

Proposing the Improvement of the Landscape Theory of Group Formation: New Replacement Factors

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Abstract—Last decades are characterized by the use of complexity approach in analyzing social group formation mechanism. Some of the approaches is landscape theory which assumes that parties movement to lower area reflects the increase of fitness between partners in a group. This approach allows the analysis of several heterogeneous and decentralized actors that take decision independently in establishing stable group. The existing models of landscape approach, indeed, have been evidenced in explaining phenomenon under scrutiny. Nevertheless, the factors in the original landscape do not fit some cases. It seems that there is opportunity to improve these models by introducing new factors to replace the existing. This paper provides rough evidences, in which, the new factors are able to explain the phenomenon similar to that have been explained by the original (existing) factors. Moreover, the new factors are also able to model the phenomenon that cannot be explained by the original factors. These evidence show that introducing the new factors and replacing the existing expand the coverage of landscape model.

Keywords: *Landscape Theory, Group Formation, New Replacement Factors*

I. INTRODUCTION

Group formation is always interesting to investigate for decades. There are many reasons for studying group since human are naturally social creatures. Such characteristic is embedded to human study since there are many things that cannot be achieved by individually. In business case, Chesbrough (2006) found that firms in high-tech industries tend to ally with other firms and sometimes even allying with their competitors because knowledge is distributed across firms. No firm has superior knowledge over the other firms. Thus, to survive in such the industry that is characterized by high uncertainty and high fluctuation, firms should ally for their survival in the business. In many cases, survival is the reason for establishing group, not only in the case of business, but also in the others cases such as political or military. This paper shows that survival can be achieved by allying with partner with complementary and less threatening characteristics.

Earlier studies have investigated various mechanisms of group formation. They investigates the factors that attract some people to establish group exclusively with some other groups of people. Some studies found that people tend to establish group with those with similar of identity, e.g. same race, similar culture, same religion (Schelling, 1969; Axelrod, 1997; Mark, 1998), same region, similar experience, same

social level, or similar task (Latane, 1996; Flache & Hegselmann, 1999).

Some other studies focus on group formation in a social network. Some of these studies found that people tend to establish network with some others due to their extreme differences to common people (Dittrich, Liljeros, Soulier, & Banzhaf, 2000; Grönlund & Holme, 2004). Palla, Derényi, Farkas, and Vicsek (2005) categorize people in social networks based on the clique (similarity of partners) between them. The other investigations of this network study utilize the minimization of math equation as a proxy of the inverse of fitness between partners (Girvan & Newman, 2004; Reichardt & Bornholdt, 2004; Girvan & Newman, 2006; Reichardt & Bornholdt, 2006). This equation is aimed to include those that have network connection with each other as much as possible and exclude those without connection.

The rest of the studies show much more diverse factors behind group formation. Some of these studies found that people tend to join a group if there are a number people, that acts as threshold level, who also join the group (Granovetter, 1978; Chwe, 1999; Miller & Page, 2004). Another study, Riker (1962), found that a political party tend to establish coalition with another party simply to achieve a minimum number to become majority in parliament, hence, sometimes a large partner is unexpected since a coalition still has to further share the spoiler between the winning parties that form the coalition. Gale and Shapley (1962) propose a model of stable marriage, in which can be achieved after there is no more preferred and available others beside the current spouse. Axtell (1999) proposes a concept in which people tend to maximize their own utility.

Most of the studies mentioned above utilize conventional sociological concept and research observation (cross-sectional and longitudinal) to explain the factors behind group formation. Unfortunately, there are many things that cannot be explained using such methods due to complexity of relationship between people. Such complexity makes the people, who are unlikely to collaborate, establish alliance. On the other hand, those, who should collaborate, join opposing groups. To deal with such complexity, we should utilize complexity method, such as landscape theory.

Landscape theory is a model of energy minimization. This approach originally comes from physic rather than sociology, i.e. thermodynamics, Ising Hamiltonian model. This approach

is used to model the way atoms behave during material condensation period. In this period, initially, in the fluid phase, atoms ally with any others randomly. Afterward, atoms tend to ally with those of similar electron spin. Once, they found and couple with those with similar spin their energy reduces and their phase becomes solid.

This landscape approach is brought to the study of social science by Axelrod, Mitchell, Thomas, Bennett, and Bruderer (1991), Axelrod and Bennett (1993), Levinthal (1997), and Van de Ven, Polley, Garud, and Venkataraman (1999). The first two studies investigate group formation using landscape theory. Levinthal (1997) utilizes landscape approach to identify chaotic characteristic of outcome when firms shift their policy. Van de Ven et al. (1999) model chaotic innovation development with landscape approach. The landscape approach allows these researchers to explain chaotic and non-linear behavior that seems behave randomly without pattern.

II. LANDSCAPE APPROACH IN GROUP FORMATION

There are some studies that utilize landscape approach in modeling group formation. In earlier section, I have mentioned Axelrod et al. (1991) and Axelrod and Bennett (1993), who utilize landscape approach for group formation. Beside these studies, some others have been mentioned also in the previous section, i.e. Girvan and Newman (2004), Reichardt and Bornholdt (2004), Girvan and Newman (2006), and Reichardt & Bornholdt (2006). These later studies are limited to group formation in social network. The grouping emphasize on the maximization of the number of agents, that are connected with each other, and the minimization of those, that are not connected, within a group. The mechanism of this group formation is in line with that in landscape approach. Beside these mentioned studies, some others (Kijima, 2001; Murata & Kijima, 2005; Kimura & Nishizawa, 2010; Sukanuma, Huynh, Nakamori, Wang, & Lai, 2003) have also contributed further in the development of landscape approach in group formation.

These studies of landscape approach in group formation can be categorized into human approach and non-human approach mechanism. Those that investigate human group formation and also treat human as human are Axelrod et al. (1991) and Axelrod and Bennett (1993), Kijima (2001), Murata and Kijima (2005), and Sukanuma et al. (2003). They model a bottom up process, how people with their unique characteristics arranging themselves, selecting, and leaving partner, as a consequence of the interaction between them. On the contrary, Girvan and Newman (2004), Reichardt and Bornholdt (2004), Girvan and Newman (2006), and Reichardt & Bornholdt (2006), and Kimura and Nishizawa (2010), assign human to group of humans based on the existence of link of relationship, which is a more top down approach. Moreover, Reichardt and Bornholdt (2004), Reichardt and Bornholdt (2006), and Kimura and Nishizawa (2010) implements their research on a group of physics entity, e.g. computers, machines, rather than to human.

In this study, I will focus on landscape approach to group of people. Among these studies, Axelrod et al. (1991) and Axelrod and Bennett (1993) are the base of the other landscape approaches. In their investigation, Kijima (2001), Murata and Kijima (2005), and Sukanuma et al. (2003) expand the earlier work of landscape approach of group

formation (Axelrod et al., 199; Axelrod & Bennett, 1993). The mechanism that lies behind these models will be explained in the following section.

III. MECHANISM OF LANDSCAPE APPROACH

Landscape approach assumes that there is an imaginary frustration landscape. This landscape consists of numbers of abyss and hills. The landscape pattern is constructed by the combination of different factors. The change of the combination is reflected by the shifting from one partner to another partner. Within the landscape, firms interact with each other to identify partners that can reduce their frustration. Once they found such partner, they establish an alliance. This alliance is stable as long the firms do not find alternative partners that are fitter than their current partners.

Axelrod et al. (1991) and Axelrod and Bennett (1993) suggest landscape objective function as follow:

$$\min \sum_i^n (size_i) \left[\sum_j^{n-1} (size_j)(propensity_{ij})(distance_{ij}) \right]$$

n: number of agents j ≠ i

This objective function represents frustration function. Size represents the level of importance or the strength of an agent, i (for the focal agent), and j (for its partner). Propensity, the tendency the partners (i and j) working well together, indicates similarity, suitability, and interest between them. Distance reflects the location of the two agents (i and j), whether are located in the same alliance or not.

The model suggested by Axelrod et al. (1991) and Axelrod and Bennett (1993) has some assumption. The first assumption takes place in the propensity factor. It is assumed that the propensity information is pairwise, between agent i and j. It is also assumed that agent i knows its propensity toward all other agents and this information is given from the beginning. This information is fixed, it does not change over time. Another assumption is that this propensity information is symmetrical. A small, weak, and unimportant agent has tendency to like a larger, stronger, and important partner, but not vice versa.

They also assume that size is fixed and known from the beginning. Another assumption is that the decision of an agent decision is independent to its other decisions. There is no interaction between the previous and the current decision. The next assumption is that only an agent moves at a time. It is also assumed that the number of groups has been decided by researchers from the beginning. The last assumption, initially, agents choose their group randomly.

IV. THE DIFFERENCE AND SIMILARITY OF THE EARLIER LANDSCAPE STUDIES

As explained earlier, Axelrod et al. (1991) and Axelrod and Bennett (1993) are the base of the study of the landscape approach of human group formation. Both Axelrod et al. (1991) and Axelrod and Bennett (1993) utilize the same objective function. Their difference takes place in the application of landscape approach. Axelrod et al. (1991) concern on the group formation in the competition of standard setting for Unix operating system. In this model, size is measured by a company's share in workstation market. Firms propensity is determined by their involvement in the given

market segments, whether as generalists or specialists. A generalist tends to ally with a specialist, and vice versa. On the contrary, a generalist considers the other generalists as competitors. In similar way, a specialist also views the other specialists as threats.

Axelrod and Bennett (1993) study alliance formation in the case of World War 2nd and Cold War. They assess size with Composite Index of National Capability that reflects both military and industrial capability. Propensity between these countries is measured by the information as follow: the presence of ethnic conflict, the existence of border dispute, the similarity of the type of governments, the similarity of religions, and the recent history of wars.

The other landscape models (Kijima, 2001; Suganuma et al., 2003; Murata & Kijima, 2005) are the derivative of the earlier two models. There are some similarity and differences between these models in term of: the objective function, the object of frustration function, the type of searching algorithm, the configuration of propensity, the coverage of agents movement, and the propensity symmetry. Kijima (2001), Suganuma et al. (2003), and Murata and Kijima (2005) utilize the same objective function concept (as the two earlier studies), which consists of size, propensity, and distance variable. In term the object of frustration function, Suganuma et al. (2003) is in line to both Axelrod et al. (1991) and Axelrod and Bennett (1993) which minimize the system frustration. On the contrary, Kijima (2001) and Murata and Kijima (2005) utilize the minimization of individual frustration. They argue that firms tend to minimize their-own frustration rather than considering the others frustration. Hence, firms can bring the system energy (frustration) higher to satisfy their own frustration level.

Similar to both Axelrod et al. (1991) and Axelrod and Bennett (1993), Kijima (2001) and Murata and Kijima (2005) utilize down-hill method in as the searching algorithm in the minimization of objective function. On the other hand, Suganuma et al. (2003) adopt genetic algorithm in the minimization of the function. In term the propensity configuration, Kijima (2001) and Suganuma et al. (2003) assume that there is pairwise (dyadic) comparison between partners following both Axelrod et al. (1991) and Axelrod and Bennett (1993). On the other hand, Murata and Kijima (2005) expand the configuration to various size (rather than limited only to pairwise). Kijima (2001) and Murata and Kijima (2005) also adopt Axelrod et al. (1991) and Axelrod and Bennett (1993) mechanism of agents movement, in which there is only an agent moves at a time. On the contrary, Suganuma et al. (2003) permits various numbers of agents to move at a time. In term of the propensity symmetry, Suganuma et al. (2003) adopt Axelrod et al. (1991) and Axelrod and Bennett (1993)'s approach in which there is symmetrical propensity between partners. On the contrary, Kijima (2001) and Murata and Kijima (2005) consider the propensity between agents is not symmetrical. They argue that small, weak, and unimportant firms prefer to ally with big, strong, and important firms, but not vice versa.

V. THE DIRECTION OF LANDSCAPE APPROACH IMPROVEMENT

In this paper, I emphasize the improvement of the objective function of the landscape approach. Nevertheless, I will also discuss slightly some possible improvement in the other terms.

I suggest the modification of the original objective function of landscape theory since there are some cases that do not fit the model. As explained in the earlier, the original objective function of landscape theory is adopted by Axelrod et al. (1991), Axelrod and Bennett (1993), Kijima (2001), Suganuma et al. (2003), and Murata and Kijima (2005). This function combines size, propensity, and distance variable. According to this function, parties tend to establish alliance with the other important (strong) parties that have tendency to work well together. This tendency is reflected by similarity between them.

However, there are some cases where some parties, that have potential to work well together, become hostile to each other. On the contrary, different parties without tendency to work well together indeed establish alliances. In the case of world war 2nd, ally composed of the Western and the Eastern (Soviet Union). Despite their differences, in term of ideology and system, i.e. democratic, liberal, and capitalism on the side of Western countries, and , on the other hand, communism with marxism and proletariat, these countries indeed worked well together until the end of the war. Similar situation takes place in the Axis block, in which Nazi German allied with the Imperial of Japan. Another example takes place in the case of 30 Years War, where Catholic France allied with the Protestants (including Anglican England) rather than with two giant Catholic countries, Spain and Holy Roman Empire (Austria). Both Spain and Austria are not only have similarity in term of religion with France, but they were also very important countries. At that time, both Spain and Austria were two strongest continental nations in Europe and were considered as superpowers before the war time. The last example is China's relation with both United States (pingpong diplomacy) and Soviet Union in 1970's. China made a warmer relation with United States, on contrary, she strained her relation with Soviet Union despite their similarity in ideology. Therefore, I think the modification of objective function is required.

Responding to this phenomenon, I suggest to incorporate new variables, i.e., the first is need which is reflected by complementarity of characteristics between parties, and another variable is the potential threat of the other parties, as replacements for size and propensity. The complementarity and threat between parties are the reason of collaboration between partners in the case of co-opetition (Brandenburger & Nalebuff, 1997). Competitors are eager to collaborate to survive from the stronger external threat that may throw them out of business. The firms also tend to ally with the others to fill their shortcoming. Koffka (1968) addresses that, in social psychology, need is derived from interdependency between parties, which represents complementarity. Similar concept is also given by Sheth and Parvatiyar (1992) and Kaynak and Culpan (1993). Moreover, international relation theory mentions the balance of threat, in which a state tends to ally with a distance strong nation to balance regional threat. This idea fits to both the case of business and military as given below.

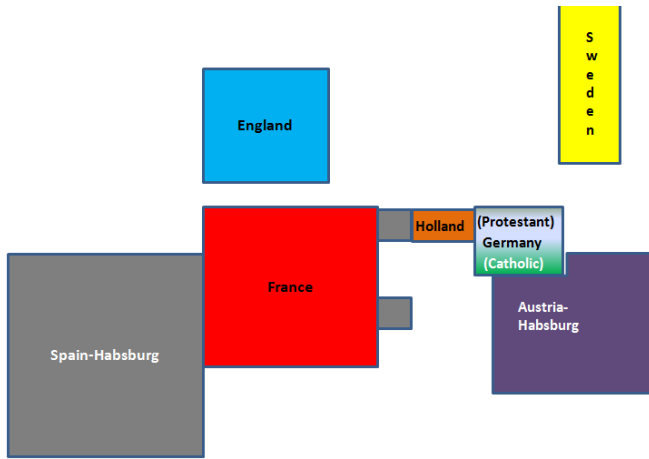


Figure 1. A rough geographic position of main countries in the 30 Years War

30 Years War. The original objective function suggests that Spain and Austria-Habsburg are favored by France due to their size and strength. Moreover, these countries have similarity to France in term of religion. Nevertheless, in the reality, France allied with the Protestant countries, including with United Kingdom (England). In this case, France saw the two Catholic countries as threats because of their size (strength) and their location that were closed. On the contrary, the non-Catholic countries (other than England) were relatively small and located in a distance, hence they were considered as allies to balance the threat. In this case, the Catholic France saw the two siblings Catholic superpowers, Spain and Austria, as threats. Therefore, she allied with the Protestants (Sweden, Holland, and England).

The alliances can also be explained by the term of complementarity. France and England had different characteristics. As a continental country, France emphasized the development of continental army. On the other hand, England is a country of islands. Their focus in on the development of strong navy and merchant fleets. In this case, France complements England in term of continental power, on the other hand, England complements France in term of naval power. In the opposing side, Spain possessed strong naval fleet which was complemented by the continental strong Austria.



Figure 2. A rough geographic position of main countries in the World War 2nd (after invasion of Poland)

World War 2nd. In the case of World War 2nd, the rough map in Figure 2 may explain the formation of unlikely alliance during the period. As mentioned earlier, democratic and liberal countries (the Western) could ally side by side with communist (Soviet Union) when facing Nazi German. On the other hand, Nazi German that was very different in term of characteristics with the Imperial of Japan allied with each other. This can be explained with the balance of threat theory.

According to the balance of threat theory, closer strong countries are considered as threats. On the other hand, distance

countries can be considered as ally. This map shows that Germany is flanked by France and Soviet Union. Hence, Germany allied with the distanced Japan. Moreover, allying with Japan could distract both Soviet Union and United States attention toward Germany. In a similar way, Soviet Union was threatened by two giant neighbors, Germany and Japan, in such circumstance the Soviet allied with the United States and France that flanked Japan and Germany (together with Soviet Union). The concept can also be applied to France that was threatened by Germany and Italy, which further forced her to ally with unlikely to be allied, Soviet Union and her arch enemy England. To sum up, a strong neighboring state is considered as a threat. On the contrary, a strong state that threatened that threatening state would be considered as potential ally. Figure 2 displays a chain of states (the Ally and the Axis) as follow: Italy – France – Germany – Soviet Union – Japan – United States.

The alliance can also explained with complementarity idea. Soviet Union possessed abundant number of armies. The Soviet was also able to sacrifice their troops. All of these characteristics were not possessed by the democratic Western countries. On the other, the Western countries were advantageous in term of technology and espionage. Thus, during the war, the Soviet was supplied with valuable information by the British intelligence as evidenced in the battle of Kursk. Moreover, the Soviet was also supplied numbers of tanks and supporting vehicles by the United States. In the case of the Axis, Japanese had strong supercarrier navy fleets that were not possessed by the German.

There are some alliance agreements that support this idea:

- Franco-Soviet Treaty of Mutual Assistance (1935), to deter Nazi Germany's aggression.
- Anglo-German Naval Agreement (1935), to balance France and Soviet Union cooperation.
- Anti-Comintern Pact (1936) between Nazi Germany and Japan to intercept Soviet Union influence (Soviet Union was located between Germany and Japan)

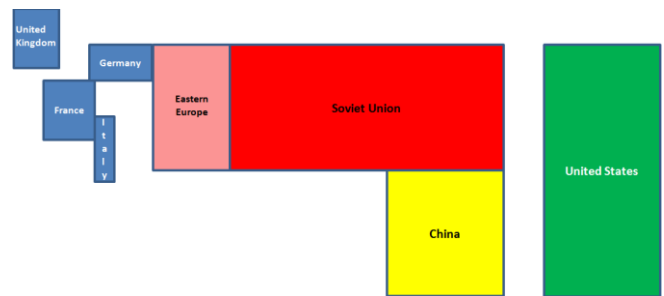


Figure 3. A rough geographic position of main countries in the Cold War

Cold War. The balance of threat factors can be seen as a dominant factor in the case of cold war. Soviet Union was seen as a terrifying giant by her Western European neighbors. On the other hand, Soviet Union and the United States saw each other as archenemy due to each both extra size and long boundary. This may be the answer of why the Western European allied with the United States. China, on the other side, considered both United States and Soviet Union as threatening neighbors. Therefore, at the outset of Cold War,

China allied intimately with Soviet Union, nonetheless, afterward she established a warmer relationship with United States after the Soviet-Sino border conflict.

In the post-world war period, Western European countries were financially depleted. Thus, they saw the United States can complement their lack of financial power to rebuild their devastated countries. On the other hand, United States also saw this as an opportunity to put their influence on the Western European countries and to inhibit the spread of communism to the West.

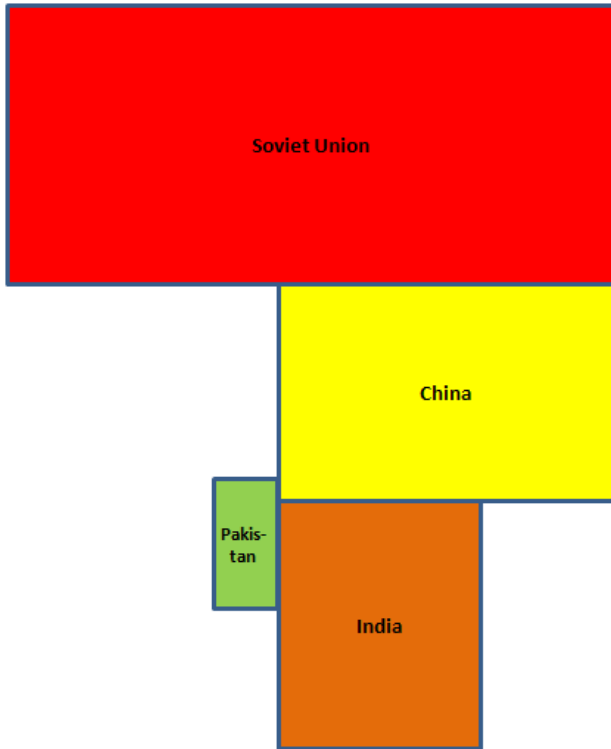


Figure 4. A rough geographic position of Soviet Union, China, India, and Pakistan

Soviet Union-China-India-Pakistan Relationship. The balance of threat factors can be seen as a dominant factor in the relationship between these countries. Pakistan is located adjacent to giant neighbors, China and India. Hence, both can be seen as threats. Nevertheless, Pakistan has longer border with India rather than China. Hence, this situation may explain why India and Pakistan are known well as archenemies. This may also explain why China has a good relation with Pakistan.

On the other hand, China had inharmonious relationship with India, as well with Soviet Union. This is evidenced by the fact that Soviet Union supplied military equipment for India. The other facts are that there were Soviet-Sino skirmish as well as Sino-India skirmish in the border. One of possible reasons is that China has long border with both Soviet Union and India. Moreover, Soviet and India can be seen as giant neighbors that are able to threat China.

In addition to this case, the balance of power theory may explain the war between China and Vietnam in the end of 70s. Vietnam can be seen as an emerging force in the Southern border by the Chinese. In this case, Vietnam could be seen as a new threat by the Chinese. To balance Chinese threat, Vietnam allied with Soviet Union, which later on responded

by the Chinese by establishing warmer relationship with United States.

The alliance in this cases can also be explained by complementarity between countries. In the case of the war between China and Vietnam, the Vietnamese was supported by the Soviet. The Soviet complements the Vietnamese in term of technology, on the other hand, the Vietnamese mastered the guerilla war that enable them to face giant countries indirectly. In the case of the war between India and China, the Indian saw the Chinese were advantageous in term of military technology, therefore, the Indian allied with Soviet Union to complement their lack of military technology. At that time, the Soviet also needed new ally, especially in the Southern region, to replace the rebelling China in Asia.

Table 1. Market share of some computer companies in 1986 and 1987 (source: [35])

No.	Workstation (1986)	Microcomputer (1986)	Midrange(1987)
1	<i>Apollo (26.0)</i>	<i>IBM (28.0)</i>	<i>IBM (27.6)</i>
2	<i>Sun (23.0)</i>	<i>Apple (9.0)</i>	<i>Digital Equipment (21.6)</i>
3	<i>Hewlett-Packard (17.0)</i>	<i>Tandy (6.0)</i>	<i>Unisys (8.4)</i>
4	<i>Digital Equipment (10.0)</i>	<i>Hewlett-Packard (4.0)</i>	<i>Hewlett-Packard (6.5)</i>
5	<i>IBM (5.0)</i>	<i>Epson (3.0)</i>	
6	<i>Silicon Graphics (4.0)</i>		

Table 2. Actual alliance configuration in 1988 (source: [1])

No.	Alliance 1	Alliance 2
1	<i>Sun</i>	<i>Digital Equipment</i>
2	<i>IBM</i>	<i>Hewlett-Packard</i>
3		<i>Apollo</i>
4		<i>Silicon Graphics</i>

The concept of balance of threat can also take place to the business case. In the alliance for standard setting for UNIX operating system, there were two competing groups of firms. In the first alliance there were Sun and IBM. On the opposing side, there were Apollo, Hewlett-Packard, Digital Equipment, and Silicon Graphics (Table 2). In line with the balance of threat concept, Apollo and Sun, the two giants of workstation did not join the same alliance. One of the possibility is that they saw each other as threat. The rests were relatively smaller firms in the workstation segment. These smaller firms were distributed between the two alliances. In the microcomputer and midrange segment, Hewlett-Packard saw IBM as prominent and terrifying giant, hence, this can also be the reason that they did not join the same alliance.

The table also shows a pattern, in which, those with almost similar market share in the same segment tend to join different alliances. This pattern supports the balance of threat concept. The first evidence has been given, in which Apollo and Sun joined different alliances. Another evidence is that Sun joined different alliance to Hewlett-Packard. Similar evidence takes place in the case of IBM and Silicon Graphics. All of these evidence based on the share in workstation segment. In the midrange segment, IBM had close share to Digital Equipment.

This may explain why did IBM join different alliance to Digital Equipment.

Complementary concept may also explain the alliance configuration. The first alliance, that comprises of Sun and IBM, shows complementarity between the members. Sun was highly capability in workstation segment, which is reflected by its market share. Nevertheless, Sun was less capable in term of microcomputer and midrange segment. This lack of competence was filled by IBM that controlled both segments (Table 2). With similar mechanism, despite taking the lead in workstation segment, Apollo was lack of competence in the microcomputer and midrange segment. This shortcoming was filled by Digital Equipment that was a strong IBM competitor in midrange segment. Hewlett-Packard also complemented the other firms in the second alliance (Apollo, Digital Equipment, and Silicon Graphics) since it was the only firms that have knowledge in microcomputer segment, in spite of the small portion of market share.

VI. CONCLUSIONS

The five illustrations, i.e. 30 years, world war 2nd, cold war, the relationship between Soviet Union, China, India, Pakistan, and the standard setting war, provide insight about the role of complementarity and threat in group formations. These two factors can explain the alliance formation in the standard setting and in the world war 2nd and in different ways to Axelrod et al. (1991) and Axelrod and Bennett (1993). Moreover, the two factors can explain the phenomenon that cannot be explained with the original landscape model. As an example is the alliance in the 30 year war, in which Catholic France did not ally with two strong Catholic countries, Spain and Austria. Another example is given by the case of cold war, in which communist China made a warmer relationship with democratic United States rather than with the communist giant, Soviet Union. In the business case, this may explain why did the two giants in workstation segment, Apollo and Sun, join different alliances.

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