more securely, if local economic agents had constant access to the local central place system as a result of cooperative behaviour undertaken to maximise regional welfare over the longer term—as opposed to non-cooperative behaviour undertaken to maximise short-run individual utility. In the long run, moreover, increased regional welfare also raises individual utility levels. This pattern can be connected, in turn, with Parr's (2015) analysis of what he calls 'regional externalities'.

6.6 Concluding Comments

This paper has explored an optimal spatial economic system for improving regional welfare by means of the secure distribution of goods and services. Using the approach of market area analysis within the framework of central place theory, the paper indicates that rural areas, where local population and economic activity do not reach a sufficient level of scale, find it difficult to compete for the distribution of goods and services from outside the region. Hence, for them to be sustainable in the long run, it is necessary to enhance beneficial economies by promoting cooperative behaviour within rural regions.

References

Arrow KJ (1950) A difficulty in the concept of social welfare. J Polit Econ 58:328–346
Arrow KJ, Scitovsky T (1969) Readings in welfare economics. Richard D. Irwin, Inc., Northampton
Baumol WJ, Blinder AS (2016) Economics: principles and policy, 13th edn. Cengage Learning, Boston
Bergson A (1938) A reformulation of certain aspects of welfare economics. Q J Econ 52:310–334
Blomquist GC, Berger MC, Hoehn JP (1988) New estimates of quality of life in urban areas. Am Econ Rev 78:89–107
Chalmers JA, Anderson EJ, Beckhelm T, Hannigan W (1978) Spatial interaction in sparsely populated regions: an hierarchical economic base approach. Int Reg Sci Rev 3:75–92
Christaller W (1933[1966]) Die Zentralen Orte in Süddeutschland, Fischer, Jena, Germany (English translation by Baskin C. (1966) The central places in Southern Germany. Prentice Hall, Englewood Cliffs)
Desmet K, Rossi-Hansberg E (2013) Urban accounting and welfare. Am Econ Rev 103:2296–2327

Glaeser EL, Kolko J, Saiz A (2001) Consumer city. J Econ Geogr 1:27–50
Greenwood MJ, Hunt GL (1989) Jobs versus amenities in the analysis of metropolitan migration. J Urban Econ 25:1–16
Hicks JR (1939) Value and capital. Oxford University Press, Oxford
Ifcher J, Zarghamee H (2011) Happiness and time preference: the effect of positive affect in a random-assignment experiment. Am Econ Rev 101:3109–3129
Israilevich PR, Hewings GJD, Sonis M, Schindler GR (1997) Forecasting structural change with a regional econometric input-output model. J Reg Sci 37:565–590
Jackson MO, Rodriguez-Barraquer T, Tan X (2012) Social capital and social quilts: network patterns of favor exchange. Am Econ Rev 102:1857–1897
Jensen MJ, Leven CL (1997) Quality of life in central cities and suburbs. Ann Reg Sci 31:431–449
Jones CI, Klenow P (2016) Beyond GDP? Welfare across countries and time. Am Econ Rev 106:2426–2457
Kaldor N (1939) Welfare propositions of economics and interpersonal comparisons of utility. Econ J 49:549–552
Little IMD (1957) A critique of welfare economics, 2nd edn. Clarendon Press, Oxford
Lösch A (1938) The nature of economic regions. South Econ J 5:71–78
Lösch A (1944[1954]) Die raümliche Ordnung der Wirtschaft (2nd edn). Fischer, Jena, Germany. (English translation by Woglom WH, Stolper WF. (1954) The economics of location. Yale University Press, New Haven)
Mills ES, Lav MR (1964) A model of market areas with free entry. J Polit Econ 72:278–288
Mulligan GF (1979) Additional properties of a hierarchical city-size model. J Reg Sci 19:57–66
Nakamura D (2007) An integrated framework of market areas and supply areas: combining market-area systems with supply-area systems. In: REAL discussion paper, REAL 07-T-3: regional economics applications laboratory. University of Illinois, Champaign
Nakamura D (2010) Spatial competition and consumer exclusion: social welfare perspectives in central-place system. Lett Spat Resour Sci 3:101–110
Parr JB (2002) Agglomeration economies: ambiguities and confusions. Environ Plan 34:717–731
Parr JB (2008) Administrative spatial structure: a note on an alternative approach. Ann Reg Sci 42:141–151
Parr JB (2015) The city and the region as contrasts in spatial organization. Ann Reg Sci 54:797–817
Parr JB, Denike KG, Mulligan G (1975) City-size model and the economic base: a recent controversy. J Reg Sci 15:1–8
Pigou AC (1932) The economics of welfare, 4th edn. Palgrave Macmillan, Hampshire
Robbins L (1938) Interpersonal comparisons of utility. Econ J 48:635–641
Robinson MH (1997) Community input-output models for rural area analysis with an example from Central Idaho. Ann Reg Sci 31:325–351
Samuelson PA (1947) Foundations of economic analysis. Harvard University Press, Cambridge
Scitovsky T (1941) A note on welfare propositions in economics. Rev Econ Stud 9:77–88
Sen A (1974) Informational bases of alternative welfare approaches: aggregation and income distribution. J Public Econ
Sonis M (2007) Central place theory after Christaller and Lösch: some further explorations. In Blum U, Funck RH, Kowalski JS, Kuklinski A, Rothengatter W (eds) Space-structure-economy: a tribute to august Lösch, 2nd revised and extended edn. Nomos Verlag, Baden Baden
Sonis M, Hewings GJD (2003) Miyazawa meet Christaller: spatial multipliers within a triple decomposition of input-output central place system. In: REAL discussion paper, 03-T-30, Regional Economics Applications Laboratory. University of Illinois, Champaign
Stiglitz JE, Sen A, Fitoussi J-P (2009) Report by the Commission on the Measurement of Economic Performance and Social Progress. Commission on the Measurement of Economic Performance and Social Progress. www.stiglitz-sen-fitoussi.fr

Stiglitz JE, Sen A, Fitoussi J-P (2010) Mismeasuing our lives: why GDP doesn't add up. The New Press, New York

Weber A (1909[1928]) Über den Standort der Industrien. Tübingen, Mohr. (English version: Weber A. (1928) Alfred Weber's theory of the location of industries (trans: Friedrich CJ) University of Chicago Press: Chicago)