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A theoretical analysis on location and  
production of industrial park

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## **A theoretical analysis on location and production composition of industrial park**

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### **Abstract**

As firms' production activity becomes large enough to cover the whole world, price and cost cutting competition become harsher among the manufacturing firms. In order to deal with the cost competition many manufacturing firms fragment the production process into small blocs, and they move the small fragmented blocs to new location sites which provide the factories with favorable production condition and reduce production costs. In searching new location site of a fragmented production process, an industrial park is reevaluated as a location factor by the governments of the countries as well as the manufacturing firms. Because industrial parks provide the factories with various sorts of external economies and they can attract the factories from foreign industrial countries into a few specific sites in their territories. Present paper theoretically analyzes the location and production composition of industrial park: First, the paper clarifies the mechanisms in which the developer of the industrial park determines the location site of the industrial park by examining the firms' location selections. Second, this paper analyzes how external economies generated in the industrial parks influence on the production composition in the park; the combination of the business types of the factories, the numbers of the factories and their profits in the industrial park are derived. Lastly, effects on factories' profits of wage rate of workers is analyzed. It is shown in this analysis that reduction of the wage rate which is generated by an improvement of the transportation condition surrounding industrial park does not raise every factory's profit because the production composition of the park is changed due to the reduction of the wage rate.

**JEL:** R30

**Keywords:** Industrial park, External economies, Locational prospective area, Transfer price, Production composition, Wage rate, Chaotic phenomenon

## **A theoretical analysis on location and production composition of industrial park**

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### **1 Introduction**

The economic globalization gives rise to a harsher price competition among the manufacturing firms, and it lead to a cost cutting competition in the manufacturing industry. In order to deal with the economic globalization many manufacturing firms fragment production process into small blocs. The fragmented small production processes are scattered beyond the nations' borders to the places which bring lower production costs to the manufacturing firms. The places which attract the fragmented processes from the foreign countries usually possess superior production condition suitable to content of the productions. And the places are equipped with adequate infrastructure enough for the firms to operate their factories smoothly. In this context, the industrial parks are highly reevaluated by the manufacturers and the governments of many countries: Since an industrial park is built in consideration of characteristics and quality of the factories attracted to the park, the industrial park surely provides the factories with appropriate external economies in the park. Thus, when the manufacturers determine factory's location in region, they naturally consider an industrial park as a location factor in searching location site of a new factory. While, the government planning to vitalize regional economy in a certain region by inducing factories often use an industrial park as one of economic tools to accomplish the aim. Because the government can establish industrial park which agglomerates the factories at a place and also induce them to a specific site in the region. In addition, industrial park manages some sorts of the business functions through IT and ICT technologies so that both manufacturers and the governments are able to speedily proceed the office works. The fact that industrial park makes the firms' management works smoother is one of the production merits of industrial park.

This paper theoretically analyzes the following issues. First, the paper clarifies the concept of the prospective spatial area in which industrial park is likely to be established through the analysis of firm's location selections, and then, by using the location prospective areas the combination of business types of the factories in an industrial park is derived. Second, the paper examines the effects of external economies generated in industrial park on the numbers and profits of the factories belonging to different business types. Lastly, effects on the production composition and factories' profits of wage rate of workers is analyzed. The government of the country often plays a role of the developer of the industrial park and it can influence the wage rates of workers by improving the transportation infrastructure surrounding the industrial park. This analysis shows that reduction of the wage rate which is generated by an improvement of the transportation condition does not raise every factory's profit because the production composition of the industrial park is changed due to the reduction of the wage rate.

Present paper is organized as follows: section 2 explains the assumptions and framework of the analysis and derives the firm's profit function. Using the profit function, the concept of the locational prospective area is elucidated by the chaotic phenomena. The location prospective area specifies spatial range for a firm to search location site of a new factory: If a firm's factory locates within the location prospective area, the firm can obtain almost highest profit irrelative to location site. And then, expanding this analysis to cover two factories' locations, the location site of the industrial park and the combination of the business types of the factories which co-exist in the same industrial park are derived. Section 3 shows how external economies in industrial park affect profits of the factories in the park. Section 4 analyzes the effects on the production composition and the factories' profits of the reduction of wage rate of workers in the industrial park. Section 5 summarizes the results derived in this analysis.

## **2 Derivation of location and composition of industrial park by location analysis of factories**

### **2.1 Assumptions and framework of analysis**

This subsection introduces assumptions and a framework of the analysis according to the traditional location theory<sup>1</sup>.

A firm produces finished goods by using two production processes, the first and the second process. The first process is conducted by the factory 1 which is in the home country. The factory 1 manufactures intermediate goods,  $mq$ . The second process is assigned to the factory 2 which locates in the foreign country. The factory 2 composes final goods by using the intermediate goods.

The intermediate goods produced by the factory 1 are transported to the factory 2 by the transfer price,  $mp$ . The factory 2 uses one unit of the intermediate goods to produce one unit of the final goods. The factory 2 sells the finished goods to the market place in the foreign country. There is no tariff in the movement of the intermediate goods from the factory 1 to the factory 2. The factory 2 is in the position of the monopoly in the market. The factory 2 can determines the supply quantity of the final goods at the market in order to maximize *the factory's* profit. On the other hand, the factory 1 decides the transfer price of the intermediate goods in order to maximize *the firm's* profits. The corporation tax rates of the home and the foreign country are represented by  $t$  and  $t^*$ , respectively.

### **2.2 Derivation of the profit function of the factory 1**

The profit of the factory 1,  $Y_1$ , is given by equation (1),

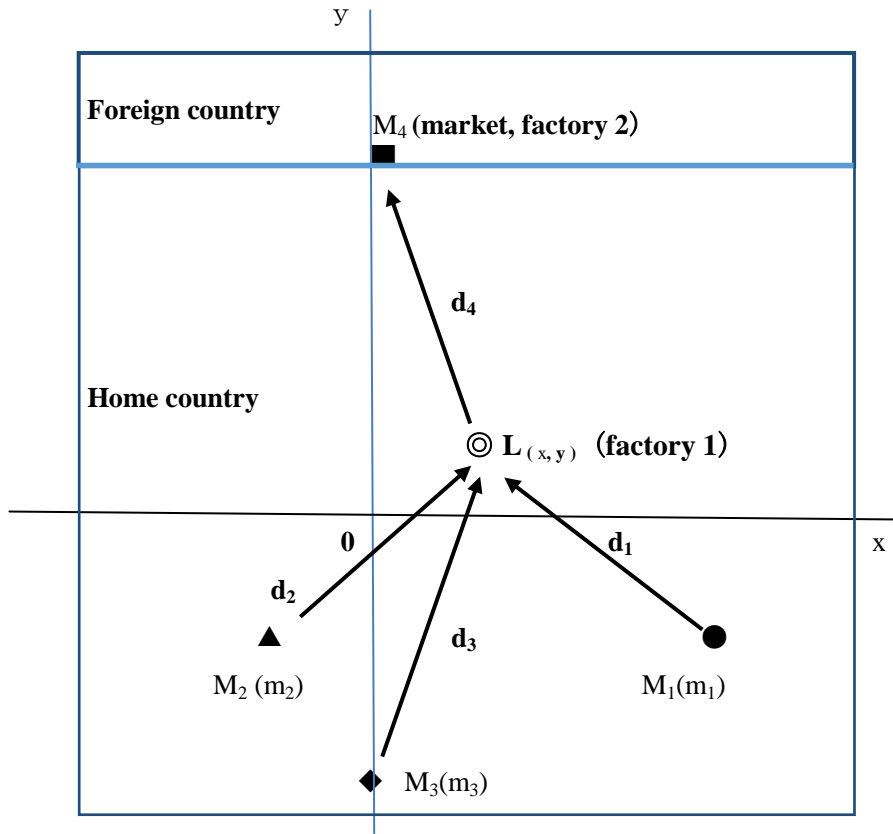
$$Y_1 = (1 - t)[mp * mq - C(mq) - F_1] \quad (1)$$

where  $C(mq)$  is the cost function of the factory 1 and  $F_1$  is fixed cost. The cost function  $C(mq)$  is

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<sup>1</sup> The basic framework is constructed according to Weber (1909), Puu (1998), and Ishikawa (2016).

derived on the basis of the following assumptions. The factory 1 uses two different kinds of materials  $m_1$ ,  $m_2$  to produce the intermediate goods. And the factory 1 needs lubricating oil  $m_3$  to operate machines. The materials  $m_1$ ,  $m_2$  and the oil  $m_3$  are produced at points  $M_1$ ,  $M_2$  and  $M_3$  which are identified by coordinates  $(x_1, y_1)$ ,  $(x_2, y_2)$ , and  $(x_3, y_3)$ , respectively. These materials are transported to the factory 1 located at point  $L$  which is indicated by  $(x, y)$ . Freight rates of the materials  $m_1$ ,  $m_2$  are denoted by  $t_m$ , and the rate of the oil  $m_3$  is given by  $t_e$ . The intermediate goods are transported from the factory 1 to the factory 2 which locates at the market at point  $M_4$ ,  $(x_4, y_4)$ . The freight rate of the intermediate goods is  $t_g$ . Mill prices of these materials and oil are assumed to be given for the simplicity, and these prices are denoted by  $p_1$ ,  $p_2$ , and  $p_3$ . Figure 1 illustrates the geographical relationships between the factory 1, the factory 2, the market and points of the three materials.



**Figure 1 Location figure**

The territory of the home country is shown by the square area and that of the foreign country is rectangle area. The market is indicated by the black square mark at point  $M_4$ . The border between the two countries is shown by the horizontal bold line in Figure 1.

The production function of the factory1 is supposed as equation (2),

$$mq = Am_1^\alpha m_2^\beta \quad (2)$$

where A indicates the production efficiency of the factory 1,  $\alpha$  and  $\beta$  are parameters and they are defined as  $A > 0$ ,  $0 < (\alpha + \beta) < 1$ . And the distances between the material places,  $M_i$  ( $i=1, 2, 3$ ) and the factory 1 are represented by  $d_1, d_2, d_3$ , respectively:

$$d_1 = ((x - x_1)^2 + (y + y_1)^2)^{0.5} \quad (3a)$$

$$d_2 = ((x + x_2)^2 + (y + y_2)^2)^{0.5} \quad (3b)$$

$$d_3 = (x^2 + (y + y_3)^2)^{0.5} \quad (3c)$$

The distance between the factory 1 and the factory 2 which locates at the market  $M_4$  is given by  $d_4$ ,

$$d_4 = (x^2 + (y - y_4)^2)^{0.5} \quad (3d)$$

The delivered prices  $P_i$  ( $i=1, 2, 3$ ) of the two materials and the lubricating oil at the location site of the factory 1 are shown by equations (4a, b, c), respectively:

$$P_1 = p_1 + t_m d_1 \quad (4a)$$

$$P_2 = p_2 + t_m d_2 \quad (4b)$$

$$P_3 = p_3 + t_e d_3 \quad (4c)$$

And the price of the intermediate goods at location of the factory 2,  $DP$ , which is needed to calculate the revenue of the factory 1, is represented by equation (5),

$$DP = mp - t_g d_4 \quad (5)$$

Now, making use of the law of equi-marginal productivity, that is, the ratio between the productivities of the two intermediate goods should be equal to the ratio between the delivered prices of them, quantities of these materials are derived as equations (6a) and (6b): (For simplicity,  $\alpha$  and  $\beta$  are assumed  $\alpha = \beta = 0.4$ ):

$$m_1 = A^{-1.25} mq^{1.25} ((p_2 + t_m d_2) / (p_1 + t_m d_1))^{0.5} \quad (6a)$$

$$m_2 = A^{-1.25} mq^{1.25} ((p_1 + t_m d_1) / (p_2 + t_m d_2))^{0.5} \quad (6b)$$

The quantity of the oil  $m_3$  is given by a linear function of amount of the final goods as equation (6c),

$$m_3 = mq \quad (6c)$$

From above equations, the cost function  $C(mq)$  is obtained as equation (7),

$$C(mq) = 2A^{-1.25}mq^{1.25}(p_1 + t_m d_1)^{0.5}(p_2 + t_m d_2)^{0.5} + mq(p_3 + t_e d_3) + F_1 \quad (7)$$

The profit function of the factory 1 can be rewritten as equation (8),

$$Y_1 = (1-t)[mq((mp - t_g d_4) - (p_3 + t_e d_3)) - 2mq^{1.25}A^{-1.25}(p_1 + t_m d_1)^{0.5}(p_2 + t_m d_2)^{0.5} - F_1] \quad (8)$$

### 2.3 Profit functions of the factory 2 and the manufacturing firm

Let us derive the profit of the factory 2. The profit is derived under the following assumptions: The market demand function is represented by equation (9),

$$p = a - vQ \quad (9)$$

where  $p$  is the market price of the final goods,  $a$  is the maximum reservation price and  $v$  is a parameter. For simplicity  $a$  and  $v$  are assumed 600 and 1, respectively. If the cost of composing the intermediate goods to the finished goods is represented by  $C(Q)$  and the fixed cost of the factory 2 is represented by  $F_2$ , the profit of the factory 2,  $Y_2$ , is represented by equation (10),

$$Y_2 = (1 - t^*)[pQ - mp * mq - C(Q) - F_2] \quad (10)$$

Suppose that the composing cost  $C(Q)$  is given by equation (4-11),

$$C(Q) = b Q(g + Q)^2/h \quad (11)$$

where parameters  $b$ ,  $g$ ,  $h$  are assumed as 1.5, 2, 200 for the simplicity of the calculation, respectively.

Since the factory 2 uses one unit of the intermediate goods to produce one final goods, the  $mq$  can be replaced by  $Q$ . The profit function is rewritten by equation (12),

$$Y_2 = (1 - t^*)[(p - mp)Q - 1.5 Q(2 + Q)^2/200 - F_2] \quad (12)$$

Since the market price of the final good,  $p$ , is a function of the quantity  $Q$  as shown by equation (9), the optimal quantity supplied at the market to maximize the profit of the factory 2 can be derived by

using equation (12). The optimal supply quantity is given by equation (13),

$$Q=0.22(-206 + (582409 - 900mp)^{0.5}) \quad (13)$$

As the supply quantity  $Q$  is a function of the transfer price, the profit of the factory 2 is also represented as a function of the transfer price as equation (14),

$$Y_2 = (1-t^*) [(600-(0.22(-206+(582409-900mp)^{0.5}))-mp)(0.22(-206+(582409-900mp)^{0.5}))-F_2]. \quad (14)$$

Summing up the profits of the factory 1 and 2, the firm's profits,  $Y$ , can be obtained as equation (15). The firm's profits is a function of the transfer price,  $mp$ , and the location,  $(x, y)$ , of the factory 1.

$$Y = (1-t)[(0.22(-206 + (582409 - 900mp)^{0.5}))(mp - t_g d_4) - (p_3 + t_e d_3) - 2(0.22(-206 + (582409-900mp)^{0.5}))^{1.25} A^{-1.25} (p_1+t_m d_1)^{0.5} (p_2+t_m d_2)^{0.5} - F_1] + (1-t^*) [(600-(0.22(-206+(582409-900mp)^{0.5}))-mp)(0.22(-206+(582409-900mp)^{0.5}))-F_2]. \quad (15)$$

## 2.3 Derivation of Location Prospective Area

### 2.3.1 Usefulness of chaotic phenomenon

Let us derive the optimal location  $(X, Y)$  of the factory1 and the transfer price by using equation (15). To derive transfer price and the location of the factory 1, the gradient dynamics is used (Puu, 1998, Ishikawa, 2016). This method is useful because if the solution could not be specified, the area in which the solution is included is indicated by a chaotic phenomenon.

The essence of the gradient dynamics is that first, an initial value set is given to  $x_n$ ,  $y_n$ , and  $mp_n$  in the following equations (16a, b, c) as a temporal solution, and obtain the second tentative values of  $x_{n+1}$ ,  $y_{n+1}$ , and  $mp_{n+1}$  by calculations indicated by the three equations (16a, b, c). The same calculation is iterated until a given tentative solution can be approximately judged as the solution: If the values of  $(x_{n+1}, y_{n+1}, mp_{n+1})$  in equations (16a, b, c) become approximately the same as those of  $(x_n, y_n, mp_n)$ , the values can be admitted as the solution.

$$x_{n+1} = x_n + j * \partial Y / \partial x, \quad (16a)$$

$$y_{n+1} = y_n + j * \partial Y / \partial y, \quad (16b)$$

$$mp_{n+1} = mp_n + j * \partial Y / \partial mp, \quad (16c)$$



where  $j$  is the width of a step and  $n$  shows the number of the calculation. And  $\partial Y/\partial x$ ,  $\partial Y/\partial y$ , and  $\partial Y/\partial mp$  are given by the following equations (17a, b, c), where the production efficiency  $A$  is assumed as 1 and the corporation tax rates of the two countries are assumed as  $t=t^*=0.82$ .

$$\begin{aligned} \partial Y/\partial x = & 0.18[-t_g x (299.4-0.5mp)/d_4 + (299.4-0.5mp) (-t_g(x/d_4) - t_e(x/d_3)) - \\ & - 1^{-1.25} (299.4-0.5mp)^{1.25} t_m [ \{(p_2+t_m d_2)^{0.5}/(p_1+t_m d_1)^{0.5}\} (x-x_1)/d_1 + \\ & + \{(p_1+t_m d_1)^{0.5}/(p_2+t_m d_2)^{0.5}\} (x+x_2)/d_2] = 0 \end{aligned} \quad (17a)$$

$$\begin{aligned} \partial Y/\partial y = & 0.18[-t_g(y-1)(299.4-0.5mp)/d_4 + (299.4-0.5mp) (-t_g((y-y_4)/d_4) - t_e((y-y_3)/d_3)) - \\ & - 1^{-1.25} (299.4-0.5mp)^{1.25} t_m [ \{(p_2+t_m d_2)^{0.5}/(p_1+t_m d_1)^{0.5}\} (y+y_1)/d_1 + \\ & + \{(p_1+t_m d_1)^{0.5}/(p_2+t_m d_2)^{0.5}\} (y+y_2)/d_2] = 0 \end{aligned} \quad (17b)$$

$$\begin{aligned} \partial Y/\partial mp = & 0.18[-(0.5*mp-299.4)] + 0.22[299.4-2*0.5mp+0.5t_g d_4 + 0.5(p_3 + t_e d_3) + \\ & + 2.5*1^{-1.25} (p_2+t_m d_2)^{0.5} (p_1+t_m d_1)^{0.5} (299.4-0.5mp)^{0.25}] = 0. \end{aligned} \quad (17c)$$

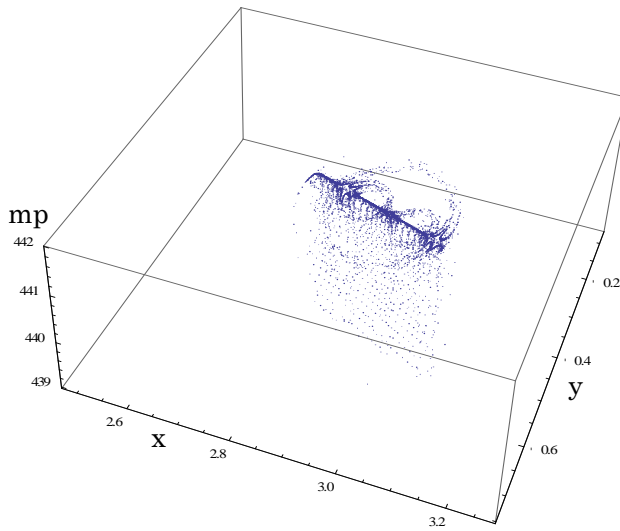
Let us derive the optimal location of the factory 1 and the transfer price by assigning numerical values to parameters as follows:  $(x_1=3, y_1=-0.5)$ ,  $(x_2=-3^{0.5}, y_2=-0.5)$ ,  $(x_3=0, y_3=-1.5)$ ,  $(x_4=0, y_4=1)$ ,  $p_1=0.25$ ,  $p_2=2$ ,  $p_3=0.2$ ,  $t_m=0.11$ ,  $t_e=0.01$ ,  $t_g=0.225$ ,  $F_1=5000$ ,  $F_2=2500$ . The calculation results derived from the gradient dynamics are shown by Figure 2. Figure 2 indicates that the optimal transfer price is approximately 442 and the optimal location site is hidden by a chaotic phenomenon<sup>2</sup>. Although the accurate location of the factory 1 is not identified by the appearance of the chaotic phenomenon, the chaotic phenomenon provides very an important information that the optimal location site is within the area where a chaotic phenomenon appears because phenomenon appears surrounding the optimal solution. If firm locates the factory 1 within the chaotic area, the firm's profit is not varied so much<sup>3</sup>. When the firm locates the factory 1 at point  $M_1$ , the profits is derived as 3307. The firm can obtain the almost same profits when the factory1 locates within the area where the chaotic phenomenon appears.

In this situation, if location of the factory 1 is fixed at point  $M_1$ , profits of the factory 1 and firm and production amount can be derived; they are shown at the upper row in Table 1. And if the freight rate of the intermediate goods is higher as 0.85, as shown by Figure 2B, the location prospective area appears around the market place. In this case the factory locates near the market place. And the

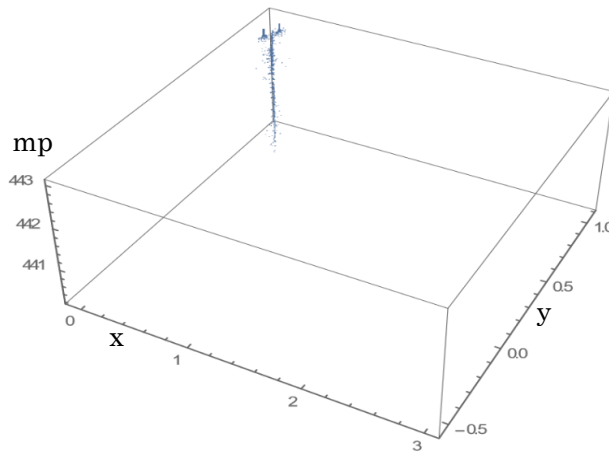
<sup>2</sup>The phenomena shown in Figure 2A and 2B are real *chaos* or *chaotic* phenomena which are generated from the Cauchy convergence in the solution derivation process. The study to identify these phenomena is not conducted in this paper because this problem does not make any obstacle to logical development. This interest issue is going to be discussed elsewhere in near future.

<sup>3</sup>See the analysis of Ishikawa (2016) and the subsection,3.1 in this paper. The difference of the profits among the sites within LPA may be estimated less than 1 percent to the obtained profits.

location of the factory 1 is fixed next to the market place, profit and transfer price of the factory 1 and profits and production amount of firm are derived and they are indicated in the lower row in Table 1.



**Figure2A** Location prospective area of factory in low freight rate



**Figure2B** Location prospective area of factory in high freight rate

**Table1** Location, transfer price and profit of factory in different freight rates

freight rate	location	transfer price	amount	profit of firm	profit of factory1
$t_g=0.225$	around $M_1$	442	49.19	3307	2968
$t_g=0.85$	around $M_4$	443	48.97	3278	2948

### 2.3.2 Interpretation of location prospective area

The chaotic phenomenon can be interpreted as follow: If a firm decides the location of the factory 1 and transfer price of the intermediate goods in the sphere of the chaotic phenomenon, the firm's

profits are almost same because the optimal solution is contained in this sphere. It can be, therefore, considered that the spatial range of the phenomenon indicates a *location prospective area*, LPA for a possible factory's location. By setting a LPA in large geographical space by using the chaotic phenomenon the firm can determine the searching area into a small range; they can reduce significantly the searching costs. Chaotic phenomenon may provide a firm with useful information in the case a firm does not have adequate information about several countries and many regions in a large space. Furthermore, the LPA provides a firm with various locational chances: when a firm decides the factory's location within the LPA, a firm can consider the factory's location in a broader perspective. A firm can incorporate education, culture, housing, safety, and welfare within the area into its locational decision-making. Considering of the locational effects of these location factors, a firm can find out the location site of its factory, which would be the best site for the firm's activity as a whole.

## **2.4 Construction of industrial park**

### **2.4.1 Necessity of industrial park**

As shown in the above analysis, when the freight rate of the intermediate goods is relatively high, the factory 1 locates near the market place, while, if the freight rate is relatively low, the factory locates near point  $M_1$ . Thus, it is suggested that in the period that infrastructure of the transportation is not adequate, industrial park tends to be constructed near market place; when the transportation infrastructure is adequate and logistics system is developed, location of industrial park is not limited to near the market place, but it is built at various sites departing from the market place. In the derivation of these results, agglomeration economies are not incorporated into the framework of the analysis. If these economies would work in firm's location decision-making, location of the factory 1 is surely influenced.

Suppose that when the factory 1 is moved to the market place, point  $M_4$ , in the foreign country to co-exist with the factory 2, scale economies are generated at the market place and decrease the production costs of the factories. Scale economies exercise its locational power for the factory 1 to shift to the market place. If the agglomeration of the two factories is realized at the market place in the foreign country, the home country loses the tax revenue from the factory 1. In this context, the importance to build industrial park is realized by the home country. It is said that the government of the home country establishes an industrial park, which provides the factories with external economies and useful business functions, in order to retain the factory 1 in the home country, or to regain the factory from the foreign country into its territory<sup>4</sup>.

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<sup>4</sup> Bredo (1960) analyzes industrial estates as a tool for industrialization. This analysis is instructive to examining the role of the industrial parks for development of regional economy.

### 2.4.2 Combination of business types within an industrial park

According to the above analysis, location of industrial park is not confined to a specific site, but it is selected considering the LPAs of firms. And industrial park selects the factories which possesses the resemble characteristics in terms of the nature of the goods and production facilities. Hence, when a developer establishes an industrial park in a region, the developer is likely to induce factories of which LPAs make overlapping area and establishes the park within the overlapping area. If the factories' LPAs, therefore, are not overlapped, these factories would not co-exist in the same industrial park. Figure 3A and 3B describe these situations. Two chaotic phenomena in Figure 3A are shown based on the analysis in the previous section. In this Figure 3A, the two factories' LPAs do not make an overlapping area, then, these two factories may not locate in the same industrial park. While, Figure 3B shows that two chaotic phenomena for the two factories are overlapped near point  $M_1$ . The possibility would be high that these two factories are induced in the same industrial park established near  $M_1$ .

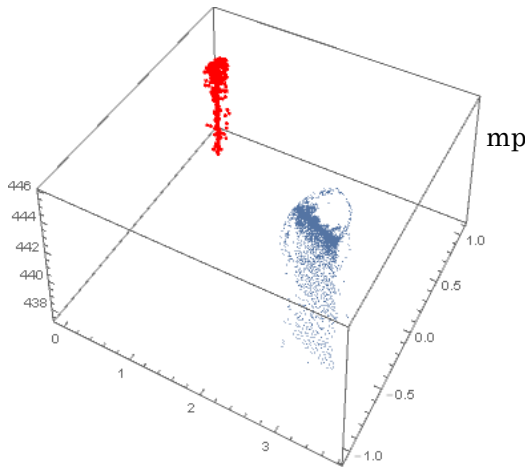


Figure 3A Two LPAs departing each other

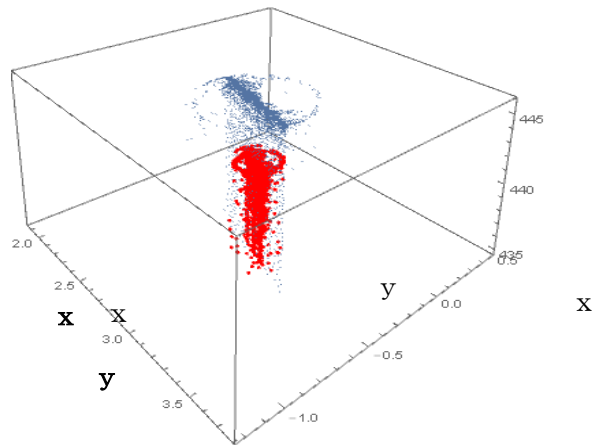


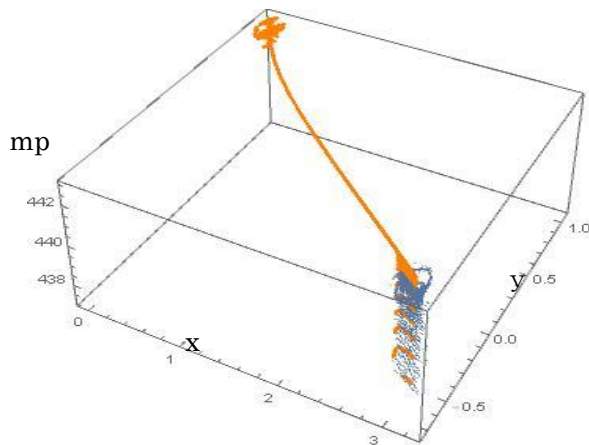
Figure 3B Overlapping of two LPAs

## 3 Relationships between external economies and production composition of industrial park

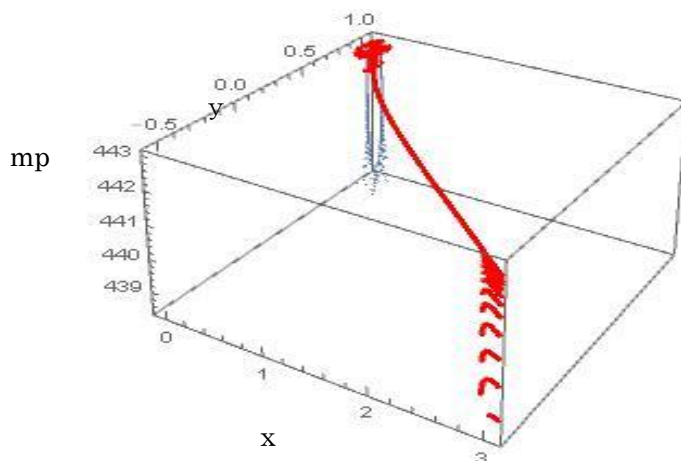
### 3.1 Business types combined in an industrial park

In order to examine the effects on industrial park of difference of the business types in an industrial park, suppose three kinds of factories which belong to different business types, a, b and c. Although they are in the same spatial and production situation shown in section 2, they are different in terms of production of intermediate goods: the factory  $I_a$  which belongs to business type  $a$  is assumed that the production efficiency  $A_a$  is 1 and the freight rate of the intermediate goods  $t_{ga}$  is 0.225; factory  $I_b$  of business type  $b$  is that  $A_b=1$  and  $t_{gb}$  is 0.7728; the factory  $I_c$  of business type  $c$  is that  $A_c=1.05$  and  $t_{gc}$  is 825.

On this assumption, let us derive the chaotic phenomena of the two factories,  $I_a$  and  $I_b$ . Figure 4 shows the two chaotic phenomena of the two factories. LPA of the factory  $I_a$  appears near point  $M_1$ , and LPA of the factory  $I_b$  is long from point  $M_1$  to the market place, point  $M_4$ . These two LPAs makes an overlapping area near point  $M_1$ . While, the chaotic phenomena of the two factories,  $I_b$  and  $I_c$  are shown in Figure 5. In this case, LPAs of the two factories,  $I_b$  and  $I_c$  are overlapped near the market place. It is said, therefore, that the industrial park established near point  $M_1$  is composed by the factories,  $I_a$  and  $I_b$ , and the industrial park established near the market place is composed by the factories,  $I_b$  and  $I_c$ . Since the factory  $I_b$  has a long LPA, this factory has a possibility to locate either industrial parks.



**Figure 4** Overlapping of LPAs of two factories near point  $M_1$



**Figure 5** Overlapping of LPAs of two factories near the market place

If the factory  $I_b$  locates at point  $M_1$ , the profit of the factory  $I_b$  is 2947.9, while, the factory  $I_b$  locates at the market place, the profit is 2948.1. The difference of profits is only 0.2, which is

negligible. As the concept of LPA indicates, profits obtained at any sites within LPA are the same level.

### 3.2 Decrease of production costs of factories by enjoying external economies

It is needless to say that the number of factories in an industrial park is not limited to two. In this subsection, introducing external economies generated in the park into the analysis, the number of the factories in industrial park is analyzed. To this end, new six assumptions are added in the analysis.

- (1) The business types of the factories are classified into the three types, *a*, *b*, and *c*; and based on the result derived in the previous section, if industrial park is constructed near point  $M_1$ , the combination of business types is the combination of the type *a* and the type *b*: When industrial park is established near the market place, the combination is the type *b* and the type *c*.
- (2) The number of the factories,  $N_i$  ( $i=a, b, c$ ), of each business type in the two industrial parks is determined by the developer of industrial park to maximize the profits of the individual firms.
- (3) Individual factories employ workers,  $L_i$  ( $i=a, b, c$ ), to operate the factory as a whole. The number of workers of a factory is determined by a factory to maximize its own profit.
- (4) Industrial park provides two different kinds of external economies: One kind of external economies,  $EE_v$ , reduces the variable cost of the factories, and the extent to which the economies reduce the cost is a function of the *total* numbers of workers employed by in the park. Equation (18) shows the function of  $EE_v$ .

$$EE_v = -h(0.05(TL))^2 + j(0.05(TL)) - k \quad (18)$$

where  $TL$  is the number of the employees in the park, and  $h$ ,  $j$ , and  $k$  are parameters. Wage rate of each business type is a function of the number of workers who are employed by *each business type*; wage rate of each business type is indicated by equation (19)

$$w_i = g(N_i L_i)^\Phi \quad (19)$$

$i=a,b,c$

where  $N_i L_i$  is the number of the workers employed by the factories of business type  $i$  ( $i=a, b$ , and  $c$ ),  $g$  and  $\Phi$  are parameters.

- (5) Another kind of external economies,  $EE_F$ , reduces the fixed cost of the factories, and the extent to which this kind of external economies reduce the fixed cost is a function of the total quantity,  $TQ$ , produced in the park. Equation (20) shows the function of  $EE_F$ ,

$$EE_F = -\alpha(TQ_j)^2 + \beta(TQ_j) - D \quad (20)$$

$$j = M_1, M_4$$

$$TQ_{M1} = N_a * mq_a + N_b * mq_b, TQ_{M4} = N_b * mq_b + N_c * mq_c$$

where  $\alpha$ ,  $\beta$ , and  $D$  are parameters. When industrial park is constructed near point  $M_1$ ,  $TQ$  is shown by  $TQ_{M1}$ , and the park is constructed near the market place,  $TQ$  is given by  $TQ_{M4}$ . In this section the fixed cost are supposed that the fixed cost contains not only the costs which are directly related with goods production but the overhead costs of training of workers, guest accommodation, catering and so on.

- (6) Production amount and transfer price of each factory have been determined in the same way used in the previous section. Therefore, minimizing the production costs of the factory is compatible with maximizing profits of the firm.

### 3.3 Derivation of the number of the factories in industrial park

Using the analysis in the previous section, profit of individual *factories* is given by equation (21),

$$Y_{1i} = (1-t) [ mq_i ((mp_i - t_g d_4) - (p_3 + t_e d_3)) - (2mq_i^{1.25} (A_i)^{-1.25} (p_1 + t_m d_1)^{0.5} (p_2 + t_m d_2)^{0.5}) / EE_v - F_i / EE_F - g(N_i L_i)^\Phi ] \quad (21)$$

$$i = a, b, c$$

Let us suppose that using the results in the previous section, production amount and transfer price of the factory  $I_a$  are that  $mq_a = 49.19$ ,  $mp_a = 442$ , and those of the factory  $I_c$  are  $mq_c = 49.09$ ,  $mp_c = 442.5$ : And when factory  $I_b$  locates in industrial park established near point  $M_1$ , production amount and transfer price are  $mq_b = 49.09$ ,  $mp_b = 442.5$ ; while, when the factory  $I_b$  locates in industrial park near market place, they are that  $mq_b = 48.97$ ,  $mp_b = 443$ . Based on the supposition, let us analyze the production composition and profits of each industrial park.

Developer of industrial park decides the number of factories of each business type in order to maximize profit of individual firms. The developer which establishes an industrial park near point  $M_1$  determines the numbers of the factories,  $I_a$  and  $I_b$ . And each kind of the factory decides the number of workers to maximize its profit. Thus, the number of each factory and the number of the workers of each factory in the industrial park near point  $M_1$  are derived by solving equation system (22<sub>i</sub>,  $i = a, b, c, d$ ) with respect to  $N_a$ ,  $N_b$ ,  $L_a$ , and  $L_b$ ,

$$\partial Y_{1a} / \partial N_a = 0 \quad (22a)$$

$$\partial Y_{1b} / \partial N_b = 0 \quad (22b)$$

$$\partial Y_{1a} / \partial L_a = 0 \quad (22c)$$

$$\partial Y_{1b} / \partial L_b = 0 \quad (22d)$$

In the same way, the numbers of factories,  $l_b$  and  $l_c$  and the numbers of workers of the factories in the industrial park near the market place are obtained.

Now, the parameters that determine the two kinds of external economies generated in the industrial parks are the same and they are shown in Table 2. First, let us derive the number of each factory and the number of the workers of the factory in the industrial park which is established at point  $M_1$ .

**Table 2 Parameters' values that define external economies**

h	j	k	$\alpha$	$\beta$	D	g	$\Phi$
0.01	4	20	0.0008	0.71	52.57	0.6	0.15

Solving equation system (22<sub>i</sub>, i=a, b, c, d) with respect to  $N_a$ ,  $N_b$ ,  $L_a$ , and  $L_b$  gives the production composition of the industrial park near point  $M_1$ . The production composition and profits are indicated in Table 3A.

**Table 3 A The production composition of the industrial park near point  $M_1$**

	number of factories	number of workers	production amount	profit
factory1 <sub>a</sub>	—	85.23	49.26	3872
<b>factory1<sub>b</sub></b>	—	<b>121.37</b>	<b>49.09</b>	<b>3843</b>
business type <i>a</i>	5.29	450.4	260.1	20449
<b>business type <i>b</i></b>	<b>3.74</b>	<b>454.3</b>	<b>183.6</b>	<b>14385</b>
industrial park	9.02	904.7	443.7	34834

Second, the number of each factory and the number of the workers of the factory in the industrial park which is established at the market place are obtained in the same way. The production composition and profits are indicated in Table 3B. The comparison of production compositions in the two industrial parks which are shown in Table 3A and 3B indicates that even if the two industrial parks have the same size and same quality, the production composition and profit generated in the two parks are different. Their differences are changed by the production characteristics of the factories which co-exist in the industrial park.

**Table 3B The production composition of the industrial park near market place**

	number of factories	number of workers	production amount	profit
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<b>factory1<sub>b</sub></b>	—	<b>119.52</b>	<b>48.97</b>	<b>3862</b>
factory1 <sub>c</sub>	—	95.2	49.09	3872
<b>business type <i>b</i></b>	<b>3.79</b>	<b>504.7</b>	<b>179.2</b>	<b>14653</b>
business type <i>c</i>	5.30	452.9	264.6	20499
industrial park	9.05	957.7	443.8	35161

Especially, it is interesting to compare the profits of the factory  $I_b$  which are indifference in the factory's location between point  $M_1$  and the market place if the factory does not enter into industrial park. The profits and production composition of the business type  $b$  are indicated by the bold figures in Table 3A and Table 4B. Since the factories of the business type  $b$  are able to obtain the higher profit in the industrial park near the market place than those of the park near point  $M_1$ , the factories of business type  $b$  locate in the park near the market place. The profit difference of the factory  $I_b$  is yielded by the difference of the production composition formed in each industrial park: As indicated in the provirus subsection, when the factory  $I_b$  does not join into industrial park and the factory locates at point  $M_1$ , the profit of the factory  $I_b$  is 2947.9, while, the factory  $I_b$  locates at the market place, the profit is 2948.1. The difference of the profits is negligible of 0.2. If the factory  $I_b$  locates in the industrial park at point  $M_1$ , however, profit of the factory is increased by 895, while the factory  $I_b$  locates in the park near the market, the profit is increased by 914. These profit increases are generated by the factories' entering into the industrial park. And the profit difference of 19 in between the two industrial parks can be interpreted to be yielded by the differences of the production compositions in the two industrial parks.

#### **4. Effects on industrial park of the government intervention to transportation infrastructure**

The government of the country often establishes the industrial parks to vitalize regional economy. In order for the industrial park to contribute to the regional economy, the government can not only design the production composition in the industrial park but also influence the wage rates of workers in the park. The wage rate of the workers in the industrial park is influenced by the commuting area surrounding the park which is determined by the transportation system. Thus, the government is able to change the contents of the industrial park by the investment on the infrastructure surrounding the industrial park greatly. This section focuses the influence of wage rate of the workers on the industrial park and analyzes the effects of the reduction of the wage rate on the production composition and factories' profits.

##### **4.1 Assumptions of the analysis**

In order to analyze the relationships between the wage rate of the workers in industrial park, the

production composition and profits of the factories of the industrial park, some assumptions of the previous analysis are changed: Industrial park is limited to the area near point  $M_1$ ; the combination of the business types in the industrial park is confined to the combination of  $a$  and  $b$ : Production amount and transfer price of the factory  $I_a$  are assumed that  $m_{q_a}=49.19$ ,  $mp_a=442$ ; the production efficiency,  $A_b$ , of the factory  $I_b$  is changed to be 0.5; while, production amount and transfer price of the factory  $I_b$  are changed as that  $m_{q_b}=48.28$ ,  $mp_b=445.8$ . And the efficiencies of the two external economies and the wage rate of the workers in the industrial park are changed in this section. They are indicated by the parameters' values shown in Table 4.

**Table 4 Parameters' values that indicate external economies in industrial park**

h	j	k	$\alpha$	$\beta$	D	g	$\Phi$
0.0135	1.443	8.57	0.00033	0.3842	27.67	0.6	0.4

#### 4.2 Effects on industrial park of the government intervention to improve infrastructure

Using the same way that used in the previous sections, the production composition and factories' profit in this situation are derived. They are shown by Table 5.

**Table 5 Production construction and profits of the factories and the industrial park**

number of factories 1a	number of factories 1b	workers of factories 1a	workers of factories 1b	profit of factory 1a	profit of factory 1b	total profit of in the park
8.38	3.47	741.6	579.4	3793.7	3818.5	45011.8

Now, if the government invests to improve the transportation infrastructure surrounding the industrial park, the commuting area of the workers to the industrial park will be enlarged, as a result, the supply of the workers to the park is increased. Thus, the rise of the wage rate of the workers is curbed, and the wage rate is expected to be lower. Based on this logic, assume that the parameter  $\Phi$  is lowered from 0.4 to 0.3 at the industrial park, while, the working levels of the two kinds of external economies in the park are remained as those shown by Table 4 in order to derive the pure effects of the wage rate of workers on the industrial park. Table 6 shows the production composition and the profits of the factories and the industrial park after the government invests to transport infrastructure surrounding the park to reduce the wage rate of the workers.

**Table 6 Production construction and profits of the industrial park in better infrastructure**

number of factories 1a	number of factories 1b	workers of factories 1a	workers of factories 1b	profit of factory 1a	profit of factory 1b	total profit of the park

8.85	2.99	711.6	213.2	3830.5	3813.7	45277.1
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The comparison of Table 5 and Table 6 shows the interesting facts that the number of the factories and the total production amount in the industrial park are not varied by the reduction of the wage rate of the workers, while, the profits of the factories  $I_a$  are increased by 36.8 and also the profit of the industrial park increases to 45277.1 which is higher than that earned by the industrial park by 265.3 before the government's investment: The increases of these profits are anticipated: However, profits of the factories  $I_b$  decrease by 4.8 after the wage rate decreases from 0.4 to 0.3, which is assumed to be generated by the government's investment to improve the transportation infrastructure surrounding the park. It is interesting that the government's investment to improve the infrastructure, which aims to reduce the wage rate of the workers in the industrial park, does not make the profit of every factory in the industrial park higher.

## 5 Concluding remarks

In the period of the globalized economy, the production processes of the manufacturing firms are fragmented into the small blocs, and they are scattered over the world. Corresponding to the fragmentation of the production, many governments try to induce these fragmented processes into their territory to vitalize their regional economy. In this context, the industrial park is attractive to both the manufacturing firms and the governments because industrial park provides the factories with external economies and the necessary production functions and attract many factories to a few specific places in regions. This paper analyzes the industrial parks according to the factory location theory. The results derived from the above analysis are as follows. (i) The location site of industrial park is not limited straight away to a specific point, but it is settled, after the process of determination stages, at point within the overlapping area of the location prospective areas of the factories. Using the location prospective area of the factories, the combination of the business types of the factories in industrial park is anticipated. It would be said that the concept of the locational prospective area of the factories are useful both for the manufacturing firms and the governments. (ii) External economies generated in industrial park influence the combination of the business types, production composition, and profits of the factories and industrial park. The performances of the industrial parks are varied by the differences of the production characteristics of the factories which co-exist in an industrial park. (iii) The government invests to improve the transportation infrastructure in order to reduce wage rate of the workers in industrial park. The reduction of the wage rate of the workers does not always raise the profits of every factory due to the change of production composition in the industrial park.

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