Global R&D Location Strategy of Multinational Enterprises: an Agent-Based Simulation Modeling Approach

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Abstract
The global research and development (R&D) location strategy of multinational enterprises (MNEs) is examined using agent-based simulation (ABS) modeling. This study focuses on the positioning strategy of MNEs to understand the impact of their R&D location strategy. In ABS modeling, agents search for knowledge owners or universities in the global host market using Hotelling’s location model algorithm. We measure the result of increasing the number of entry agents from 2 to 121. Three types of equilibria are found in our agent-based simulation model: pure equilibrium, saturated equilibrium, and quasi-saturated equilibrium. Core locations attract MNEs, while peripheral countries in the global market are the least preferred. As a result, peripheral countries experience a paucity of foreign R&D investments. Even though emerging economies absorb foreign direct investment (FDI) inflows from MNEs, least-less developed countries (LLDC) may experience a dearth in FDI. Thus, the optimal location strategy of MNEs leads to economic disparities between the core and peripheral countries. This study suggests the need for developing official assistance to attract FDI inflows to LLDCs so that peripheral countries emerge as attractive global market destinations for MNEs.

Keywords Agent-based simulation · Location strategy · Hotelling location model · Periphery countries · Multinational enterprises

JEL Classification M16 · M21 · M38 · O18 · O24

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1 Introduction

The strategy of locating research and development (R&D) activities in the global market is an important issue in international business (Coronado et al. 2008; Cuervo-Cazurra et al. 2017). A multinational enterprise (MNE) looks for the best place to secure knowledge bases in the global market (Blanc-Brude et al. 2014; Buckley and Ghauri 2004). For multinational enterprises (MNEs), location strategies are crucial for achieving this objective. Most MNEs establish research projects in countries that have world-class universities as research centers and forge alliances with knowledge workers and highly innovative startups (Piperopoulos et al. 2018). Porter (1990) summarizes that strategy, structure, rivalry, factor conditions, related and supporting industries, and demand conditions as the reasons for firms to select specific locations. The location strategy of MNEs is discussed to explain agglomeration in empirical studies (Rugman 2000; Myles Shaver and Flyer 2000; Cantwell 2009) in which various elements of natural, human, and knowledge resources are included to explain the phenomenon of clustering (Sebestyén and Varga 2019).

We argue that the discussion on MNEs’ R&D location strategy has been somewhat confusing. The cause of this confusion is that the location strategy theory has been discussed in terms of natural endowment, management resources of MNEs, and the strategic positioning of MNEs in the market (Goerzen et al. 2013; McCann and Mudambi 2005). Location strategies have been discussed based on the coexistence of internal and external factors for MNEs. This coexistence causes some confusion because the location theory was not wholly captured from the perspective of theoretical confinements. In empirical studies on location strategies, relevant variables were included as long as they were observable. Explanations are provided when plausible variables are found to be statistically significant (Caves 1982; Dunning 1980, 1988, 1993).

The deductive theoretical approach is not a major thrust area in location strategy research and has not been sufficiently examined (Nielsen et al. 2017). In a scientific analytical approach, it is fundamental that researchers focus on certain factors and disregard others. The model should control and extract essential factors from various influences while focusing on theoretical factors. However, in international business research, only a few approaches focus on an essential factor in a scientific manner. In this study, we single out the strategic location effect as an essential factor in a deductive theoretical approach to inquire location strategy. Using the deductive approach of agent-based simulation (ABS), we focus only on strategic location effects, assuming that the influence of internal management resources held by MNEs is constant (Penrose 1959; Teece et al. 1997).

There are two types of simulation models used in economics. The first incorporates conditions close to reality into the model and confirms the changes caused by the changes in the parameters. These simulation models are useful when physical conditions, such as weather and aerodynamics, are stable. In economics, similar ideas are applied to macroeconomic interstate trade. The second is to loosen some of the assumptions in the theoretical model and reach conclusions in more complex situations. Simulation models in microeconomics are examples of such simulation models. This is similar to the simulation model of the infectious disease virus transmission process. With these micro-approaches, the significance of adding real-life conditions is limited. There are an infinite number of “real-world” examples, and we cannot trace them all. In the competition between firms in microeconomics, there are various conditions such as price, quantity, location, investment strategy, human resources, finance, division of labor, and logistics. If these variables are incorporated so that
the simulation model is closer to reality, it becomes impossible to find a solution. In such cases, the solution is either equilibrium or imbalance, and only ABS can find the result of market competition. Of course, we do not deny that management resources such as brand equity and technology can broaden the location selection criteria of MNEs (Porter 1998). However, we want to improve the theory of location strategy scientifically by extracting the effect of location choices. In our study, MNEs’ external factors such as factor conditions, related and supporting industries, and demand conditions in the host countries are considered equal.

The reason for such sophistication is that many MNEs relocate their R&D subsidiaries overseas over the long term (Buckley and Mucchielli 1997; Pennings and Sleuwaegen 2000). Withdrawal of investment from foreign markets has also been observed in many countries and industries (Horaguchi 1993; McDermott 2010). If factor conditions, related and supporting industries, and demand conditions are the reasons for choosing the R&D location, then MNEs do not shift the locations unless resources are exhausted, supporting industries are extinguished, or demand conditions are rapidly declining. It is common for MNEs to repeat location changes and withdraw foreign direct investment (FDI) (Vernon 1966; Mesquita 2016). A new theoretical approach is necessary to address this gap in exploring the key characteristics of the relocation strategy of MNEs in global markets (Kim and Aguilera 2016).

We propose the following research questions: What kind of competition pattern is found when it is assumed that MNEs will compete only on the strategy of selecting R&D locations to use the available knowledge resources and move the R&D locations multiple times? What kind of R&D location strategy can we find, given that all MNEs compete for absorbing the knowledge input based on market proximity? What tendencies can be observed in the selection of multinational corporations’ R&D locations if we assume that MNEs’ internal resources are equal to the pure location choice effect? Given that the preconditions of MNEs such as economies of scale by oligopolistic large enterprises are controlled completely and MNEs compete only by location selection of R&D, what kinds of trends can we find in location strategy? In the ABS modeling, can we observe agents that adopt a niche market strategy or blue ocean strategy? If so, how long will the agent adopt one of these strategies?

This location strategy perspective is relevant to the positioning strategy (Porter 1980; Mintzberg and Lampel 1999; McGrath 2013) as well as the blue ocean strategy (Kim and Mauborgne 2005) by MNEs because the concept of a niche market is prevalent among business people and in the strategic management literature (Porter 1985; Barney 2001). ABS modeling has the advantage of incorporating time as one dimension (Gómez-Cruz et al. 2017). Thus, we observe the dynamic interactions among agents in the market.

2 Literature Review and Theoretical Approach

The research questions are based on a theoretical inquiry to assess the positioning strategy in the context of location choices. To simulate the location choice, we use and extend Hotelling’s (1929) model, which has been used by many economists to study the locational effect in oligopoly (d’Aspremont et al. 1979). Moreover, it has also been extended to research in industrial organization theory (Neven 1987; Harter 1997; Meagher and Zauner 2004).
A classic version is known as Hotelling’s linear city model or a one-dimensional model. This model is called “ice-cream shops on the seashore,” where potential customers are placed in a linear location. Customers are assumed to walk to buy ice cream from the nearest shop on the seashore. If we assume that there are two ice-cream shops on the seashore, the optimal location for the shops is identified. From the standpoint of the two shops, they can be located anywhere on the seashore if they are located symmetrically. The product, or ice cream, is not differentiated in this model as shoppers can come to either of the two shops (d’Aspremont et al. 1979). From the shoppers’ perspective, the sum of the walking distance to one of the two shops is minimized if each shop is located one-fourth of the total distance from the right edge of the seashore and one-fourth from the left edge. However, because of competition, ice cream shops are located at the center of the linear market, which causes customers to walk longer distances in sum. When there are three shops, equilibrium is not attained, and one of the three shops needs to escape from the position where the other two shops sandwich the one. De Palma et al. (1987) show the existence of equilibrium in the case of three firms when the probability of purchasing from each of the firms is positive.

Another version of Hotelling’s model is known as the circular location model when roadside demand in a city is depicted as circular. Tirole (1988) explains Hotelling’s model and calculates costs and prices in the model. The circular location model shows that symmetrical positioning gives two shops a maximum market share. In the case of three shops, they can eventually attain equilibrium when the circle is divided equally by three. Okabe and Aoyagi (1991) proposed a mathematical model of the two-dimensional Hotelling model and showed that the square lattice and regular-hexagonal lattice are involved as the positions for locational equilibrium. Van Leeuwen and Lijesen (2016) proposed a model with two dimensions: location and pricing. This type of mathematical approach does not show the disequilibrium positioning strategy of firms.

The reason for dealing with the above issues by using ABS modeling is clear. It is expected that a theoretical implication can be obtained using a simplified ABS model (Davis et al. 2007). The R&D location strategy of MNEs is no exception to being targeted as the one scrutinized by the ABS (Lopolito et al. 2013). We can trace back some theoretical perspectives using simulation modeling, such as the studies of segregation (Schelling 1969), the emergence of cooperation (Axelrod 1984), cultural convergence (Axelrod 1997), creation of industrial clusters (Horaguchi 2008), the impact of trade agreements (Horaguchi 2007), information distortion (Fang et al. 2014), two-firm rivalry in a market (Alcácer et al. 2013), and rivalry between two firms in two markets with learning effects (Alcácer et al. 2015).

An approach using ABS fills the gap in most of the existing theoretical research on locational R&D choice because the latter largely depends on the ad hoc assumptions of a calculable number of entrants to attain equilibrium, and relocation is not considered. Although the simulation approach is often considered as a byway rather than a mainstream approach, it has the possibility of creating a theory-based hypothesis (Davis et al. 2007). We will see that the ABS model leads to an uneven distribution of locational choices in the global market (Hymer 1972). The basic model is explained as follows.
3 Basic Model

3.1 Assumptions on a Factor Market

As described above, the Hotelling location model was premised on the cost of transportation and delivery of goods, as seen in the retail sector and customers. In this research, we analyze the case of collaboration between industry, academia, MNEs, and host country universities as cases where such physical costs can be ignored. We extend the discussion on the impact of knowledge procurement by MNEs in the global economy (Horaguchi 2014). To simplify the setting, we follow Friedman’s (2005) “world is flat” theory. However, we show that the market becomes bumpy when MNEs make endogenous locational choices (Florida 2005).

Our model involves a factor market with two dimensions, globally. Each dimension, which is expressed by a node in a plane, is assumed to know the local organizations of the host country. Even though organizations include firms, universities, and research institutions, we deem them “university” for simplicity, thereby clarifying the purpose of this study. There is a factor market called the “world” consisting of a certain number of countries and each country is represented by a node in the “world.” International markets are subdivided into core countries, emerging economies, and peripheral countries (Alnuaimi et al. 2012). The market depicted as a grid can be interpreted as latitude and longitude, and it can also be extended to a conceptual map for an entry strategy using both technological and geographical distance (Wang and Zhao 2018).

3.2 Assumptions About MNEs

We assume the following R&D strategies for MNEs: The R&D subsidiaries of MNEs are present in one country so that they can forge the highest number of alliances with local organizations such as universities (Livanis and Lamin 2016; Alnuaimi et al. 2012). Although MNEs are located on one of the nodes, they form alliances with knowledge resources, such as universities (Silveira, et al. 2020). An R&D subsidiary of an MNE, which we call an agent, will set up an R&D base in a country. The R&D subsidiary of the MNE forms alliances with universities in both the location and neighboring countries. The R&D subsidiary moves to a location where the largest number of collaborations can be made. The subsidiary conducts joint R&D projects in collaboration with universities in the host countries. The joint R&D project will continue unless it competes with other R&D subsidiaries of MNEs. If another MNE’s R&D subsidiary enters the market, the new entrant acquires a joint R&D project. In case of the same distance, half of the payoff or 0.5 is given to the two agents. Thus, subsidiaries of MNEs compete to occupy the largest share of the global knowledge market, which is closer to their locational choice (Rugman and Verbeke 2001). In our setting, the superiority of managerial resources (Penrose 1959) among all MNEs is considered equal.
3.3 Assumptions on Agent-Based Simulation Modeling

Based on these overall settings, we develop the following set of assumptions in our ABS model:

Assumption 1. The procurement cost, $c$, of unit R&D performance is at the same level for all firms.
Assumption 2. The MNE locates an R&D subsidiary at the node of a foreign market, and the demand density for allying with the university has uniform unity at each node.
Assumption 3. Each node involves a single university with a unit supply of knowledge workers that is inelastic with respect to price.
Assumption 4. The alliance cost with respect to the Euclidean distance is the same for all universities, but the alliance is made when the R&D subsidiary and the node are the shortest.
Assumption 5. When a firm relocates to gain wider knowledge inputs, the R&D subsidiary conjectures that all other R&D subsidiaries will not change their positioning for one round of relocation choices by other competitors. Here, we define “one round” as the moves made by all agents in the market. In Fig. 1, one step is made by each of the agents, and they reach equilibrium in one round.

This assumption is an alternate progression game (sequential turn game) of game theory. An alternating game (sequential turn game) is a game, such as chess or poker, in which you can think of your strategy and change it after seeing your opponent’s strategy. In this study, we assume a situation in which a company can decide where to locate its R&D by looking at the location of other companies’ R&D sites. This assumption is also a game with perfect information in game theory. A game with perfect information is where all the information is on the board, and the player can see all the information, as in chess. In this study, we assume a situation in which all R&D locations of other companies are known.

Assumption 6. The relocation cost of any R&D subsidiary is zero.

This assumption is a simplification of the fact that there is no difference in relocation costs between multiple agents or companies. For example, if there are two companies, A and B, and both have the same relocation cost level, the difference will be close to zero given multiple relocations. Even if the number of companies increases to three or more,
the meaning of this assumption does not change. Even if the distances of relocation differ for each company, the difference is negligible. When subtracting the relocation cost from the profit of each company, if the number of relocations is the same, it means that each company will eventually incur the same cost.

Assumption 7. The R&D subsidiary \((P)\) selects its location \((x_j, y_k)\) so that it can maximize alliances with local universities.

Assumption 8. The market consists of \(x_m\) by \(y_n\) nodes.

The subsidiary of an MNE is called an agent \((P)\). We also assume that each node has one unit of the “university” \((C)\). In this setting, the distance between an agent \((P)\) and a university \((C)\) is measured by the “Manhattan distance.” If the coordinates of the agent \((P)\) are \((x_1, y_1)\) and the coordinates of the university \((C)\) are \((x_2, y_2)\), the Manhattan distance between the agent and the university is calculated as follows: \(|x_2 - x_1| + |y_2 - y_1|\).

Meanwhile, the Euclidean distance between the producer and the university is given as \(\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}\). For example, the Manhattan distance is 2, and the Euclidean distance is \(\sqrt{2}\) at a distance consisting of one row and one column square. We do not employ the Euclidian distance because it is unrealistic to measure the distance between two locations regardless of road or flight connectivity. Even though we measure the distance between two cities on a map using a scale, you cannot jump over buildings when moving from one corner of the city to another (Mans 2014). This is also true in the case of airlines since connecting flights are required.

3.4 Mathematical Exposition

The specifications of the simulation are explained using a numerical formula. We assume that the left upper coordinate of the two-dimensional map is the origin \((0,0)\). Thus, the Y coordinate is measured from 0 to \(Y_{\text{max}}\), and the X coordinate is measured from 0 to \(X_{\text{max}}\). Both \(x\) and \(y\) are assumed to be measured by an integer. Thus,

\[0 \leq x \leq X_{\text{max}}\]
\[0 \leq y \leq Y_{\text{max}}\]

The market consists of universities in each national market distributed over each coordinate. Thus, market size \(M\) is as follows:

\[M = (X_{\text{max}} + 1) \times (Y_{\text{max}} + 1)\]

The demand of university \(i\) is expressed as \(C_i\), which has the coordinates \((c_{xi}, c_{yi})\) in the market. Thus, demand is denoted as follows for university \(i\):

\[C_i(c_{xi}, c_{yi})\]

where \(1 \leq i \leq (X_{\text{max}} + 1)\times(Y_{\text{max}} + 1)\).

The total number of entrants is expressed as \(R_{\text{max}}\). The location of the entrant is expressed by the coordinates \(x\) and \(y\), which are denoted as follows:

\[R_j(r_{xj}, r_{yj})\]

where \(1 \leq j \leq R_{\text{max}}\).

We define the distance from university \(i\) to entrant \(j\) using the Manhattan distance:
A university $C_i$ forges an alliance contract with agent $R_j$ with the smallest distance. We define

$$\text{minDistance}_{ij} \equiv \min(1 \leq j \leq R_{\text{max}}) \{\text{Distance}(C_i, R_j)\}$$

$$\text{nearest}_n \equiv \{ R_j | \text{Distance}(C_i, R_j) = \text{minDistance}_{ij} \}$$

When there are multiple entrants for which the distance is the smallest, we assume that they share demand equally.

$$\text{gain}_{R_j} = \frac{1}{|\text{nearest}_{R_n}|} \text{ if } R_j \in \text{nearest}_{R_n}$$

$$\text{gain}_{R_j} = 0, \text{ otherwise}$$

where $|\text{nearest}_{R_n}|$ is the number of $R_j$ in the nearest$_n$ position.

The total gain in the market of the entrant is then summed as follows.

$$\text{totalGain}_{j} = \sum_{i=1}^{(X_{\text{max}}+1)(Y_{\text{max}}+1)} \text{gain}_{R_j} = M$$

4.1 Four Patterns of Equilibrium

Based on Assumption 8, for simplicity, and to construct our ABS model, we set a model that has an $11 \times 11$ world market as nodes ($x_m = x_{11}$ and $y_n = y_{11}$). Each node represents a country market offering knowledge workers at the university. Thus, we assume that there are 121 domestic markets in the world economy, which have subdivisions of core countries, emerging economies, and periphery countries. “Core countries” are the $(3 \times 3) = 9$ countries at the center of the figure and “peripheral countries” are the $(1 \times 10 \times 4) = 40$ countries located on the edge of the figure. The number of “emerging economies” consists
of 72 countries, calculated by subtracting 49 from 121. Figure 2 shows these three segments from the center to the periphery of the market.

We simulated 10,000 rounds for each entrant in the 120 cases, from 2 to 121 agents in the market. Table 1 lists some of the results. We found four patterns as a result of the simulation. The first pattern is a pure equilibrium that emerges when the number of participating agents are 2 and 16. Figure 3 shows the location where equilibrium is reached. If the number of participating agents is 2, the first agent ceases to move in the third step. When the number of participating agents is 16, no agents move after the 4351st step.

The second pattern is disequilibrium. The agents continue moving during a simulation of 10,000 steps. Note that equilibrium is not reached even when the number of participating agents is 3 in the case of an 11 × 11 global market. The trajectories of the simulated agents’ movements are similar to the observation of electrons that continue to move around the nucleus.

The third pattern is saturation equilibrium (see Tables 1 and 2). In this pattern, similar to the pure equilibrium, the movement of the entry agent stops. Figure 4 shows the saturation equilibrium observed for the 27 agents. The saturation equilibrium is defined as equilibrium, where 25 or more agents relocate and attain equilibrium. One agent can occupy one node at a distance of zero or the place where the agent is located. The same agent can reach four nodes within a distance of one from its location nodes. Then, one node occupies five nodes within a distance of one. If there are 24 agents in the market, they occupy 120 nodes. The difference between the total number of nodes, 121, and the nodes covered by the 24
agents is one. Given that 25 agents exist in a market made up of $11 \times 11$ or 121 nodes, 25 agents occupy 125 nodes within a distance of one. In this case, the market is saturated by the entry of 25 agents. The agents in the saturation equilibrium show a pattern in which a relatively large number of agents entered the market compared to the market size of 121, leaving no room for any change in the location. When the number of agents increases from 17 to 26, only disequilibrium is observed.

The fourth pattern is called the quasi-saturation equilibrium. Figure 5 illustrates the quasi-saturation equilibrium observed in the case of 32 entrant agents. While the market is saturated, as in the third pattern, most of the participating agents stop moving at the

| Number of agents | Equilibrium/disequilibrium | Number of moves to reach equilibrium | Number of agents | Equilibrium/disequilibrium | Number of moves to reach equilibrium |
|------------------|----------------------------|--------------------------------------|------------------|----------------------------|--------------------------------------|
| 2                | Pure equilibrium           | 3                                    | 24               | Disequilibrium             |                                      |
| 3                | Disequilibrium             | 25                                   | Disequilibrium   |                            |                                      |
| 4                | Disequilibrium             | 26                                   | Disequilibrium   |                            |                                      |
| 5                | Disequilibrium             | 27                                   | Saturation equilibrium | 4454                     |                                      |
| 6                | Disequilibrium             | 28                                   | Saturation equilibrium | 4983                     |                                      |
| 7                | Disequilibrium             | 29                                   | Saturation equilibrium | 231                      |                                      |
| 8                | Disequilibrium             | 30                                   | Saturation equilibrium | 539                      |                                      |
| 9                | Disequilibrium             | 31                                   | Saturation equilibrium | 1487                     |                                      |
| 10               | Disequilibrium             | 32                                   | Quasi-equilibrium |                            |                                      |
| 11               | Disequilibrium             | 33                                   | Quasi-equilibrium |                            |                                      |
| 12               | Disequilibrium             | 34                                   | Quasi-equilibrium |                            |                                      |
| 13               | Disequilibrium             | 35                                   | Quasi-equilibrium |                            |                                      |
| 14               | Disequilibrium             | 36                                   | Quasi-equilibrium |                            |                                      |
| 15               | Disequilibrium             | 37                                   | Saturation equilibrium | 9027                     |                                      |
| 16               | Pure equilibrium           | 4351                                 | Saturation equilibrium | 2735                     |                                      |
| 17               | Disequilibrium             | 39                                   | Quasi-equilibrium |                            |                                      |
| 18               | Disequilibrium             | 40                                   | Saturation equilibrium | 14,839                    |                                      |
| 19               | Disequilibrium             | 41                                   | Quasi-equilibrium |                            |                                      |
| 20               | Disequilibrium             | 42                                   | Quasi-equilibrium |                            |                                      |
| 21               | Disequilibrium             | 43                                   | Quasi-equilibrium |                            |                                      |
| 22               | Disequilibrium             | 44                                   | Saturation equilibrium | 17,291                    |                                      |
| 23               | Disequilibrium             | 45                                   | Saturation equilibrium | 10,394                    |                                      |

We checked the simulation results from 2 to 45 agents. We simulated 10,000 times (300 rounds) of moves by each entrant for the above 44 cases of agents. The simulation program is available at: [https://drive.google.com/…](https://drive.google.com/drive/folders/1_euHWrnRPl57vB1YJTICWCSokHCbg-ON?usp=share_link)
location, but a small number of participating agents continue to move through similar places. In Fig. 4, only agents 1, 5, 6, and 29 repeat their movements.

### 4.2 Disequilibrium: the Case of Eight Entrants

We present a typical example of disequilibrium in our ABS results. Consider the case when the number of participating agents is 8, and disequilibrium continues for at least 10,000 steps for each agent. We develop a flexible simulation program so that we can change the number of entrants to provide any simulation results upon request based on the authors’ needs. Figure 6 shows the operation of the simulation. Figure 6 (a) shows the positions where the eight entrants initially entered the global market sequentially. The first entrant occupies the center of the global market. The second and third entrants chose positions close to the center. They are located at places with a shorter distance or within two Manhattan distances from the first entrant. They form a cluster to occupy the central position in the global market. Within a short distance of locations, the 3 entrants have 5 other entrants. Thus, 8 agents compete with each other by changing their locations in the simulation process.

The 4th-8th entrants also choose their location to secure the largest share of the global market. Figure 6 (b) shows the second round. The entrants are gradually located further away from the center of the market. Figure 6 (c) shows that the 5th and 7th entrants have acquired a specific niche in the market (Lopolito et al. 2013). The 6th entrant acquires a similar positioning, but the niche market is soon deprived by the 8th
| Number of agents | Equilibrium/disequilibrium | Number of moves to reach equilibrium | Number of agents | Equilibrium/disequilibrium | Number of moves to reach equilibrium |
|------------------|-----------------------------|--------------------------------------|------------------|-----------------------------|--------------------------------------|
| 46               | Quasi-equilibrium           | 84                                   | 84               | Saturation equilibrium      | 335                                  |
| 47               | Disequilibrium              | 85                                   | 85               | Saturation equilibrium      | 339                                  |
| 48               | Disequilibrium              | 86                                   | 86               | Saturation equilibrium      | 343                                  |
| 49               | Disequilibrium              | 87                                   | 87               | Saturation equilibrium      | 347                                  |
| 50               | Disequilibrium              | 88                                   | 88               | Saturation equilibrium      | 263                                  |
| 51               | Disequilibrium              | 89                                   | 89               | Saturation equilibrium      | 177                                  |
| 52               | Disequilibrium              | 90                                   | 90               | Saturation equilibrium      | 179                                  |
| 53               | Disequilibrium              | 91                                   | 91               | Saturation equilibrium      | 272                                  |
| 54               | Disequilibrium              | 92                                   | 92               | Saturation equilibrium      | 275                                  |
| 55               | Disequilibrium              | 93                                   | 93               | Saturation equilibrium      | 278                                  |
| 56               | Disequilibrium              | 94                                   | 94               | Saturation equilibrium      | 281                                  |
| 57               | Disequilibrium              | 95                                   | 95               | Saturation equilibrium      | 189                                  |
| 58               | Disequilibrium              | 96                                   | 96               | Saturation equilibrium      | 191                                  |
| 59               | Disequilibrium              | 97                                   | 97               | Saturation equilibrium      | 193                                  |
| 60               | Disequilibrium              | 98                                   | 98               | Saturation equilibrium      | 195                                  |
| 61               | Disequilibrium              | 99                                   | 99               | Saturation equilibrium      | 197                                  |
| 62               | Disequilibrium              | 100                                  | 100              | Saturation equilibrium      | 199                                  |
| 63               | Disequilibrium              | 101                                  | 101              | Saturation equilibrium      | 201                                  |
| 64               | Disequilibrium              | 102                                  | 102              | Saturation equilibrium      | 203                                  |
| 65               | Disequilibrium              | 103                                  | 103              | Saturation equilibrium      | 205                                  |
| 66               | Disequilibrium              | 104                                  | 104              | Saturation equilibrium      | 207                                  |
| 67               | Disequilibrium              | 105                                  | 105              | Saturation equilibrium      | 209                                  |
| 68               | Disequilibrium              | 106                                  | 106              | Saturation equilibrium      | 211                                  |
| 69               | Disequilibrium              | 107                                  | 107              | Saturation equilibrium      | 213                                  |
| 70               | Disequilibrium              | 108                                  | 108              | Saturation equilibrium      | 215                                  |
| 71               | Saturation equilibrium      | 8,945                                | 109              | Saturation equilibrium      | 217                                  |
| 72               | Saturation equilibrium      | 13,103                               | 110              | Saturation equilibrium      | 329                                  |
| 73               | Saturation equilibrium      | 5,109                                | 111              | Saturation equilibrium      | 332                                  |
| 74               | Saturation equilibrium      | 591                                  | 112              | Saturation equilibrium      | 335                                  |
| 75               | Saturation equilibrium      | 1,124                                | 113              | Saturation equilibrium      | 338                                  |
| 76               | Saturation equilibrium      | 379                                  | 114              | Saturation equilibrium      | 227                                  |
| 77               | Saturation equilibrium      | 384                                  | 115              | Saturation equilibrium      | 229                                  |
| 78               | Saturation equilibrium      | 311                                  | 116              | Saturation equilibrium      | 231                                  |
| 79               | Saturation equilibrium      | 315                                  | 117              | Saturation equilibrium      | 233                                  |
| 80               | Saturation equilibrium      | 319                                  | 118              | Saturation equilibrium      | 235                                  |
| 81               | Saturation equilibrium      | 323                                  | 119              | Saturation equilibrium      | 237                                  |
| 82               | Saturation equilibrium      | 327                                  | 120              | Saturation equilibrium      | 239                                  |
| 83               | Saturation equilibrium      | 331                                  | 121              | Saturation equilibrium      | 241                                  |

We checked the simulation results from 46 to 121 agents. We simulated 10,000 times (300 rounds) of moves by each entrant for the above 76 cases of the agents.
entrant. Thus, the entrants consecutively relocate to deprive the incumbent market. If the entrants are not allowed to move from their initial positions, then the last entrant can take a reasonable amount of the global market share because the first entrant is surrounded by later entrants.

4.3 Gaining a Niche Market

All entrants compete for strategic positioning in the second round. Each entrant is assumed to choose a new position one after the other. Figure 6 (c) shows that entrant number 4 chooses the southwest market segment and entrant number 6 occupies the southeast position. Entrant number 5 finds a niche market in the northwest, where the positioning is close to the periphery. Subsequently, all entrants move to secure non-center market segments. Figure 6 (d) and (e) shows that each entrant relocates to gain a position in the emerging economies for a wider global market share during the second-round move.

Figure 6 (d) shows how the 8th entrant moved from the previous position to the new one. The move made by the 8th entrant at time 16 is interesting because it secures the fringe market by moving several positions down, which can be defined as a niche market. In Fig. 6 (e), the 8th entrant moves to obtain the lower-left (southwest) corner position to deprive the market for the 4th entrant. The 8th entrant then occupies the corner niche market.
in the southwest. Figure 6 (f) shows that the other entrants moved into the market, and the positioning was further clustered in a portion of the emerging economies’ market. This cluster is observed in the positioning of emerging economies.

4.4 Losing the Niche Market

It is intriguing to observe how the 8th entrant loses its niche market positioning. As seen in Fig. 6 (e), the 8th entrant occupies niche positioning at time 25. Figure 6 (f) shows that the 5th entrant moves to the left of the 8th entrant. Until then, the 8th entrant was located in the southwest market. Figure 6 (g) shows that at time 32, the 8th entrant moves to the northeast market. This market is wide and can be called the blue ocean market (Kim and Mauborgne 2005). However, it soon becomes a major battlefield due to a second entrant. We can assess the impact of losing niche positioning based on the moves made by the 2nd entrant, as shown in Fig. 6 (g). As can be seen in Fig. 6 (h), the 8th entrant moves further to gain market share.

Proposition 1. Under the conditions of ABS modeling, niche market strategies are undermined by the positioning strategies of other market entrants.

Proposition 2. A positioning strategy does not provide sufficient conditions to secure a blue ocean strategy in a flat market.
Fig. 6 Relocation moves by eight agents. Each figure shows how the niche market is occupied by the relocation of agents.
4.5 Location Landscape

MNEs often select a few locations in the global market, but some locations are neglected over time, even if we assume flat conditions (Friedman 2005). Figure 2 shows the three sub-divisions of global markets: center states, emerging countries, and periphery countries (Alnuaimi et al. 2012). Krugman (1991) and McDonald et al. (2018) analyzed the dichotomy called the core and periphery of the international location strategy.

In this study, we show that location decisions create an endogenous economic landscape in which MNEs compete with one another in the global market (Celo et al. 2015). We check the simulation results for 2 entrants and continue the process till 121 entrants are admitted. Our focus is centered on the locational choices of MNEs in the global market. Since R&D involves employment from local economies, agents engaged with the simulation modeling will make alliances with the “universities,” which involves the reachable knowledge workers as a determinant factor of their investment decisions.

Figure 7 (a) shows how two entrants choose their location during 100 rounds of locational choices (200 steps in total). In the case of the first two entrants, they attain equilibrium after three rounds to stay at the center of the global market. As explained above, the first entrant relocates to the center of the global market. The second entrant chooses a position next to the center of the global market. The first and second entrants attain equilibrium and stop moving. Figure 7 (b)–(f) shows the cases of 3, 10, 18, 19, and 20 entrants. The figures show how many times MNEs have chosen their R&D locations in the global market. The choice of the same location is understood as a continuation of R&D subsidiary operations. The bar graphs show how often MNEs have chosen a certain location during 10,000 steps of simulation time.

In Fig. 7 (d) and (e), we see a typical landscape of location strategy. The location selection of MNEs does not show a symmetrical landscape that is normally distributed from the core toward the periphery. The bar graph is high in some locations in emerging economies, and this can be attributed to the selection made by MNEs multiple times. It can be observed that MNEs rarely choose the periphery. MNEs have never chosen locations in the fringes of the global market, as shown in Fig. 7 (d). As shown in Fig. 4 and (f), when the market becomes saturated, location shifting toward the periphery is rarely observed. Some places near the core country emerged as preferable locations for MNEs.

Proposition 3. The periphery of the global market is rarely chosen as the R&D location in the disequilibrium cases of the ABS model.

Proposition 4. Endogenous moves by agents in the ABS model generate a bumpy landscape in the global market.

4.6 Uneven Development

Figure 8 depicts some ABS cases of Lorenz curves to show the disparity in market share gains of each agent. When the number of participating agents is two, it is a straight line that is almost a right angle. This indicates the highest inequality in the market. As the number of participating agents increases, crescent-shaped curves are formed, approaching the diagonal line. After the number of entrants increase, the curves move closer to the diagonal line, indicating perfect competition.
Figure 9 shows the Gini coefficients according to the number of participating agents. The vertical axis shows the magnitude of the Gini coefficient, and the higher the inequality of market share among the agents, the higher the value. The horizontal axis is the number of participating agents, showing from two agents to 121 agents. The graph of the Gini coefficient is expected to level out as more agents enter. However, there are various exceptions in each agent’s tendency to acquire a share of the knowledge labor market.

![Graphs of Gini coefficients for different numbers of agents](image-url)
The exceptional tendency appears as spikes in the Gini coefficient, as shown in Fig. 9. These spikes occur when pure equilibrium, saturation equilibrium, or quasi-saturation equilibrium occur. If the agents attain equilibrium, their market share stops increasing, and the disparity between them is fixed. In the case of disequilibrium in which the entry agent continues to move from one location to another during the simulation rounds, the market share acquired by the agent is leveled. As such, the Gini coefficient is recorded as low to reflect the disequilibrium dynamics.

Proposition 5. When the location strategy of the agents reaches pure equilibrium, saturation equilibrium, or quasi-saturation equilibrium, the imbalance in acquiring a market share among the participating agents continues to accumulate, resulting in unequal market share gains.
Proposition 6. Disequilibrium in the global market levels the market share disparities among entry agents and reduces inequality.

5 Discussion and Conclusions

5.1 Limitations

In this study, the ABS model is constructed such that agents consider only the current market share. The agent makes short-term decisions when it considers the present strategic positioning of opponents in the market. One can extend the agent’s assumption to consider the opponents’ moves and the subsequent reaction by agents in the market. This assumption could involve the application of Bayes’ theorem. If we assume several players in the two-dimensional model moving between multiple stages, we must consider an exponential explosion of the second-and third-stage moves in our calculation. The burden on the calculation will be greater if we include the multiple moves made by the agents.

If we assume two qualitative dimensions of the market, this assumption leads to a positioning strategy. Two dimensions, product differentiation, and price level are possible candidates. Our model can be applied to marketing, where multiple dimensions occupy the essential characteristics of segmentation in the market. A two-dimensional model can also incorporate two factors in international business strategies, such as the degree of cultural proximity and similarity of living conditions.

We can also incorporate risk factors, that is, if we assign a risk factor to each of the nodes, then we can represent the latent country risk. The risk-return trade-offs may be explicitly calculated as an extension of this agent-based simulation model. Factors such as imperfect information can be added in this line of extension of the model. In practice, firms do not have perfect information about competitors’ actions. It is worth noting here that the payoffs gained by each agent approached the average market share when we iterated several thousands of times. In the present analysis, it is unclear whether these results can be confirmed even after incorporating risk factors, which indicates the limitations of our research.

5.2 Implications of Equilibrium Analysis

Our research results provide important contestations to mainstream economics. Propositions 1 and 2 show that economic disparity continues when equilibrium is obtained and leveled in the case of disequilibrium. This suggests that there is a clear risk in the analytical approach to compare economic welfare-based mathematical models with static equilibrium in mainstream economics. Analyzing a mathematical model that provides equilibrium in the market may represent a stable economy with continued disparity. When we observe mathematical economic models that apply Hotelling’s location framework in which the equilibrium attained by two companies is analyzed (Okabe and Aoyagi 1991; Harter 1997), care should be taken when we read the implications of the analysis.

Propositions 3 and 4 cast doubts on the two important concepts of management strategy: the niche market and the blue ocean strategies. In our ABS modeling, both strategies were sustained within an extremely short period of time, and the strategy collapsed because of
pure location competition. Positioning in the market alone makes it impossible to sustain a niche market strategy or a blue ocean strategy. Therefore, if some companies adopt either strategy, they possess managerial internal resources or external resources, which are the source from which quasi-rent can be acquired. Neither niche nor blue ocean strategies exist without MNEs’ internal resources.

Corollary 1. The location advantage is transient when the MNEs’ internal resources are assumed to be equal.

Corollary 2. A company that adopts a niche market strategy can sustain the approach if and only if the company sustains internal resources with competitiveness.

Corollary 3. Given that the internal resources of MNEs are equal among competitors, the blue ocean strategy does not exist.

5.3 Policy Implications

Policy implications are suggested when the simulation results can be interpreted as follows. Multinational enterprises repeat entry and exit by aiming at an optimum location in the global market. When MNEs freely seek profit maximization in the global market and compete in a location, they will locate their subsidiaries in emerging economies or member countries of the G7 or G20. As the number of entering MNEs increases, they begin by locating in countries that are closer to the periphery. The landscape graphs show the locations where MNEs have positioned their subsidiaries. Many subsidiaries of MNEs have moved from the center of the market to emerging economies. However, MNEs rarely select countries located at the periphery of the market.

We call countries in such positions least-less developed countries (LLDC). We also observe the following facts in the simulation model: Even if the global market is saturated by FDI, MNEs will not spontaneously increase location choices in peripheral countries. Proposition 3 indicates that the optimal location strategy of MNEs will not cause foreign investment to flow to peripheral countries. In other words, LLDCs may have a paucity of FDI, even though emerging economies would continue to absorb FDI. If private investment dominates global investment flows, peripheral countries will experience shortages in private investment. Proposition 3 suggests that policy measures that redirect the flow of FDI to LLDCs are needed so that the peripheral countries become attractive locations for MNEs to rationally position their strategies in the global market.

Corollary 4. A recipient country needs to promote national economic policies to attract FDI.

Corollary 5. The global economic policy to support FDI flows from developed countries to LLDCs needs to be promoted.

These corollaries suggest the need for official development assistance (ODA) to redirect FDI flow to the LLDCs so that the peripheral countries will become attractive locations in the global market and facilitate MNEs to position their strategies. This result supports the policy that both world organizations and local governments in peripheral countries should support the invitation program of foreign R&D investment from multinational enterprises.

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Declarations

Conflict of interest The authors declare no competing interests.
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