AGGLOMERATION ECONOMIES AND LOCATION DECISION-MAKING OF FIRMS IN LOCATION-TRIANGLE APPROACH*

Daisuke Nakamura
The International Centre for the Study of East Asian Development (ICSEAD), 11-4 Otemachi, Kokurakita, Kitakyushu, 803-0814, Japan, +81-93-583-6202, +81-93-583-4602 (fax), Email: nakamura@icsead.or.jp

Abstract:
The location-triangle framework, which was originally established by Alfred Weber, has been expanded in various ways and generalized as the Weber-Moses location-triangle model. However, several essential elements, in particular, regarding agglomeration economies have been excluded from the model framework. This may cause a potential difficulty to connect location-triangle approach with recent more advanced spatial economic analysis. In this paper, an alternative hypothetical model is introduced to the location triangle framework with the notions of agglomeration economies and corresponding transportation costs. The alternative model framework enables the location-triangle model to deal with investigating modern complex industrial organizations. Further avenues of extension are also discussed.

JEL Classification: L14; O21; R30; R58

Keywords: Location-triangle model; agglomeration economies; transportation costs; firm location

1 Introduction

The location-triangle model was initially developed by Weber (1909 [1929]), applying the relationship between physical distance and transportation costs, which was originally explored by Launhardt (1885). Weber included the notion of trade-off interaction between transportation costs and agglomeration economies with respect to the economy of labor in order to specify the optimal firm location by setting two different extracting sites of inputs for processes and one location of consumption for selling the final products. Regarding external terms of agglomeration economies in his period of time, it was solely necessary to consider the localization type of economy, which was also indicated by Marshall (1890) as the concentration of specialized industries in particular localities.

Since the initial establishment of the model framework by Weber, the location-triangle model was further expanded by Moses (1958), Khalili et al., (1974) and Mai and Hwang (1992), those who attempted generalizations by introducing the homogeneous production function, the homothetic production function and the condition of market demand, respectively. These advanced methods are commonly known as the Weber-Moses location-triangle model. However, during these expansions, agglomeration economies were almost fully dropped from the model framework and this may cause certain difficulties to apply for more recent location economic analysis.

Agglomeration economies are divided into two parts as internal and external dimensions. According to the categorization by Parr (2002a), each dimension can be further categorized under three criteria, namely, economies of scale, scope and complexity. In the

* An earlier version of the paper was conducted under the funded projects of Núcleo Ciencia Regional y Políticas Públicas (Iniciativa Científico Milenio de MIDEPLAN) and Comisión Nacional de Investigación Científica y Tecnológica (CONICYT) in Chile. The final version was completed during the ICSEAD research project 2010/2011. The author would like to thank Dr. Stilianos Alexiadis and anonymous referees for their comments and suggestions. A preliminary version of the paper was presented at the 66th International Atlantic Economic Society Meeting in October 2008 at Montreal, Canada.

external dimension, these are also referred to as localization, urbanization and activity-complex economies. While this paper mainly focuses on these external forces, internal forces have also important roles when the location model involves in upstream and downstream external linkages between neighbor different firms within the industry.

The concern of this paper is to reveal a missing relationship between location triangle and agglomeration economies. As introduced earlier, the established location-triangle analysis employed at most the localization type of agglomeration economies, which are referred to the spatially-constrained economies of scale. In order to enable the analysis to investigate urbanization and activity-complex economies in addition to localization economies, the central-place system, particularly, market-area analysis should be encouraged to employ in this framework. By applying the established framework of market areas, an alternative hypothetical model is developed in this paper, which demonstrates the determination of optimal firm location for different types of conditions.

Market-area analysis was systematically formalized by Lösch (1944 [1954]), which examines how products are distributed to an economic plane under the given conditions of output price, density of demand and distribution transportation costs. This areal framework validates the studies of different sizes and shapes of regions, spatial distributions of labors, households and types of production orientation. While this paper limits the scope of the study on a non-hierarchical spatial model, the central-place theory also deals with the urban hierarchical structure. Those contributions were made by Christaller (1933 [1966]) and Lösch (1944 [1954]) as initial attempts, and Mulligan (1982) and Parr (2002b) for more detailed investigations. These may have particularly important roles for the analysis of firm location and agglomeration economies with respect to localization and urbanization economies.

In addition to these agglomeration elements, activity-complex economies become more common to be observed in modern industrial structures. These are relevant to vertical integration or specialization, if the economies are internal to the firm. The vertical integration was systematically formalized by Stigler (1951) and applied to the vertical specialization and trade in Hummels et al., (1995), and the idea was also given to fragmentation of production by Jones and Kierzkowski (2005). Furthermore, the recent operational and location changes in the relationship between headquarter and production plant was attempted by Silva and Hewings (2007). Under these progresses, the framework of location-triangle model lost its significance due to exclusions of agglomeration criteria. However, there still have rooms to investigate the optimal firm location from the approach of location-triangle model, if the neglected elements are properly taken into account.

In this paper, instead of attempting a modification of the generalized Weber-Moses framework, it is aimed to re-examine the original Weber model in order to avoid complication of the argument and to reveal the fundamental nature of location-triangle analysis and the studies of agglomeration economies.

2 Agglomeration economies and the location-triangle model

Agglomeration economies are spatially-constrained internal and external economies. As introduced earlier in the previous section referring to Parr (2002a), spatially-constrained internal economies have three dimensions in terms of scale, scope and complexity. First, the internal economies of scale can be relevant to the horizontal integration. In other words, a larger quantity of output achieves the more cost reduction for processing a product as long as the average-cost curve falls. Secondly, the internal economies of scope may be referred to the lateral integration, which can be exemplified that a variety of production enhances more opportunities of revenues. A representative case is a motorbike company who also produces motorboats, audio speakers and music instruments. Finally, the internal economies of complexity can be relevant to the vertical integration, which achieves lower-cost production by an integrated process within a single firm than operations by different firms.

In addition, spatially-constrained external economies also have three dimensions, commonly known as localization, urbanization and activity-complex economies. First, localization economies can be referred to the original Weber model that the economic

concentration at a particular location creates the economy of labor. In addition, as indicated in Marshall (1890), localization economies also include joint action for input extraction and specialized services. Secondly, urbanization economies are typically available at the metropolitan area, brought by advantages of concentration on the variety of economic activity. These economies include administrative accessibility, well-organized infrastructure, variety of labor supply and highly-advanced systems of communication and transportation. While it is excluded from the analysis in this paper, the inclusion of central-place system validates to examine urbanization economies with respect to hierarchical spatial structure. Further details should be referred to the notion of functional system in Parr (2007). Finally, activity-complex economies are commonly observed in modern advanced industries, where upstream and downstream stages have important roles for processing. These can be exemplified by the Ford campus of automobile-assembly plant in Chicago and the aero-space industries complex in Toulouse.

Those elements of agglomeration economies can be examined within the framework of the location-triangle model. In order to integrate these different approaches, it is initially necessary to set a model under the following conditions. There are multiple firms those who produce different products. However, some of inputs such as coppers are common to use during the processing stages. Also, the place of consumption for the final product of each firm is assumed to place at the same location, therefore, certain parts of infrastructure facilities such as the network of transportation can be shared among these firms. Under these conditions, an alternative location-triangle model is investigated in the following section.

3 An alternative location-triangle model

In order to examine the notion of agglomeration economies within the framework of location-triangle model, an alternative model considers three independent firms in an economic plane. These are defined as firms A, B and C, those who are engaging productions in a particular economic space. First, firm A produces q_A, which has a place of consumption at MK, using inputs RM_1 and RM_2 for processing this particular product. Similarly, firm B produces q_B, which is also consumed at MK, using inputs RM_2 and RM_3. In addition, firm C produces q_C, which has a place of consumption at MK, and uses two different inputs RM_2 and RM_4. As commonly assumed in the established location-triangle model, each firm determines the optimal firm location where the aggregate transportation costs are minimized. Here, transportation costs have three types. First, shipping costs between the first input and the firm location, secondly, costs between the second input to the firm location as well as costs between the firm location and the place of consumption. These costs for inputs are relevant to assembly transportation costs, and costs for the final product are referred to distribution transportation costs.

In this paper, each firm is assumed to bear these transportation costs. In other words, transportation costs are regarded as the elements of production costs, therefore, each firm attempts these costs to keep at minimum level. The minimization of transportation costs is affected by the value and bulkiness of shipping goods, in addition to the physical distance between two relevant locations. As a result, the structure of production function also has an important role for the determination of the firm location. In this way, for instance, the optimal firm locations of each firm A, B and C may be given as points P_A, P_B and P_C, which are respectively plotted in Fig. 1. From the above assumptions, the point P_A satisfies the minimization of the sum of transportation costs from RM_1 to P_A, from RM_2 to P_A, and from P_A to MK. Similar discussions are applied for locations P_B and P_C of firms B and C, respectively.

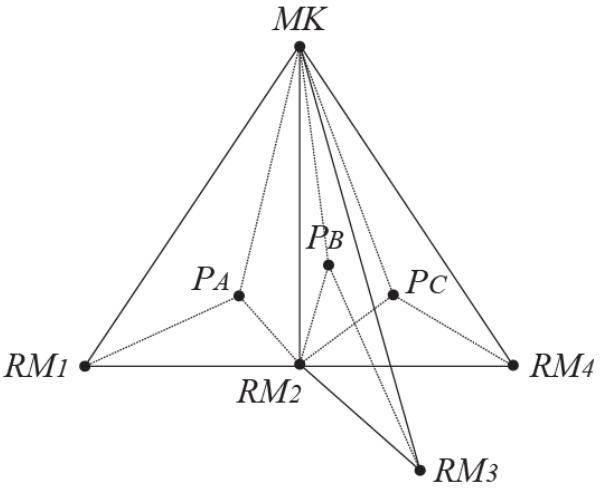

Fig. 1 Location triangles of three firms

However, if these firms have certain opportunities of agglomeration economies by locating at immediate nearby each other, the optimal locations of three firms may be given at a specific single point. There are three different scenarios shown as follows. First, they may locate at a common-use raw-material site and have the advantage of localization economies, if the raw-material extraction or other production-related cooperation is jointly organized. Secondly, the location can be at the metropolitan area, if the economies of urbanization and accessibility to the place of consumption have important roles for all three firms. Here, the place of consumption may be treated as the center of metropolitan area in the location triangle model, while this assumption is not revealed in their original framework. Finally, one more different location incentive can be considered in cases of activity-complex economies for more advanced industries. In this way, the optimal location varies depend on spatial proximity both to raw-material sites and to the place of consumption. Moreover, each corresponding transportation-cost element also affects this location decision-making process. These aspects are further detailed individually in the following section.

4 Hypothetical analysis

4.1 Firm location and localization economies

First, a consideration is given to examine the relationship between firm location and localization economies. From the assumption in the previous section, all three firms need to use the common input RM_2. As a result, they may locate at P_L in Fig. 2, and have certain opportunity to share the process of raw-material extraction. At the same time, other types of localization type of economy such as the economy of labor and specialized services can be also available under this circumstance. Such agglomeration force is encouraged, particularly, if the shipping cost of RM_2 to the firm location is significantly high level, while the shipping cost to the place of consumption is relatively lower level. If the price of land is significantly high level at populated areas, the lower price of land may be an incentive to locate at raw-material sites those are normally situated at local regions of a country. Such areas are also suitable for productions which need good quality of air, water, soil and space.

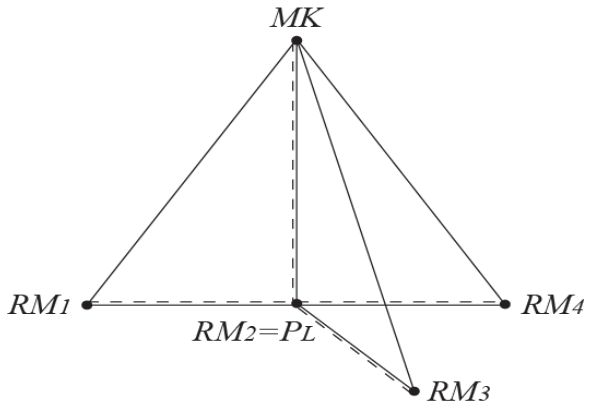

Fig. 2 Location triangle and localization economies

Finally, it should be noted that this alternative location is situated within each critical isodapane of all three firms. In other words, transportation costs of other raw materials are needed to be lower enough to cover the re-locating production site within each critical isodapane, which represents the maximum level after the lines of aggregate minimum transportation costs that radiate in all directions from the center of the original firm location (see Weber, 1909 [1929]: 147-153).

4.2 Firm location and urbanization economies

Urbanization economies are usually available at the center of market area. It implies that the optimal firm location can be situated at the center of an area. However, there are a number of exceptions where the optimal location may not be the center of market area. This can be seen for firms those who supply products as intermediate, which are purchased by downstream firms as household-unrelated commodities. These are the cases where the condition of centrality of market area and supply area is not satisfied (Nakamura, 2008). By contrast, the place of consumption may be at the center of market area, if the products of this operation are the final goods or commodities for households. In this case, these firms are not necessarily locating closely to each other, as urbanization economies are separately available to entire economic activity who locates at this area. Such criterion is a remarkable difference to other types of agglomeration economies, which location proximity to other economic activity is required. In this scenario, the optimal firm location may be preferred to situate at the center of area at P_U in Fig. 3.

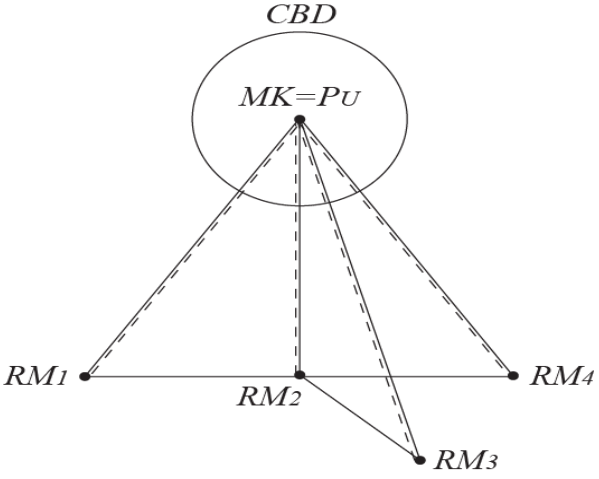

Fig. 3 Location triangle and urbanization economies

It should be noted that urbanization economies do not solely work as an incentive to locate three firms together. As a result, it is more plausible for this scenario to consider that there are also spatially-constrained economies of scale or complexity, which are exclusively available at the metropolitan area, in addition to the advantages of urbanization economies. Since the optimal firm location is at or very close to MK, the distribution costs between the firm location and the place of consumption become negligibly small. As a result, the overall physical distance of transportation is minimized, while assembly transportation costs between raw-material sites and the firm location are higher than the original firm locations.

4.3 Firm location and activity-complex economies

If the products of three firms are similar but solidly product differentiated, the concentration of the production may bring certain cost savings by joint production at some processing stages during the processes. As shown in Fig. 4, the optimal firm location P_X may be somewhere between raw-material sites and the place of consumption MK. If the transportation system from P_X to MK is possible to share among these three firms, the distribution transportation costs may be saved by enhancing the economies of scale. However, the optimal firm location still approaches toward the center MK, if the joint cost-saving distribution is significantly high level. By contrast, if the assembly transportation contains bulky and high-cost structure, they are locating close to raw-material sites.

Also, the presence of CBD also leads to a similar outcome. Namely, the larger CBD locates the firm away from the center in order to avoid highly price of land, congestion and pollution. It can be refereed to the centrifugal forces of urbanization economies or more simply urbanization diseconomies. In this way, agglomeration economies and transportation costs have important roles to solve the problem of optimal firm location.

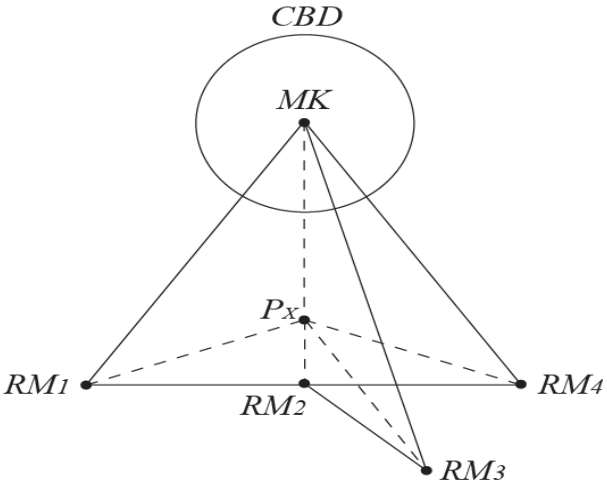

Fig. 4 Location triangle and activity-complex economies

5 Policy implications

In order to generalize the alternative framework, the following cost function of a representative firm is given:

$$\min C = \left(\left(w_i + t_i d_i\right)x_i + \left(w_j + t_j d_j\right)x_j + \alpha \cdot t_k d_k q_k\right) \cdot \beta \tag{1}$$

where w_i = price of input i, t_i = transportation cost rate for i, d_i = distance from the input site i to the firm location, x_i = the amount of input i, w_j = price of input j, t_j = transportation cost rate for j, d_j = distance from the input site j to the firm location, x_j = the amount of input j,

α $(0<\alpha<1)$= cost saving index by sharing the distribution transportation system, t_k = distribution transportation rate, d_k = distance from the firm location to the place of consumption, q_k = the quantity of product, and β $(0<\beta<1)$= index of the economies of agglomeration.

Here, α and β are zero, if each firm establishes their plant location separately. In that case, each firm can minimize the sum of distance d_i, d_j and d_k. By contrast, the sum of distance cannot be minimized when a firm locates together with other two firms in order to obtain opportunities of agglomeration economies and shared distribution costs. In that case, α and β are set non-zero and certain cost saving may be available. This is a trade-off interaction between agglomeration economies and physical distance in Weber sense. However, a remarkable difference is that this analysis also includes the cost-saving opportunity of distribution transportation costs. The evaluation can be provided as follows. First, each firm does not locate together, if the benefit of α and β are less than the cost increase by additional distance of d_i, d_j and d_k. Otherwise, each firm locates together and the optimal firm location varies depend on the conditions given in Table 1.

As an exception, it should be noted that these firms are not locating at the place of consumption, if the diseconomies of urbanization are set significantly high level. In that case, there is a centrifugal force from the center and the optimal location is away from the center. In this circumstance, the parameter β may be exceptionally set more than 1 as the impact of diseconomies such as pollution, congestion and highly price of land. In addition, the outcome can be affected by the formations of production function and demand curve of the product, although this analysis limits the scope of the analysis within a simplified framework.

Table 1. The location decision-making of firms and the condition

Location	Condition
the raw-material site i or j	$t_i > \frac{t_j + t_k}{2}$ or $t_j > \frac{t_i + t_k}{2}$
the place of consumption	$t_k > \frac{t_i + t_j}{2}$
somewhere between above locations	Otherwise

There is one more note regarding the cooperative behavior among different firms. As introduced earlier in the previous section, the notion of critical isodapane implies that agglomeration economies are not available to obtain, unless all three isodapanes overlap with each other. Regarding this criterion, further concerns were indicated by Isard (1956: 176-182) as a scenario where the isodapane of one firm does not reach to an overlapping area. Even though such a circumstance is faced on a firm, the economies of agglomeration are achieved when this firm is suggested to be subsidized by two other firms for the amount of complementing transportation costs to the agglomeration area. This kind of bargaining approach not only has an opportunity for solving the location problems of firms but also enable the framework to apply for welfare aspects in terms of household, producer, social and natural environment. In other words, the optimal location decision-making model may be possible to avoid the potential issues on unwilling location of economics from the standpoint of comprehensive systems of economic activity. The bargaining theory has a particularly important role when inappropriate short-run profit for a part of firms exceeds long-run social-optimal benefits. This has certain difference from regulation and tax policies by the governmental authority, as the long-run profit of any economic agent is guaranteed and this enables policy makers to avoid anticipated problematic conflicting issues between different economic agents without severe difficulties.

6 Concluding comments

In this paper, it is revealed that the notion of agglomeration economies is excluded from the Weber-Moses model and this causes potential issues to examine the optimal firm location that involves complex structures of industrial organization. An alternative hypothetical model is introduced to the original Weber model, which includes the trade-off interaction between localization economies and transportation costs. In addition, other parts of agglomeration such as urbanization and activity-complex types are also added to the alternative model by means of importing the framework of central-place system. While this examination solely includes market-area analysis, the introduction of supply-area analysis may enable the alternative framework to deal with upstream and downstream production linkages.

References

1. Christaller, W. (1933 [1966]) *Die Zentralen Orte in Süddeutschland*, Jena, Germany: Fischer, 1933. English translation by C. Baskin, *The Central Places in Southern Germany*, Englewood Cliffs, NJ: Prentice Hall, 1966
2. Hummels, D., Ishii, J. and Yi, K-M. (1995) "The nature and growth of vertical specialization in world trade", *Journal of International Economics*, 54/1: 75-96
3. Mai, C. C. and Hwang, H (1992) "Production-location decision and free-entry oligopoly", *Journal of Urban Economics*, 31/2: 252-271
4. Isard, W. (1956) *Location and Space-Economy*, Cambridge, Massachusetts, and London, England: The M.I.T. Press
5. Jones, R. W. and Kierzkowski, H. (2005) "International fragmentation and the new economic geography", *North American Journal of Economics and Finance*, 16/1: 1-10
6. Khalili, A., Mathur, V. K. and Bodenhorn, D. (1974) "Location and the theory of production: a generalization", *Journal of Economic Theory*, 9/4: 467-475
7. Launhardt, W. (1885) *Mathematische Begründung von Volkswirthschaftslehre*, Leipzig: Verlag von Wilhelm Engelmann
8. Lösch, A. (1944 [1954]) *Die raümliche Ordnung der* Wirtschaft, Jena, Germany: Fischer, 1944 (2nd edn). English translation by W. H. Woglom and W. F. Stolper, *The Economics of Location*, New Haven: Yale University Press
9. Marshall, A. (1890) *Principles of Economics*, London: Macmillan and Co., Limited
10. Moses, L. N. (1958) "Location and the theory of production", *Quarterly Journal of Economics*, 72/2: 259-272
11. Mulligan, G. F. (1982) "Tinbergen-type central place systems", *International Regional Science Review*, 7/1:83-91
12. Nakamura, D. (2008) "Spatial competition and integrated framework of central-place system with agglomeration economies" *Région et Développement*, 27: 193-214
13. Parr, J. B. (2002a) "Missing elements in the analysis of agglomeration economies", *International Regional Science Review*, 25/2: 151-168
14. Parr, J. B. (2002b) "The location of economic activity: central place theory and the wider urban system", in P. McCann ed., *Industrial Location Economics*, Cheltenham: Edward Elgar
15. Parr, J. B. (2007) "On the spatial structure of administration", *Environment and Planning A*, 39: 1255-1268
16. Silva, C. E. L. and Hewings, G. J. D. (2007) "Location, communication, and control within a vertically integrated firm" in *REAL Discussion Paper*, REAL 07-T-07: Regional Economics Applications Laboratory, University of Illinois
17. Stigler, G. J. (1951) "The division of labor is limited by the extent of the market", *The Journal of Political Economy*, 59/3: 185-193
18. Weber, A. (1909 [1929]) *Über den Standort der Industrien, Tübingen.* Translated and edited by C. J. Friedrich as Alfred Weber's Theory of the Location of Industries: Chicago, 1928