A NEW MATHEMATICAL MODEL OF MUTUALLY COMPLEMENTARY FOR CORPORATE ALLIANCES: SELECTION OF OPTIMAL PARTNERS USING EIGHT CHARACTERISTICS

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ABSTRACT

In this paper, a new mathematical model is proposed for choosing a business strategy and selecting business partners, so-called corporate alliances. We have used the real corporate data of 152 Japanese companies based on eight characteristics. These characteristics include engineering skills, sales force, capital resources and other items that represent management resources. These characteristics can be described using a one-dimensional matrix. Subtraction of two one-dimensional matrices shows the strength of the alliance between two companies where mutually complementary relationships are vectorized. We have analyzed 152 companies and the computed results of the corporate alliances based on the proposed model are the same as they exist in reality. The proposed model is implemented by the Python programming language. In addition, from the mathematical model proposed in this paper to calculate the mutually complementary strength value, we can determine which candidate from multiple potential companies would form the best alliance, and by extension, which pair of companies from a total of three would make the best alliance.

JEL: C63

KEYWORDS: Mathematical Model, Business Strategy, Corporate Alliance, Mutually Complementary Relationship, Open Source, new business development

INTRODUCTION

The author of this work consulted 152 Japanese companies between May 2008 and March 2015 regarding new business startups and increasing sales.

Additionally, the author defines an corporate alliance as “The state in which more than one company is independent and both are committed to creating new business and complement each other in providing management resources from each company in order to create new business and increase sales revenue of their current businesses, regardless of the presence or absence of a binding contract or capital relationship, by continued cooperation, to share the results.”

In this study, the hypothesis of this corporate alliance is satisfied when the mutually complementary relationship between two companies is strong. For this purpose, a mathematical model has been constructed making use of a one-dimensional matrix, bipolar vector, and a normalized-value representing the mutually complementary strength between two companies called the mutually complementary strength coefficient.

Additionally, the mathematical model created from eight different viewpoints, with values allocated from one to five, was verified to function with the data from the 152 consulted companies.

LITERATURE REVIEW

In relation to prior research on the alliance, the theoretical background of the corporate alliance between companies was prepared by Yasuda (2010). This theory relies primarily on Resource-Based Theory shown by Collis &

Montgomery(1998). The concept that the corporate alliance is comprised of the exchange of (a) Technological resources, (b) Sales resources, (c) Production resources, (d) Human resources, (e) Capital resources. One other theory also used is the Transaction Cost Theory, which is the belief of the corporate alliance such that in the event of lower costs, it is better to evolve internalized practices as opposed to reliance on external companies and normal market transactions. In this research document, we will take the view of Resource-Based View (RBV) as it applies to the hypothetical establishment of an corporate alliance (when possible) between 2 companies as it pertains to matters such as the necessary management resources for business deployment and the mutual complement to each company's strengths and weaknesses.

HOW THE DATA OF 152 COMPANIES WERE BUILT

In regards to location: Tokyo (all 23 wards) – 71%, Metropolitan area – 13%, Non-metropolitan area – 16%. Regards company size and longevity: Listed companies (including subsidiaries) – 13%, Long-time small to mid-sized businesses – 40%, Small venture businesses – 47%. In terms of industry: In-house manufacturing – 17%, Contract manufacturing/Processing/Construction – 35%, Sales and marketing – 30%, Professional/Consulting – 11%. Additionally, IT-related industries – 40%, Non-IT related industries – 60%.

In relation to sales: Under 11 billion yen – 78%, Between 1 and 10 billion yen – 15%, Over 10 billion yen – 7%. In terms of employee size: Under 20 employees – 56%, Between 20 and 100 employees – 32%, Over 100 employees – 13%.

Regarding strengths and weaknesses: (1) Sales Capability, (2) Technical Ability, (3) Creativity of Ideas, (4) Capital Resources, (5) Human Resources, (6) Production Capacity, (7) Branding and Credibility, (8) Flexibility of Organization. Note that items 1 to 5 are listed in descending order of rating.

Even though companies outside of the 152 consulted companies were introduced, in this research the verified data was limited to companies within the total 152 that were or were not in a corporate alliance.

In the research and analysis in this paper, companies are counted as "in an established alliance" are defined as "The introduction of two companies to each other resulting in the development of new products, business or services, expansion of the existing business, new transactions (orders and sales) and the benefits to both companies in mutual cooperation as well as the result of moving both businesses forward". Conversely, those counted as "not in an alliance" are defined as "Having not moved forward at all".

CONSTRUCTION OF THE MUTUALLY COMPLEMENTARY MATHEMATICAL MODEL FOR THE CORPORATE ALLIANCE

Comprehending Mutual Complement and Application of the Physical Model

As we construct a mathematical model that shows the mechanism of the establishment of corporate alliances, we devise a theory based on the physical spin glass magnetic force model (The theory that the N and S poles attract each other).

In the idea of a mutually complementary alliance model, the strengths of company B will complement the weaknesses of company A, and vice versa. It then becomes fundamental for the strengths of company A to complement the weaknesses of company B. If the complements from one of the companies or both are small, the mutually complementary strength will also be small, but if both companies are committed to complementing the strengths and weaknesses of each other, they will more strongly complement each other. That is, a mutually complementary alliance is considered to be a bipolar model based on the mutually attracting forces between two companies.

Representing the Strengths and Weaknesses of a Company as a One-Dimensional Matrix

The mutually complementary relationship between two companies can be expressed as a one-dimensional matrix. The strengths and weaknesses of companies A and B can be represented as an array of eight characteristics each having values between one and five. The eight characteristics are mainly based on the Resource-Based View (RBV) as explained in the previous chapter, so they are feasible not only as for the data set in this research but also ordinary companies. Also, the integer values represent the score evaluating the strength and weakness of these characteristics for each company.

As an example, take the two following companies,
Company A a=(1, 3, 4, 2, 5, 1, 3, 1)
Company B b=(4, 1, 1, 3, 1, 5, 3, 1)

From the above, the result "c" can be shown by calculating (subtracting) the values of each of the characteristics of Company B from Company A in order to get a directional bipolar vector with values for each characteristic ranging from 0 to 4 (positive or negative).

Company A – Company B
c = a-b = (-3, 2, 3, -1, 4, -4, 0, 0)

It should be noted that in this particular case, when calculated using the programming model described later, the mutually complementary strength is 11.997 and the related coefficient is 0.530 by making the calculation as explained in the section of "Mutually complementary strength and the related coefficient".

The Maximum Mutually Complimentary Distance from this Point

The strengths of the mutually complimentary distance are expressed by measuring the distance from the largest mutually complimentary point of strength.

Namely, in regards to the bipolar vector of the length from 0 to 4 of the 8 characteristics (expressed as numbers representing strengths and weaknesses), the maximum mutually complementary value determined from taking 2 sets of 2 characteristics with a maximum value of 8 for each.

(8 characteristics / 2) * Max length of 4 = (16,-16)

The distance between two points is calculated as follows:

$$\sqrt{(a_1 - a_2)^2 + (b_1 - b_2)^2} \quad (1)$$

The maximum value of the mutually complementary strength of (16,-16) is shown as the distance from (0, -0) to (16, -16), which becomes

$$\sqrt{(16 - 0)^2 + (-16 + 0)^2} = 22.62 \quad (2)$$

The mutually complementary strength is a value between 0 and 11.3, with a large value representing a large mutually complementary strength.

When the distance from the maximum value of (16,-16) is small, it indicates that the mutually complementary strength is strong. Since it is simpler to subtract from larger numbers, the magnitudes of the values have been inverted.

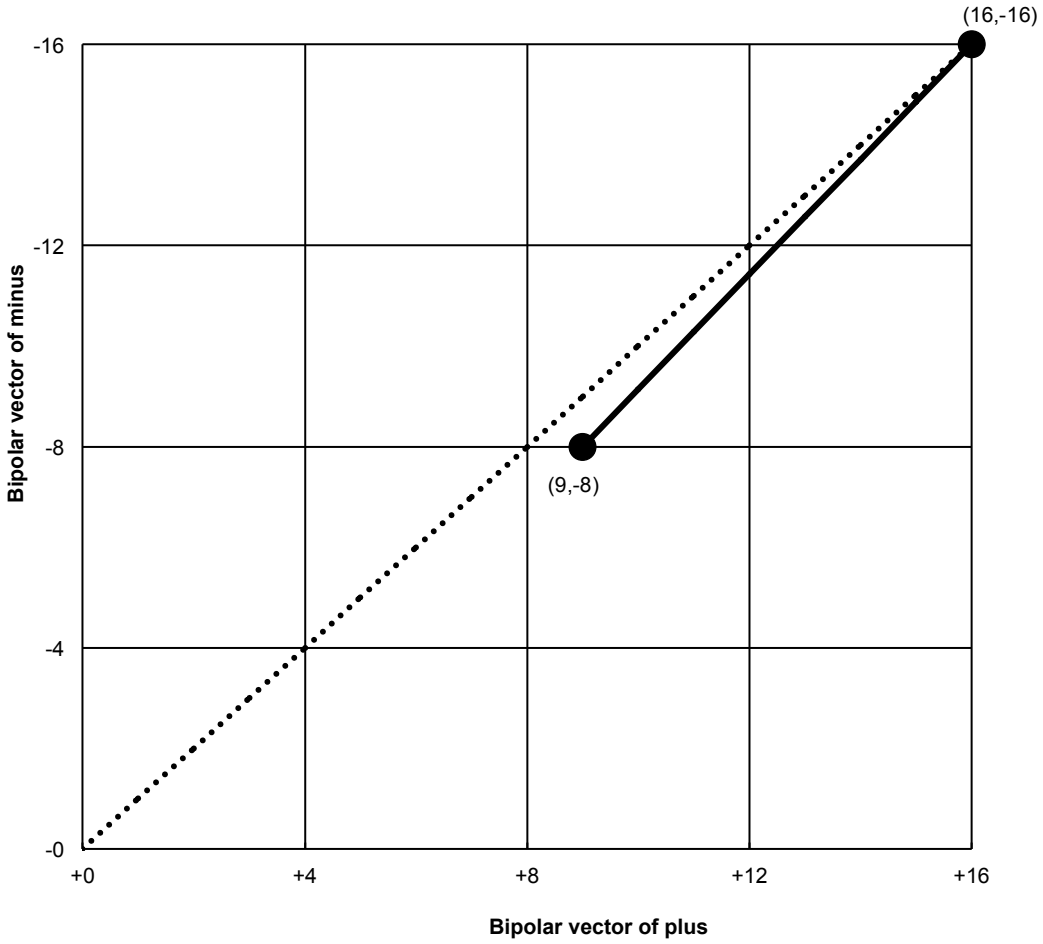
For example, with a mutually complementary strength of (9,-8) it is possible to calculate the distance from (16,-16) by means of subtraction from the maximum value.

$$\sqrt{(16-9)^2+(-16-(-8))^2} = 10.63 \quad (3)$$

For example, the mutually complementary distance of (9, -8) is calculated from the maximum value of (16,-16) as shown in the following calculation and the following Figure 1.

$$\sqrt{(16-0)^2+(-16+0)^2} - \sqrt{(16-9)^2+(-16-(-8))^2} = 11.99 \quad (4)$$

Figure 1: The Bipolar model of mutual complementarity for alliances



This figure shows the example representing the mutually complementary strength of 2 companies by the distance from the maximum value of the mutually complementary strength. In case of 8 characteristics, the maximum value of the mutually complementary strength is (16,-16) and the point presenting the mutually complementary strength of Company A and Company B is (9,-8).

Mutually complementary strength and the related coefficient

Up until this point, the eight characteristics have been described as a mutually complementary bipolar vector. Here is the general equation used to express this.

The mutually complementary strength, derived and explained above, can be expressed by the following formula:

$$\sqrt{2\times\left(\frac{4\times len(c)}{2}\right)^2}-\sqrt{\left(\frac{4\times len(c)}{2}-plus\right)^2+\left(\frac{-4\times len(c)}{2}-minus\right)^2} \quad (5)$$

When this value is normalized to a value between zero and one, it becomes easier to handle. The relative mutually complementary strength can be calculated from the following formula, and is here forth defined as the mutually complementary strength coefficient.

$$1-\frac{\sqrt{\left(\frac{4\times len(c)}{2}-plus\right)^2+\left(\frac{-4\times len(c)}{2}-minus\right)^2}}{\sqrt{2\times\left(\frac{4\times len(c)}{2}\right)^2}} \quad (6)$$

In the above formula, len(c) is the number of characteristics, plus=Σ (positive integers), and minus=Σ (negative integers).

PROGRAMMATICAL ANALYSIS OF THE DATA FROM 152 CONSULTED COMPANIES USING PYTHON

Overview of the Company Data Verification

In the data from 152 consulted companies, because the strengths and weaknesses of all eight characteristics are represented by a value from one to five for each, the maximum cross-complementary strength is determined to be (16,-16). The distance from that point shows the mutually complementary strength between the two companies. The calculation of the mutually complementary strength coefficient was executed from a script written in the open-source programming language “Python”.

Additionally, although companies outside of the consulted partners were introduced, the consulted partners accurately verified and limited the data to only that which was determined to be satisfactory.

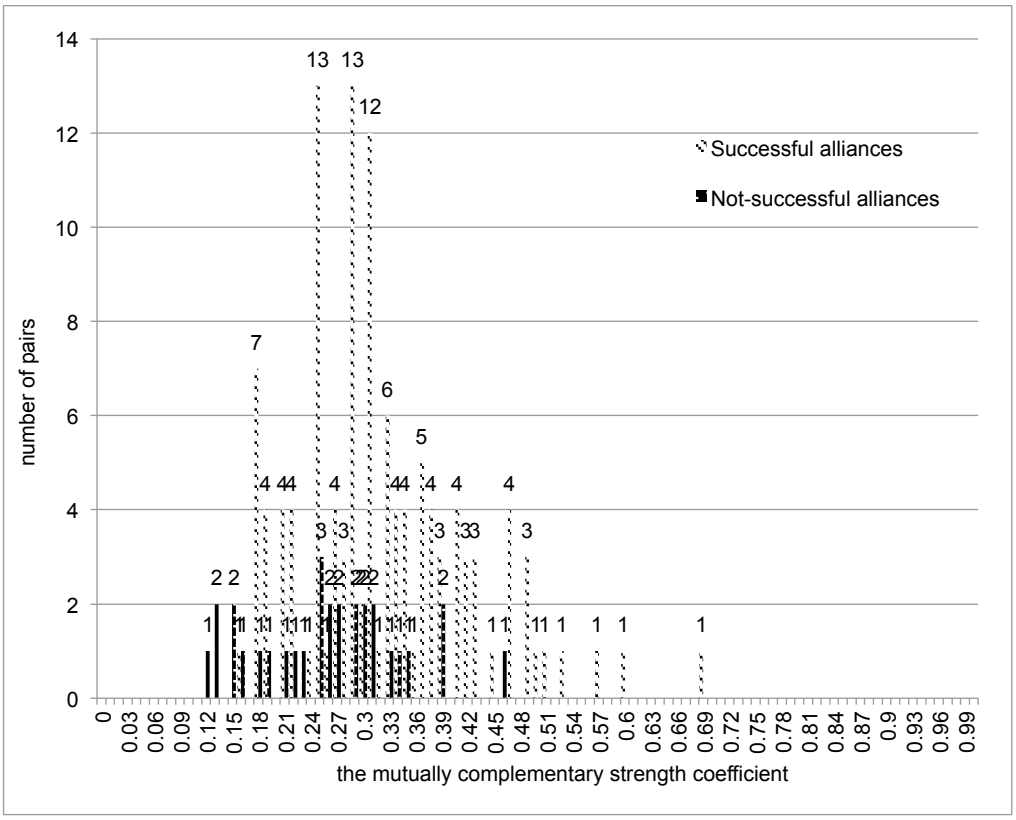
Programmatically Verifying the Results

As a result of calculating the mutually complementary strength coefficient programmatically, for 121 pairs of successfully allied companies, the average coefficient was 0.318, whereas for 30 company pairs for which the corporate alliance was not successful, the average coefficient was 0.238. This indicates that the complimentary strength coefficient is higher for two companies in a corporate alliance.

In regards to why the coefficient value does not differ much for companies in a corporate alliance versus those not in one, we begin by stating that we think there is a mutual complement between two companies, which is why they are drawn together.

It should be noted that the average coefficient overall for the 152 company alliances was 0.299. Figure 2 shows the result of tallying the coefficients for all 152 company alliances.
Hence, this mathematical model of the bipolar mutual complement constructed from the actual company data confirms the function as valid.

Figure 2: The normalized mutually complementary strength coefficients for successful corporate alliances and not-successful corporate alliances



This Figure shows the distribution of the mutually complementary strength coefficients for 121 pairs of successful corporate alliances and 30 pairs of not-successful corporate alliances.

COMPUTATIONAL MODEL FOR RELATIONSHIPS BETWEEN MORE THAN TWO COMPANIES

Using the mutually complementary model, we can determine which pairs of companies will best form a corporate alliance based on which pair has a stronger mutually complementary relationship when there are multiple possible combinations of companies for a corporate alliance.

By calculating the mutually complementary strengths and related coefficients for all pairs, it becomes possible to select and appropriate corporate alliance.

For example, take the example of the following three companies, (A, B, C) for which they are attributed values from 1 to 5 for each of their 8 attributes as represented in the following one-dimensional matrices.

a = (1, 3, 4, 2, 5, 1, 3, 1)
b = (4, 1, 1, 3, 1, 5, 3, 1)
c = (3, 5, 2, 4, 2, 3, 5, 4)

From these three companies, by calculating (subtracting) the one-dimensional matrices associated with each possible pair of companies, we can determine the mutually complementary relationship between companies A and B, A and C, and B and C. This is represented here with the following equations.

d=a-b
e=a-c
f=b-c

Based on the results from our Python program (Refer to Appendix A), the results of the mutually complementary strength and the related coefficient for d, e, and f are given below:

Strength of d (=a-b) =11.99
Strength Coefficient of d (=a-b) =0.530

Strength of e (=a-c) =11.22
Strength Coefficient of e (=a-c) =0.496

Strength of f (=b-c) =9.025
Strength Coefficient of f (=b-c) =0.398

Based on these results, we can see that for Company A, if choosing between a corporate alliance with Companies B or C, the resulting value for the calculation of "d" is larger than that of "e", so Company B becomes the more desirable alliance partner.

Conversely, for Company B, we can see that the calculated mutually complementary strength for "d" is greater than "f", so Company A becomes the more desirable alliance partner.

Furthermore, for Company C, when choosing between companies A and B, the calculations above reveal that "e" has a higher value than "f", so therefore Company A becomes the more desirable alliance partner.

Thus, by calculating the mutually complementary strengths and their related coefficients for multiple possible alliance pairings, we can determine the best alliance partners in the event of multiple possible alliances.

Furthermore, in the example of Companies A, B and C above, we can confirm that Company A and Company B are each other's best possible alliance partner, so we can use this method to determine when a corporate alliance is the most mutually beneficial to both companies.

From a number "m" of companies, we can apply this method for "n" alliance case possibilities, which is to say a total of $\binom{m}{n}$ possible alliance combinations.

CONCLUSION

In this paper, we have shown a mathematical model representing the mechanism behind the mutual complement between two companies in a corporate alliance, and have constructed and derived a one-dimensional matrix, bipolar vector, and the distance from the maximum mutually complementary point. Thus, it has been made possible to mathematically capture and express the mutually complementary relationship between two companies, and is possible to determine the complementary strength coefficient.

This mathematical model was confirmed to function based on the actual empirical data from 152 companies. (Eight characteristics each)

Additionally, when there are two possible selection candidates, when we look at them from the view of their mutual complement, we can calculate the mutually complementary strength coefficient using the mathematical model proposed in this paper. From the comparison of these values, we can determine which companies are best suited to form a corporate alliance.

Furthermore, among three corporate candidates, we can use this mathematical model to calculate the mutually complementary strength coefficient to determine if a corporate alliance between two companies is best mutually for both companies when there are alternative alliance options.

From this, we can select the best candidate for a company among m possible candidates by calculating the mutually complementary strength values for n possible corporate alliances.

Our research deals with the problems behind inter-corporate alliances, but this is also applicable to HR matters concerning new business teams, which is to say the alliances of people directly. Additionally, we can even expand this definition to incorporate alliances between countries. We can scientifically verify whether past alliances were appropriate based on this same model, and apply it to potential future alliances between countries.

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ACKNOWLEDGEMENT

We would like to express our sincerest gratitude to Mr. Hiroshi Yamamoto of Graduate School of Media and Governance at Keio University for his cooperation in creating a programmatic solution in Python, as well as Mr. Aaron Tokunaga for his cooperation in the composition of this paper in English.

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