Euclidean Distance and Corporate Performance in the DEC Spatial Model

Takao Ito, Tsutomu Ito, Katsuhiko Takahashi, Rajiv Mehta, Makoto Sakamoto, and Satoshi Ikeda

***Abstract*—**Identifying specific inter-firm relationships that are associated increased efficiency can guide the formulation of corporate strategy. Although many tools have been developed for measuring qualitative (e.g., friendship and workflows) and, but also quantitative relationships (transactions and cross-shareholdings), owed largely to changes resulting from uncertainty and globalization, additional mathematical methods are required. Consequently, this research proposes a new approach known as the DEC spatial model to calculate Euclidean distance embedded in three-dimensional space composed of three network indices: degree, effective size, and capacity. Transaction data drawn from Mazda's Yokokai is used to compute degree, effective size and capacity. The relationship between Euclidean distance, which is calculated, and sales (an indicant of corporate performance) is also assessed. Managerial implications, study limitations and suggestions for future research are offered.

***Keywords*—** Euclidean distance, keiretsu, three-dimensional spatial model, Yokokai.

I. Introduction

KNOWN to fall within the domain of corporate strategy, determining the structure of inter-business Japanese networks—more commonly called keiretsus—can be aided by discerning salient rational inter-firm relationships, which contribute in increasing efficiency of firm. Keiretsus are typical of the many different types of strategic alliances in Japan, although it should be noted that all networks do not embody all the characteristics of Keiretsu. Widely accepted as being successful, keiretsus are made-up of affiliated organizations that are ordered and characterized by long-term continuous rationality, trade exclusivity, and information concealment. However, cross shareholdings as reflected by the percent and amount of stock cross ownership, which is also known to be a central facet of keiretsus, is being abandoned. As a result, automakers are losing control of their crucial auto-parts suppliers, who are now increasingly focusing on developing their customer base by selling to non-network members. Largely owed to a condition referred to as keiretsu loosening, the inter-organizational network of suppliers and carmakers now has begun to resemble an affiliated group company network rather than a classic keiretsu. This phenomenon of keiretsu loosening begs the following questions: What kind of inter-firm relationships will be most effective in improving corporate performance? What are the differences between a keiretsu and an affiliated group company network? With the structural nature of inter-business networks changing rapidly and frequently, this knowledge will provide managerial implications that can be used as guidelines in formulating business strategy. Accordingly, this paper proposes a new approach embedded in three-dimensional space comprising degree, effective size, and capacity. This DEC spatial model calculates the Euclidean distance among firms, which is then used to analyze the rational interrelationships between Euclidean distance and sales (a corporate performance index) using transactional data gathered from Mazda's Yokokai.

The structure of this paper is as follows. In section 2, we review the literature associated with network approach and three-dimensional models. Section 3 will explain the measurement of three indices including degree, effective size, and capacity, and the computation of Euclidean distance. Managerial implications emerging from the results will be discussed in Section 4. Section 5 will mention the limitations of this paper and provide directions for future research.

II. Background

The term strategy, which has been around for a long time, has been frequently been used by organizational scholars. For instance, Mintzberg's perspective of strategy comprises of five Ps: planning, pattern, position, perspective, and ploy [1]. And Chandler asserted that strategy can be defined as the "determination of the basic long-term goals and objectives of an

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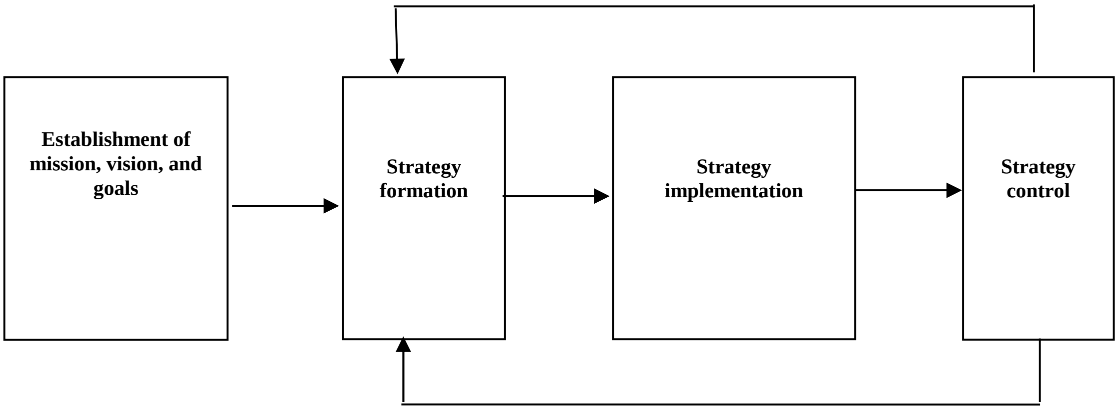

Fig. 1 Process of strategy making

enterprise, the adoption of course of action and the allocation of resources necessary for the carrying out of these goals" [2]. In general, the strategic decision-making process comprises of several steps shown in Fig. 1 [3].

Strategy formation is an important phase in corporate making process. Of the plethora of studies that have focused on strategy formulation, two aspects are noteworthy: coordination of managerial resources within firm and establishment of rational relationships with outside shareholdings. Evidently, as inter-firm relationships with external constituents are important, the network perspective can effectively increase our collective understanding of the dynamics between network members Recent investigations on inter-firm relationships have focused on examining centrality [4], the relationship between corporate governance and closeness [5], firm centrality measurement of transaction and cross-shareholdings and capacity index analysis [6-11].

There are relatively few studies associated with three-dimensional network models. One study developed a 3D data model for representing topological relations, adjacency and connectivity relationships between 3D spatial objects for urban features [12]. Another scholar investigated internal structures of micro-scale environment [13], while another developed a 3D data model for emergency response in urban areas [14]. Moreover, a study on the relationship between corporate strategy and three-dimension network has been reported recently [15]. As such, there is a paucity of research on inter-firm relationships using three-dimension models. Consequently, this paper proposes a new approach for developing a three-dimension model composed of degree, effective size and capacity to investigate rational inter-firm relationships. In this paper, the Euclidean distance of each firm is computed in three-dimension space, and is used to analyze the correlation between the degree, effective size, and capacity and corporate performance.

III. Method, data collection and Results

We first calculate the three network indices and then measure the distance among the firms, as described below.

A. Measurement

The detailed calculation of the three network indices are as follows.

1. Degree

Degree is defined as the number of nodes that connect with it directly. It will be calculated as follows [16].

$$C_D(p_k) = \sum_{i=1}^{n} a(p_i, p_k); \qquad (1)$$

k=1, 2, …, n

where

$a(p_i, p_k)$=1, if and only if p_i and p_k are connected by a line

$a(p_i, p_k)$=0, otherwise

Degree generally can be considered as the index of communication.

2. Effective size

Effective size is network size (n) minus redundancy in network. It can be calculated as follows [17].

$$ES_i = \sum_j [1 - \sum_q p_{iq} m_{jq}]; \quad q \neq i, j \qquad (2)$$

where

m_{jq}: i's interaction with q divided by j's strongest relationship with node

p_{iq}: proportion of I's energy invested in relationship with q

3. Capacity

Capacity is an index to calculate the numbers of connection line between any two nodes under the consumption of when the length of the path between two nodes equals to r, the value of the length r should be higher than r+1. In other words, it holds that the value of the capacity is higher, the bigger capacity we have. It can be calculated as follows if the length of r is equal to infinity [7].

$$C = (I - (\frac{A}{\eta}))^{-1} - I \qquad (3)$$

where
A: Adjacency matrix
I: Identity matrix
η : Parameter of distance

4. Euclidean distance
Euclidean distance is defined as the length of the line connecting any two nodes. It can be calculated as follows.

$$d_{ij} = \sqrt{(C_D(p_i) - C_D(p_j))^2 + (ES_i - ES_j)^2 + (C_i - C_j)^2} \quad (4)$$

B. Data Collection and Results

To test the interrelationships among the focal constructs, data for fiscal year 1983 was drawn from Mazda's Yokokai keiretsu [18]. In 1983, 11 carmakers and 173 suppliers are included in Yokokai. Any firm included in transaction network that has a relationship with only one other firm, but no other firm is called a singleton. 4 automobile manufacturers and 109 suppliers are singletons.

The inter-firm transactional relationship in 1983 is illustrated in Fig. 2.

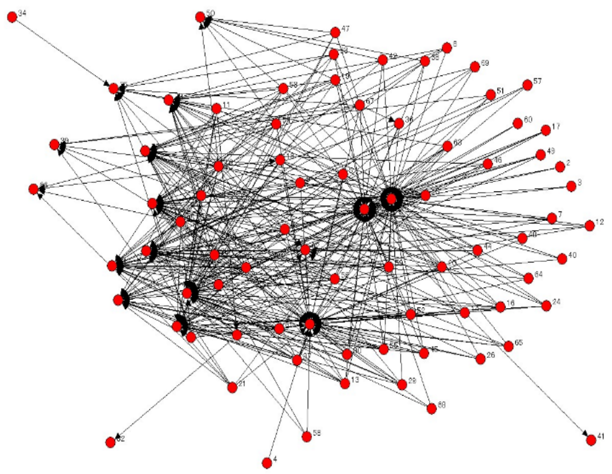

Fig. 2 Transactional networks in Yokokai

We put all data in a matrix table. In the matrix below, the amount in (i, j)th cell means the firm in ith column sells parts to the firm in jth row, or the firm in jth row purchases parts from the firm in ith row.

Table 1 shows the transactional data in Yokokai. For instance, Topy Industries Ltd. (No. 84) sells 11.11 percent parts to Hitachi Ltd. (No. 102). As such, the cell between Topy Industries Ltd. and Hitachi Ltd. is 11.11 percent. In other words, Hitachi Ltd. purchases parts from Topy Industries Ltd. and it occupy 11.11 percent of Topy Industries Ltd.'s total sales.

Before our calculation, we collected the data including both of amount and percent from the transaction network, and analyzed the correlation with sales. As all correlation coefficients are significant ($p<0.5$), thus percentage data is used in this paper.

Table 1 Yokokai Network Matrix Data in 1983

		101	102	103	104	105	106	107
1		0	0	0	0	0	0	0
3		0	0	0	0	0	0	0
19		0	0	0	0	0	0	0
39		0	0	0	0	0	0	0
59		0	0	0	0	0	0	0
60		0	0	0	0	0	0	0
61		0	0	0	0	0	0	0
62		0	0	0	0	0	0	0
63		0	0	0	0	0	0	0
64		0	4.54	0	0	0	0	0
65		0	7.69	0	0	0	0	0
71		0	0	0	0	0	0	0
72		0	0	0	0	0	0	0
74		0	0	0	0	0	0	0
75		0	0	0	0	0	0	0
77		0	0	0	0	0	0	0
79		0	0	0	0	0	0	0
80		0	0	0	0	0	0	0
81		0	0	0	0	0	0	0
82		0	0	0	0	0	0	0
83		0	0	0	0	0	0	0
84		0	11.11	0	0	0	0	0
85		0	0	0	0	0	0	0

Based upon the methods shown in Section III, we calculated degree, effective size, and capacity. The results are shown in Table 2 and Table 3.

Table 2 Results of each firm in Yokokai
(Degree and Effective size)

	Out-Degree	In-Degree	Effective Size
1	0	677	55.797
2	92	0	2
3	92	0	2
4	17	0	0
5	82	0	9
6	100	0	9.653
7	87	0	4
8	59	0	4
9	96	0	9
10	73	0	15.331
11	62	0	7.682
12	38	0	4
13	85	0	8

14	72	0	6.845
15	87	0	8
16	100	0	6
17	40	0	4
18	71	5	5.075
19	78	0	7
20	58	0	7
21	54	0	7
22	89	0	8
23	92	0	11
24	46	0	5
25	68	0	13
26	75	0	4
27	90	8	8.944
28	81	0	13
29	70	0	7
30	100	0	0
31	77	0	11
32	0	7	1
33	94	0	6
34	10	0	1
35	0	72	10
36	90	9	4.941
37	62	0	9
38	66	0	5
39	0	28	6
40	80	0	3
41	0	1	1
42	76	0	6
43	73	0	11
44	90	0	4.082
45	88	0	7
46	81	0	5
47	71	0	5
48	48	0	3
49	82	0	4
50	0	41	7
51	70	0	4
52	70	0	7
53	61	0	9
54	32	0	10
55	77	0	7
56	93	0	8.222
57	42	0	3
58	100	0	3
59	74	0	8
60	60	0	2
61	82	0	9
62	93	47	8.086
63	75	0	6
64	50	0	4
65	76	0	5
66	0	26	4
67	29	0	6.947
68	60	0	3
69	96	0	4
70	0	786	36.734
71	0	615	33.995
72	0	327	28.642
73	0	670	45.812
74	0	178	23.991
75	0	190	28.237
76	0	179	22.529
77	0	280	28
78	0	208	25
79	0	124	19

Table 3 Results of each firm in Yokokai (Capacity)

	Out-Capacity	In-Capacity
1	0	8.66327
2	1.16456	0
3	1.16456	0
4	0.210886	0
5	1.03557	0
6	1.41484	0
7	1.10506	0
8	0.746835	0
9	1.20886	0
10	1.03909	0
11	0.903309	0
12	0.486076	0
13	1.06962	0
14	1.13708	0
15	1.1	0
16	1.26532	0
17	0.506329	0
18	0.903797	0.0574684
19	0.98443	0
20	0.738101	0
21	0.677215	0
22	1.12506	0
23	1.15987	0
24	0.577215	0
25	0.86557	0
26	0.949367	0
27	1.27976	0.0973418
28	1.02848	0
29	0.886076	0
30	1.26582	0
31	0.97519	0
32	0	0.0930657
33	1.18861	0
34	0.126582	0

35	0	0.913291
36	1.13924	0.113924
37	0.78481	0
38	0.831646	0
39	0	0.359114
40	1.01241	0
41	0	0.0126582
42	0.957975	0
43	0.927342	0
44	1.19095	0
45	1.10759	0
46	1.02785	0
47	0.903797	0
48	0.603797	0
49	1.03797	0
50	0	0.517848
51	0.883544	0
52	0.886076	0
53	0.76962	0
54	0.403797	0
55	0.972152	0
56	1.23772	0
57	0.526582	0
58	1.2657	0
59	0.936709	0
60	0.759494	0
61	1.03797	0
62	1.17722	0.609804
63	0.949367	0
64	0.632911	0
65	0.967089	0
66	0	0.329114
67	0.498141	0
68	0.759494	0
69	1.21139	0
70	0	10.4123
71	0	7.83374
72	0	4.23939
73	0	8.56375
74	0	2.26473
75	0	2.47009
76	0	2.32557
77	0	3.61577
78	0	2.62722
79	0	1.57

The three-dimensional scatter diagram of all firms can be shown as Fig. 3.

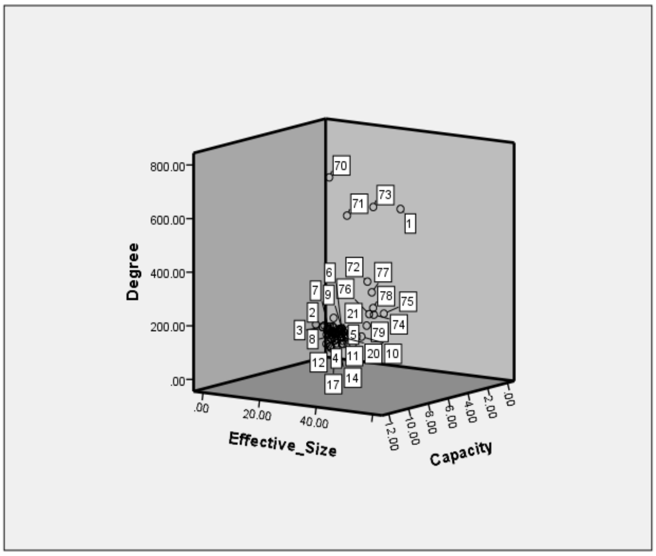

Fig. 3 Three-dimensional scatter diagram of Yokokai

As illustrated in Fig. 3, Mazda is No. 1, Mitsubishi is No.73, Nissan is No.71, and Toyota is No. 70. All of these automotive producers are located at the periphery. Thus, the Yokokai could be considered as a supplier-concentrated group company.

The distances among all firms are illustrated in Fig. 4.

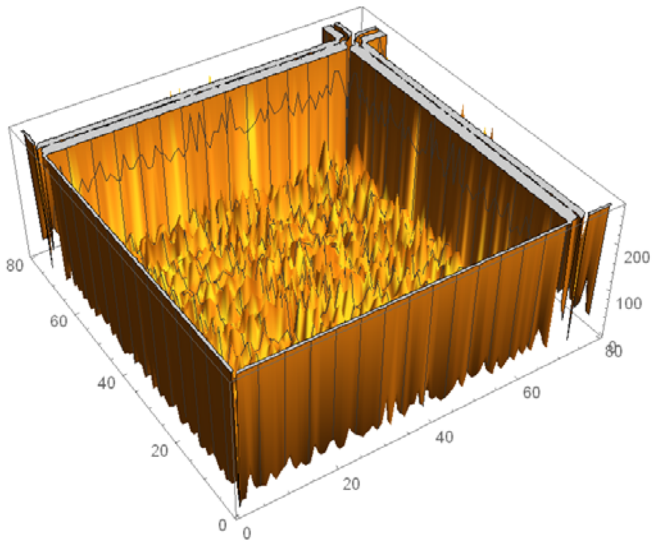

Fig. 4 The distances among all firms in Yokokai

Evidently, the distances among carmakers are much longer than the distances among suppliers. This means that two groups can be dichotomized into automotive manufacturers and suppliers.

IV. DISCUSSION

The distances are measured successfully. To understand the implications, we analyzed the relationship between Euclidean distances and sales, one of the indices of the corporate performance using regression model. Euclidean distance is composed of five indexes: out-degree, in-degree, effective size, out-capacity and incapacity. Table 4 provides the results of the analysis of variance.

Table 4 Result s of analysis of variance

	Sum of Squares	Degree of Freedom	Mean Square	F Test
Total	7.34E+24	63		12.6797
Regression	1.25E+24	1	1.25E+24	Prob.
Residual	6.09E+24	62	9.83E+22	0.0007

Coefficient of determination: 0.16979
Multiple correlation coefficient: 0.41205
Adjusted R-square: 0.39547
AIC: 3,571.89
DW ratio: 1.9355

From Table 4, we find the coefficient of determination is 0.16979, and DW ratio is 1.9355. Therefore, the regression model is significant. The estimation of regression coefficients is shown in Table 5.

Table 5 Estimation of regression coefficients

	Sales	Intercept
Partial correlation coefficient	-1.1E+10	7.63E+12
Standard coefficient	-0.4121	0
T value	-3.5609	3.6265
Degree of Freedom	62	62
Prob.	0.0007	0.0006
Correlation coefficient	-0.4121	-

Partial correlation coefficient is negative in Table 5. It means that the distance is inversely proportional to sales. Therefore, as distance increase, sales decrease. It corroborates the fact that directly dealing with multiple firms will aid to improve corporate performance.

In order to understand the changes of keiretsu, we collected the data of the fiscal year 2004 from Mazda Yokokai, and calculated the relationship between distances and sales. The result is shown in Table 6 (left row).

In Table 6, we note that the coefficient of determination is low, and the probability is high. This means that the regression model is not effective. Furthermore, this result contradicts the findings using the 1983 data-set.

Apparently, during the 2004 period is that businesses reorganized, thus resulting in the condition known as keiretsu loosening in automobile industries.

Table 6 Coefficients of distance-sales regression model

	Explanatory variable	
	Distance from Mazda	Distance from Toyota
Partial regression coefficient	-7.585E+8	-1.364E+9
Intercept	8.965E+11	1.196E+12
Coefficient of determination	0.023	0.063
Multiple correlation coefficient	0.152	0.25
Adjusted R- square	0.103	0.224
F value	1.832	5.133
Degree of Freedom	1, 77	1, 78
Probability	0.180	0.026
AIC	4525.28	4526.19
DW ratio	1.971	1.973

To find further support for keiretsu loosening, transaction data were collected from Toyota for fiscal year 2004. Similar results were obtained (Table 6). We find that not only the coefficient of determination is higher than that of Mazda, but also the probability is lower. This means that the regression model is significant, and that distance has an impact on the sales in the Toyota group. Therefore, a reasonable explanation is that the Yokokai group is under the process of dissolution and Toyota group still maintains a tightly-interwoven keiretsu to derive benefits and advantages.

V. MANAGERIAL IMPLICATIONS

The results of this study offer several implications for corporate management. Hence, to enhance corporate performance, suggestions for managing the network interrelationships among the various partners comprising a keiretsu are offered. First, this paper introduced a unique method for measuring the Euclidean distance in a newer paradigm known as the spatial DEC model. It is intuitive that automotive manufacturers and their supplier partners behave differently as exhibited by the different distances in Fig. 2. Therefore, Euclidean distance should be considered a standard effective index of keiretsu network groupings. Second, this study found a negative correlational linkage between sales and the three dimensions of distance—degree, effective size, and capacity—not only in Mazda, but also in Toyota's keiretsu. Shortening the distance with other firms is, thus, considered as the effective way to improve corporate performance because the correlation coefficients between sales and distances are negative. Third, regression analysis and other linear models employing corporate finance indices are often used for testing hypotheses. This approach similarly yielded strong statistical support for degree, effective size, and capacity as predictors of corporate performance. Thus, emphasis should be placed on these three indices as a means of augmenting corporate performance. Finally, the DEC model is only one of several spatial frameworks that can be employed for analyzing the rational relationships between degree, effective size, and capacity positions as a determinant of corporate performance. Thus, other such effective spatial models should be developed to identify best corporate practices for effective keiretsu management.

VI. Limitations of the Study

The study possesses certain limitations that are redolent of future research efforts, which are suggested as follows. First, the linkages among the focal constructs should be tested using data drawn from keiretsu in different industries, such as steel, electronics, and shipbuilding. Second, and in a like vein, the linkages among the focal constructs should be replicated using data gathered from additional automotive keiretsu that include Nissan and Honda to test the external validity of the findings. Third, additional network indices, such as influence, density, and balance, should be used to calculate the position in a given spatial space. And finally, the present research only used data from only one fiscal year. Specifically, longitudinal data should be gathered to ascertain the rational interrelationship between structural position indices and corporate performance.

VII. Conclusion

In this paper, we proposed a new approach of Euclidean distance using three-dimensional embedding space composed of degree, effective size, and capacity using data collected from Mazda Yokokai. Euclidean spatial distance was calculated and its relationship was analyzed relative to distance and corporate performance. We found that inter-firm relationships is changed after comparing the results of Mazda's Yokokai in 1983 and 2004, whereas Toyota still maintains its keiretsu to develop its business. However, the limitation of this research is additional data is required to shed light on the real relationship between the distance and sales. Furthermore, not only percent data but also amount data also should be used to test and find support for new approach suggested in this research endeavor.

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