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How Strategic Networking Impacts the Networking Outcome: A Complex Adaptive System Approach

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Abstract: In this study, we provide an interaction model based on complex adaptive system theory, to explain how different methods of network growth and strategic responses of existing network members towards them impact the outcome of networked individuals (i.e., utility gain at the individual level or a society's collective utility known as social welfare). The proposed interaction model allows us to perform our experiments with dynamic utility computation, while individuals act strategically in response to what other individuals do in the network. We utilized the formulation of the co-author model, as it augments the concept of network structure for modeling individuals' utilities. The experimental results show that different methods of a network growth lead to different networking outcome for its members. We observed that total networking outcome is the highest (with respect to the co-author model), if newly entered individuals establish their links strategically to other existing members in a way to maximize their own payoffs. We believe that reduction in the total utility due to strategic responses within the network is acceptable in exchange of having a homogenous utility distribution within the population. Our observations give us the idea that, with the help of strategic responses, central network members can be prevented from gaining very high utilities compared to others. Furthermore, network structures can be prevented, in which the utilities of network members are widely dispersed. In such a setting, individuals experience no discrimination in utility gain against other people in their community.

Keywords: Co-Author Model; Social Welfare; Strategic Behavior; Utility Maximization; Network Growth Models; Complex Adaptive System Approach; Agent-based Modeling and Simulation.

JEL Classification Numbers: A13, C02, C15, C63, C73, D85.

1. Introduction

The process of network growth among people within an organization or a society is inevitable. That is because people agree to communicate with others and establish links among themselves, feeling that the link establishments are beneficial for them. However, the process of network growth is not random. In the world of networked individuals, each individual tries to reach an efficient outcome out of the alternative options that exist.

A large body of literature has focused on developing mechanisms to produce the interesting features of real world networks. Examples include: random network formation models for networks with a short average shortest path length but low clustering coefficient; small-world network formation models for networks with a short average shortest path length but high clustering coefficient; and scale-free network formation models for networks with hubs and a power-law degree distribution [2, 5, 12]. However, each of those stochastic network formation models with their own particular formation mechanisms has been proposed to produce a desired network structure independent of the causes of observing such network characteristics [21]. Till now, current literature lacks well-designed studies to relate the emerging network characteristics with their causes.

In this paper, we argue that by looking further and deeper into changes in the structural properties of a network, we can also relate them to the strategic interactions of individuals that are located in the network. The individuals act strategically, in order to maximize their utilities obtained from their connectivity patterns in the network [8]. As the result, the underlying network structure is constantly changing.

From our view point, strategic interactions can happen at two intervals, during the process of network growth and during link establishment among the existing members. In this study, we argue that the process of network growth has the potential to trigger strategic responses among existing network members.

We envision a scenario, in which the process of establishment of potential links among existing individuals is not based on a simple random selection of partners or the well-known method of FOAF (Friend of a friend link formation) [33]. The interruption in the underlying topology of the network as a response to the method of network growth by its members may have many reasons and interpretations. We believe that management of time and resources of this type is the trigger for many people. In response to what others are doing in the network, they can perform their best strategic responses, which can sometimes be seen as a utility maximization process. In this regard and in order to fill the existing gap in the previous studies, we provide an interaction model to show that the changes of the structural properties of networks and networking outcome are caused through a variety of dynamic processes such as methods of network growth and strategic responses of existing individuals who undergo competition to maximize their own payoffs.

Contrary to strategic network growth models that demonstrate how simple payoff functions produce different network structures from scratch (e.g., from isolated nodes to dyads and stars) [7, 8], or stochastic network growth models that explain specific characteristics of networks with their generative mechanism [1, 4, 16, 17, 18, 27], we apply a complex adaptive system approach to formulate the process of network

formation. We focus on human-to-human communication in environments, where the process of network growth follows different patterns and triggers strategic responses among the existing network members. Its consequences are reflected in both the network structure and the outcome of the whole population. Therefore, we can state that there is a feedback loop between individual actions and the network structure.

We formulate the following research question based on our above mentioned arguments: How strategic networking among individuals impacts the networking outcome? Since strategic networking can be seen as utility maximization process by network members, this research question can be rewritten as: How utility maximization behaviors of individuals within a network impact a society's collective utility (i.e., social welfare)?

In order to answer our research question, we need a utility function for individuals that depends on connectivity patterns of individuals and their contacts. We utilized the formulation of the co-author model [7, 8], as it augments the concept of network structure for modeling individuals' utilities. To quantify the effect, we use an agent-based modeling approach. With the help of agent-based modeling, we can test our interaction model and capture the dynamics among the individuals within a network.

The experimental results show that different methods of network growth lead to different networking outcome for its members. Total networking outcome is the highest (with respect to the co-author model), if newly entered individuals establish their links strategically to other existing members in a way to maximize their own payoffs. The second and third rank goes to random strategy and preferential node attachment strategy, respectively. Our results also show that utility maximization behaviors of existing individuals in the networks, which have been generated in response to different growth models, reduce the social welfare of the whole society. We believe that reduction in the total utility is acceptable in exchange of having a homogenous utility distribution within the population.

The remainder of this paper is organized as follows. The principles and theoretical background on the topic are discussed in section 2 in detail. In section 3, we introduce our model. The experimental results and discussion are presented in section 4. Finally we present our conclusion in section 5.

2. Theoretical Background

Networks of opportunity seeking individuals are more than a simple collection of nodes and links. Each individual's behavior and the group dynamics among the population make the network setting more dynamic and complicated. Actors of the network apply various strategic processes to achieve their goals. Therefore, there is a need to study such complex networks systematically with respect to its actors and their strategic interactions as it evolves over time. The terms 'actors' and 'nodes' are used interchangeably throughout this paper. There are two branches of literature that are related to this topic: stochastic network growth models and strategic network growth models.

2.1 Stochastic Network Growth Models

In the first category of literature, we can find mainly different network topologies with their own specific degree distribution patterns like random networks, regular networks, scale-free networks, and small-world networks. Models for generating these networks mainly fall into two categories: random growth and preferential attachment growth. Random growth models have widely been studied in the literature and existing nodes have a uniform probability of link establishment with a newly entered node during the process of the network growth [1, 2, 3]. Preferential attachment growth models have applications in many areas of science and engineering [4, 5, 6]. In fact, it creates networks with non-trivial topological features, which do not exist in other simple networks (e.g., lattice networks). The majority of nodes in scale-free networks have a low number of connections while few of them have a huge number of connections to others. Stochastic style of link establishment is considered to be the structuralism approach, as it focuses on a generalized way how individuals are interconnected in a network. Although the structuralism approach has the potential to tell us what the interesting features of networks are, the extent, to which such varieties of structural properties affect the outcome of individuals, has received little attention.

2.2 Strategic Network Growth Models

In the second category of literature, frameworks are proposed to analyze the strategic interactions of individuals in a network. From this point of view, each individual in a system obtains a utility due to its interaction with others in the network. Utility describes the level of an individual's performance from interaction with others. The utility is defined through a payoff function. For example, the payoff function might consider the number of connections or the distance between the source and the destination. The utility can also be used to measure the social welfare (i.e., a society's collective utility). We can look at the social welfare as a level of well-being of the entire society.

Jackson presented different strategic network formation models (e.g., co-author model), in which choices of individuals have certain impact on the topological features of the network [7, 8]. Among the vast majority of literature that tries to identify the effects of individuals' interaction in a network, we can distinguish a few topics: network games [9, 11], public good provision [10], and bargaining and power in networks [7]. Each of the topics can be represented with different theoretical models. Konig et al. [22] presented a network formation model where links are formed on the basis of agents' centrality [28, 29, 30, 31, 32], while the network is exposed to a volatile environment, in which connections between agents can be interrupted. Addressing how to formally model situations, in which individuals purposefully alter the network structure, can also be seen in the work of Buechel [23]. Buechel used closeness centrality as the strength of an agent's position in a network of relationships [25]. Betweennes centrality also was used in some other studies [26, 27]. Furthermore, Konig [24] delivered a comprehensive tutorial that introduces the reader to some basic concepts used in a wide range of models of economic networks.

In the co-author model [8], the utility function is defined in a way to encourage the cooperation between two individuals. That means, two isolated individuals do not

receive any payoff in case of no cooperation but, as soon as they establish a link with each other, the co-author utility function assigns a positive utility to both parties. If another individual joins the network and establishes a link with any of the existing nodes, the receiver of the link gains a credit, while the other one faces a lower utility due to the negative externality caused by the co-author utility function. If this process continues, we can conclude which kinds of structures are optimal and can produce the highest social welfare.

In this paper, despite the fact that we are using the utility function of the co-author model, we are considering a new scenario, in which individuals are not in competition at the initial stage and have organized themselves in a certain network structure (e.g., scale-free network structure with 10 nodes and 20 links). The competition starts when new members join the network (based on random, preferential and strategic growth models). If an actor perceives a utility decrease due to a new link establishment of their direct neighbors, the actor initiates its own new link establishment to an actor of the network.

3. Interaction Model

3.1 Concept

Within our interaction model, changes in the utility gain of individuals in a network are consequences of two factors impacting interactions: (1) strategy of network growth, which allows new individuals to enter a network; and (2) strategic responses, which occur when neighboring nodes accept new nodes. Key features of our interaction model with respect to the complex adaptive system approach are the heterogeneity of agents, working with adaptation, and feedback loops. This combination of features distinguishes our contribution in this paper with previous works in this area.

To formalize our interaction model, we consider a set of nodes $N = \{1, 2,... 3\}$ and a set of M potential candidates for each node i through whom the utility maximization process is possible. A utility maximization process can be considered as a node's strategic response (i.e., a new link establishment that provides the node the highest utility) to link establishment behavior of other network members. Among those M potential candidates node i prefers the one, which maximize its utility. Each node corresponds to a user, who has the choice in selecting one of the M potential candidates, while observing other's interactions in the network. The pseudo-code of our interaction model and its detail description are given in Algorithm 1.

3.2 Strategic Response of Individuals

For expressing strategic responses, the graph $G = \{N; L; U_i\}$ is considered. It specifies the actor set $N = \{1,... n\}$, a link set L, and a utility function $U_i: G \rightarrow \mathbb{R}$ for each actor $i \in N$.

A strategic response of actor i is defined as the establishment of link iq as the best response to actor j's strategy with two conditions:
- Actor q belongs to the *distance-k ball* of i, denoted by $B^k[i]$, where $q \neq i$ and $iq \notin L_i(G)$

- $U_i (G + iq) > U_i (G)$

Algorithm 1. Pseudo-code of our interaction

If actor *j* decides to establish a link with a new actor and user *i* perceives that it causes a reduction in his utility, he may also try to establish a link with an actor in another part of the network to recover the loss imposed by actor *j*. Based on the utility function of the co-author model, we argue that the creation of a link with an actor at the *distance-k ball* at *i*, which has the lowest number of connections gives the highest utility to actor *i* and can be considered as user *i's* rational behavior to maximize his utility. *Distance-k ball* of node *i* covers all neighboring nodes of *i* at distance *k*. Therefore, node *i* can select any of those possible candidates ($q \in B^k[i]$), with whom its link establishment maximizes its utility. In our experiments, we select the value of $k = d$ (*d* is the diameter of the network and it means access to the entire node set of the network). The creation of such a link leads to a better outcome for actor *i* and, at the same time, can be considered as a penalty for actor *j*'s action.

3.3 Utility Function

The utility function used in our model is the co-author utility function [8] that captures the payoff of individuals in terms of their connectivity patterns with others. We select the co-author utility function, because the utility of each individual in this model is a function of both, its own connectivity degree and its neighbors' connectivity degree.

The co-author utility function allows expressing that each actor tries to increase its utility based on the cognition of the population and the new knowledge obtained through the interaction with others. The original payoff function of the co-author model is presented in Equation 1. Equation 2 shows a different representation of the payoff function, factoring out the common terms.

$$U_i = \sum_{n \in neig(i)} \left(\frac{1}{l_i(G)} + \frac{1}{l_n(G)} + \frac{1}{l_i(G)l_n(G)} \right) \qquad (1)$$

$$U_i = 1 + \left(1 + \frac{1}{l_i(G)}\right) \sum_{n \in neig(i)} \left(\frac{1}{l_n(G)} \right) \qquad (2)$$

The degree of actor i is denoted as $l_i(G)$. The more direct neighbors of actor i are involved in collaborations with other network members $l_n(G)$, the lower the obtained payoff of actor i from its collaborations. The term $\left(\frac{1}{l_i(G)}\right)$ captures the connectivity degree of node i, while the term $\sum_{n \in neig(i)} \left(\frac{1}{l_n(G)} \right)$ captures the connectivity degree of all its direct neighbors. In this way, utility of node i is proportional to the connectivity degree of its own and its direct neighbors. Since the term $\frac{1}{l_i(G)}$ in Equation 1 is repeated n times (n is number of neighbors of node i) their summations equals one and it creates the first term of Equation 2. Factoring the common term $\sum_{n \in neig(i)} \left(\frac{1}{l_j(G)} \right)$ from Equation 1 produces the second term of equation 2 as well, namely $\left(1 + \frac{1}{l_i(G)}\right) \sum_{n \in neig(i)} \left(\frac{1}{l_n(G)} \right)$. The following example gives the reader an insight on how the utilities of nodes can be calculated in our interaction model.

Example: Consider the graph G depicted in Figure 1. Suppose node j decides to establish a connection with a newly entered node m during the network growth, a process that imposes a decrease in the utility of node i from $\frac{5}{3}$ to $\frac{3}{2}$ (calculated based on Equation 1 or Equation 2). According to the definition of strategic responses, a rational choice for actor i is to establish the link im or in (or any other possibilities depicted with dashed links) as a best response to j's strategy, because it satisfies the conditions and increases its utility from $\frac{3}{2}$ to $\frac{17}{8}$. It should be noted that another possibility for node i is to establish a link iq but with utility maximization objective (second condition of the definition), node i prefers to choose the node that provides the highest utility.
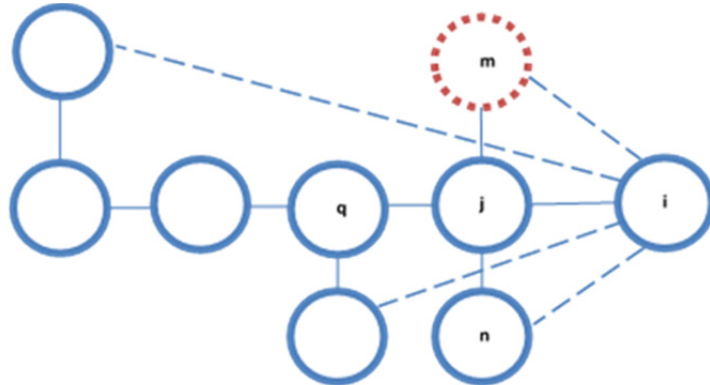

Figure 1. Link creation of node j with newly entered node m and strategic response of neighbor i of node j upon it.

3.4 Social Welfare

The social welfare in our model is based on the utilitarian measure of a society's welfare [15]. It is the sum of all individual utilities and is defined as below:

$$W = \sum_{i=1}^{n} U_i \qquad (3)$$

where W is the society's welfare (collective utility), U_i is the utility of node i and n is the total number of nodes in the network.

4. Results

4.1 Simulation Environment

An agent-based simulation in Netlogo [14] has been developed to perform the experiments on synthetic data sets. An advantage of agent-based simulation is that, from a computational perspective, it allows having a separate computational thread for each agent (node) that is responsible for the information exchange. Another advantage is that it allows dynamically changing the computing environment to model the real scenario. The simulation parameters and their descriptions are listed in Table 1.

Table 1. Simulation parameters and their descriptions.

Parameter Name	Description	Values
M_{ng}	Methods of network growth	• Preferential node attachment strategy • Random growth strategy • Strategic growth strategy
d	Diameter of the network	d is dynamic and grows over time
K	Distance from node i to node j	K = d
$B^k[j]$	Neighbors of node j at distance k	Subset of N
n_{start}	Population size at start up	10
n_{end}	Total size of the population	200
W	Social welfare	$W = \sum_{i=1}^{N} U_i$
U_i	Utility of node i	$U_i = 1 + \left(1 + \frac{1}{l_i(G)}\right) \sum_{n \in neig(i)} \left(\frac{1}{l_n(G)}\right)$

4.2 Results

Our results capture the changes in the social welfare during the process of the network growth and strategic establishment of potential links among existing individuals

(Figure 2). The x-axis shows the type of network growth model, while the y-axis shows the social welfare of the whole network with respect to three different network growth models and in the presence or absence of strategic responses of individuals towards network growth strategies.

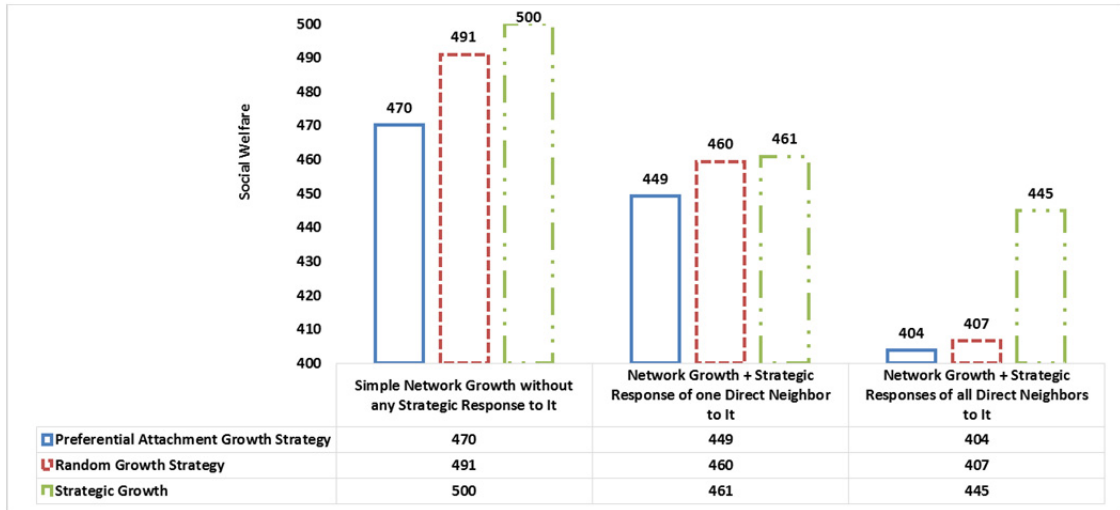|	Simple Network Growth without any Strategic Response to It	Network Growth + Strategic Response of one Direct Neighbor to It	Network Growth + Strategic Responses of all Direct Neighbors to It
☐ Preferential Attachment Growth Strategy	470	449	404
⊔ Random Growth Strategy	491	460	407
⊓ Strategic Growth	500	461	445

Figure 2. Total utility of the whole society with respect to different network growth strategies and in the presence of strategic responses of individuals. Strategic growth produces the highest social welfare. Adoption of strategic responses by all direct neighbors leads to reduced social welfare.

In particular, Figure 2 shows how social welfare changes occur with respect to different parameter configurations. The process of network growth continued until the size of the network reached 200 (n_{end} = 200), as we assume a medium-sized organizational network which usually consists of 200 people. However, this is a generative network formation model and size of the network can be set to larger values. Since the process of network growth and strategic responses has a sequential pattern, it can be assumed that is does not affect the obtained results.

Figure 2 illustrates that different models of network growth lead to different results in the social welfare. In detail, the computed social welfare is the highest, if the method of network growth strategy is set to strategic growth. That is to say, new individuals enter the networks in a way to maximize their utilities. They search for the candidate among the existing network members that provides them with the highest utility (following the co-author formulation, it is the one that has the lowest degree of connectivity). The social welfare for this method ranges from a score of 445 to 500. The second rank goes to the random node attachment strategy, in which new individuals select their partners randomly. The results range from a score of 407 to 491. That means the entrance of new individuals with preferential attachment strategy negatively affects social welfare.

Another observation, depicted in Figure 2, is that social welfare decreases in the presence of strategic responses of the individuals. That is to say, utility maximizing behaviors of existing individuals in networks, which have been generated in response to different growth models, reduce the social welfare of the whole society. It can easily be observed that, as long as a small population of individuals adopts such strategic

responses, we can expect an increase in the social welfare. Although this has been recognized as a general trend, the result of our third set of experiments shows an interesting phenomenon. If the method of network growth is set to strategic growth and all direct neighbors act strategically upon it, the difference between the social welfare is the highest (i.e., the observations range from a score of 445 for strategic growth to 407 for random growth and to 404 for preferential growth). This indicates that strategic growth of a network triggers a fewer number of strategic responses. That is to say, based on the co-author utility function, connectivity to low degree nodes not just provides the focal individual the highest utility but also provokes a lower number of strategic responses. This, in in its own turn, positively impacts the overall social welfare compared to the random strategy and the preferential node attachment strategy. For example, the negative impact of sudden strategic responses of all direct neighbors of hubs (i.e., high degree nodes) in preferential attachment grown networks reduces the social welfare from 449 to 404.

Minimum and maximum utility of the whole society with respect to different network growth strategies and in the presence of strategic responses of the individuals are also calculated. The results show that the highest utility (20.06) can only be achieved in the presence of preferential node attachment strategy and in the absence of strategic responses of individuals. The lowest value is 1.06. However, a large gap between the minimum utility and the maximum utility of an individual is the consequence. An interesting observation is related to the case of all direct neighbors deciding to perform strategic responses. One consequence of such behavior is that the gap between the minimum utility and maximum utility gets smaller. The minimum utility is 1.02 and the maximum utility is 2.6. We relate this observation to having a denser network as a consequence of link formation between them. In case of preferential attachment growth, higher density can be seen as the result of behavior of direct neighbors of hubs in the utility maximization process. Since high degree nodes have a higher probability of being selected during the network growth, the number of direct neighbors of those hubs that respond strategically is larger than those in other networks.

Another interesting observation is that the minimum utility value is larger if the method of network growth is set to strategic growth (i.e., the observations range from a score of 1.49, 1.58 and 1.75) compared to other network growth strategies.

Finally, the utility distributions of the whole society with respect to different network growth strategies are also investigated in this paper and the results are presented in Figure 3, Figure 4 and Figure 5. The results show that, regardless of the method of network growth, in the presence of strategic responses of all direct neighbors, utilities of the whole population is evenly distributed (Figure 3.C, Figure 4.C and Figure 5.C).

It can easily be observed that, as long as a small population of individuals performs their strategic responses, the distribution of the utilities of the whole population becomes more homogeneous (Figure 3.B, Figure 4.B, and Figure 5.B). Compared to a random growth strategy (Figure 3.A), the utility distribution of the whole society with respect to preferential attachment growth strategy follows a power law pattern (Figure 4.A). Finally, the utility distribution of the whole society with respect to strategic growth does not change a lot in the presence of strategic responses (Figure 5.B and

Figure 5.C). This observation can be related to the emergence of a network topology, in which the utility cannot be improved through strategic responses.

We also performed sensitivity analysis with respect to four different initial underlying network structure among individuals (e.g., a scale-free graph, a bernoulli random graph, a regular graph and a small-world graph). However, the difference in the summation of the utilities of the individuals were not significant. For this reason we picked the graph with scale-free topology (with 10 node and 20 links) as the initial underlying network structure and we performed our experiments.
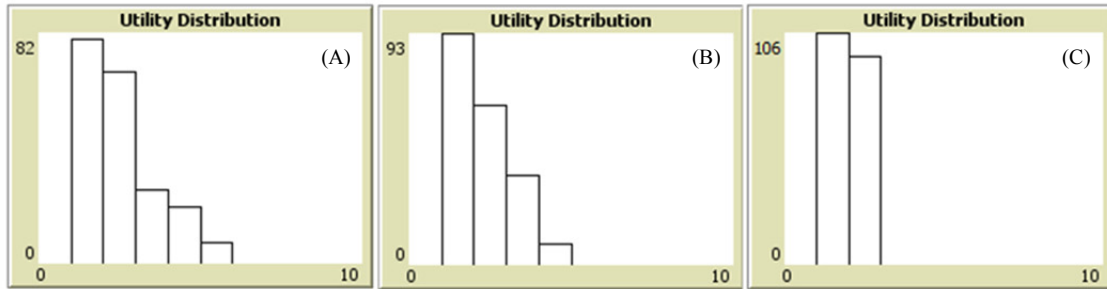

Figure 3. Utility distribution of the whole society with respect to random growth strategy. The x-axis shows the utility values, while the y-axis shows the number of individuals with respect to a certain utility value in the:
(A) Absence of strategic responses of the individuals;
(B) Presence of one strategic response of a direct neighbor;
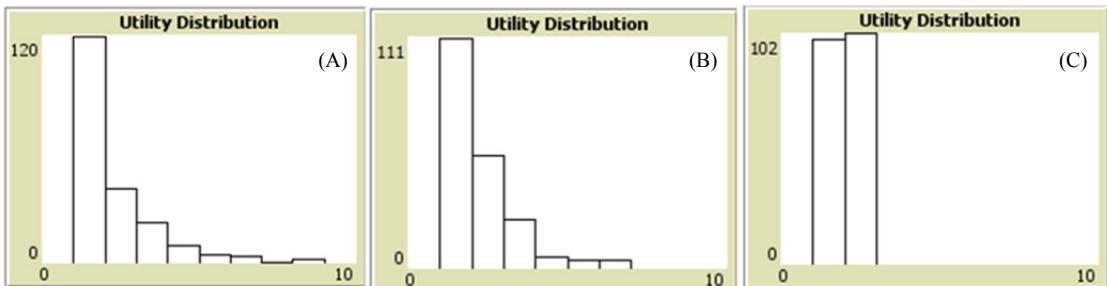**(C) Presence of strategic responses of all direct neighbors.**

Figure 4. Utility distribution of the whole society with respect to preferential attachment growth strategy. The x-axis shows the utility values, while the y-axis shows the number of individuals with respect to a certain utility value in the:
(A) Absence of strategic responses of the individuals;
(B) Presence of one strategic response of a direct neighbor;
(C) Presence of strategic responses of all direct neighbors.

Figure 5. Utility distribution of the whole society with respect to strategic network growth strategy. The x-axis shows the utility values, while the y-axis shows the number of individuals with respect to a certain utility value in the:
(A) Absence of strategic responses of the individuals;
(B) Presence of one strategic response of a direct neighbor;
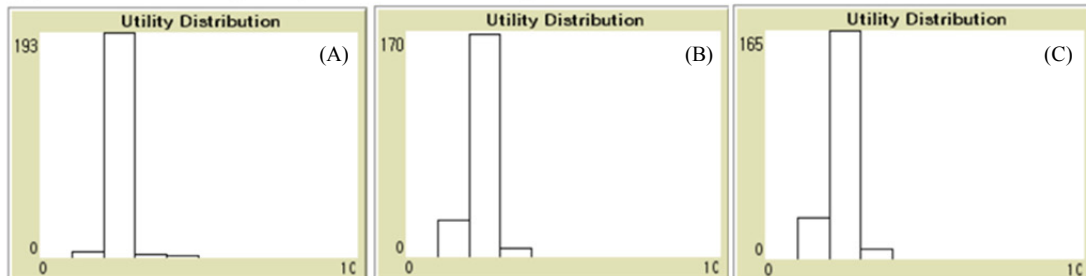**(C) Presence of strategic responses of all direct neighbors.**

5. Conclusion

The work presented in this paper investigates the interaction among individuals with respect to their benefits. For initiators of interactions, benefit is clearly given. However, the interaction with an existing network member triggers further dynamics among network members. Having such dynamics makes the network bigger over time on the one hand. It also creates further cognition in its members about future strategies that they should perform to maximize their networking outputs.

In order to explain the networking outcome out of those dynamics, we provide an interaction model based on complex adaptive system theory. It shows that changes of the structural properties of networks are caused through a variety of dynamic processes (e.g., the method of network growth and the strategic responses of individuals). The proposed interaction model is built on the assumption that a utility maximization process can be considered as a form of incentive for link establishment among network members. There is a feedback loop between individual actions and network structure and it affects the societal welfare and the distribution of the utility among the individuals. Consequently, we can justify why the underlying network structure is constantly changing and, as the result, a certain type of network with specific characteristics emerges. Key features of our proposed interaction model with respect to the complex adaptive system approach are the heterogeneity of agents, the adaptations of agents, and feedback loops.

What we can conclude from the obtained results is that the introduced factors in our interaction model (i.e., methods of network growth and strategic responses towards them) impact the networking outcome among individuals. For a utility function like the co-author model, in which the utility of an individual is a function of its own and its direct neighbor's connectivity degrees, a strategic growth strategy always produces higher social welfare compared to random growth strategy and preferential attachment growth strategy. The random growth strategy, which provides the whole population a uniform probability of link establishment to new members joining the network, produces a higher social welfare compared to the preferential attachment strategy. The preferential attachment strategy favors some specific individuals obtaining a high utility but, due to the large number of direct neighbors, cause a huge drop in social welfare in the utility maximization process. In the presence of strategic responses of all direct neighbors of nodes, it leads to the lowest social welfare, the lowest minimum utility, and lowest maximum utility among the whole population. Our observations also show that the utility distribution is less homogeneous under the preferential attachment growth strategy compared to the random growth strategy and the strategic growth strategy. Moreover, the utility distribution of the whole society with respect to the strategic growth strategy does not change a lot in the presence of strategic responses, which is due to the fact that a fewer number of strategic responses within the network will be initiated.

Although, in the absence of strategic responses of existing network members, strategic growth produces a better social welfare in comparison to random growth strategy, the difference in the social welfare of the other growth strategies is only 2% (500 vs. 491). We relate this observation to the nature of the utility function that we used in our interaction model. That is to say, new individuals enter the networks in a way to maximize their utilities. They search among the existing network members for

the one that can provide them with the highest utility. Following the co-author formulation, the one providing the highest utility is the one who has the lowest degree of connectivity. We should also mention that in the presence of a small number of strategic responses of existing network members, the difference in the social welfare becomes negligible (460 vs. 461). This shows that strategic responses of individuals have a bigger impact on the networking outcome compared to the impact of the strategy of network growth. However, in the presence of a large number of strategic responses, the strategic growth model produces a better social welfare (i.e., the observations range from a score of 445 for strategic growth strategy to 407 for random growth strategy with 404 for the preferential attachment growth strategy).

The most important observation of this study is related to the utility distribution. We believe that the reduction in the total utility is acceptable in exchange of having a homogenous utility distribution within the population. Our observations give us the idea that, if individuals react to actions of individuals in a society, we can avoid utility-maximizing network members to gain an imbalanced level of utility compared to other network members. Furthermore, network structures can be avoided, in which utilities of the network members are widely dispersed. In such a setting, individuals experience no unfairness in resource allocation in their community. Therefore, we state that strategic responses of individuals create a society with increased happiness.

As an implication of our research, we highlight the fact that network organizers can support network formations that are beneficial (i.e., finding a trade-off between high social welfare and a homogenous utility distribution) to the entire society by considering the connectivity of individuals for the network growth method. In one of our previous works [34], we showed that, despite the creation of new knowledge and the process of learning at an individual level, organizational structure affects the nature of human interactions and the information flow. Therefore, we believe that top managers and leaders could apply proper structural changes within the network of employees within the organization, in order to achieve a better organizational learning outcome and a better mechanism for increasing the knowledge flow. Managers within companies with a proper incentive mechanism are able to provide motivations for employees to be more open towards collaboration with others. Since, in this study, our main goal was to make a connection between emerging network characteristics and a performance measure, we did not discuss the type of incentives and other factors (e.g., organizational culture), which might influence the level of collaboration between individuals within the network. The quality of the relationships and the limitation, which might be imposed from the organizational hierarchy to the individuals, are also of interest for future studies.

The proposed interaction model in this paper is suitable for human-to-human communication environments, where the process of network growth triggers a strategic response among the existing network members due to having limitations in the amount of available resources (e.g., time and attention). The hypothesis that utility maximization underlies human behavior is a widely accepted paradigm among economists [7, 8]. However, it has been criticized by sociologists and psychologists, who specialize in studying human behavior. They argue that a simple rational choice model based on the utility maximization behavior assumes that the individual has full or perfect information about the alternatives. In the extension of this work [35], we will extend our interaction model with respect to network visibility and bounded rationality.

With the help of network visibility (i.e., parameter k), we can apply some restrictions on having the perfect knowledge about the alternatives during the process of utility maximization. Therefore, the extension of the current work focuses on smaller values of network visibility k to depict scenarios, in which individuals do not have access to global connectivity patterns of individuals within a network and, therefore, can apply their strategies only to those actors located within a certain distance from them. We are also interested in investigating the potential changes in the emerging network characteristics in the absence of a perfect visibility of the global topology of the network.

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