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A case study of the pyramid scheme in China based on communication network

Pihu Feng [a,b,*], Xin Lu [b], Zaiwu Gong [c], Duoyong Sun [b]

[a] Command & Control Engineering College, Army Engineering University of PLA, Nanjing, 210001, China
[b] College of Systems Engineering, National University of Defense Technology, Changsha, 410072, China
[c] School of Management Science and Engineering, Nanjing University of Information Science and Technology, Nanjing 210044, China

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ABSTRACT

This paper discusses the structure and endogenous process of a pyramid scheme organization. While most previous studies focus on the operation mode of pyramid scheme and its destruction to social economy, we investigate the non-trivial microstructure and endogenous interaction within the pyramid scheme. By using the motif analysis and the exponential random graph model (ERGM), we conducted an in-depth study on the communication network of a specific pyramid scheme organizations. Through integration of the communication networks with the organizational hierarchical structure, we explore what is the typical structure of a pyramid scheme organization and how do people interact with each other in the organization. The results show that the pyramid scheme communication network is a sparse network and obeys a core–peripheral structure. In terms of personnel interactions, pyramid scheme communication network presents significant homogeneity, with minimal cross-community and cross-hierarchy interactions.

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1. Introduction

In recent years, pyramid scheme has presented new feature, and the diffusion has gradually sped up [1,2]. The number of people involved in pyramid scheme has grown exponentially, and the economic losses caused by pyramid scheme have become increasingly severe [3–9]. It also brings great harm to social stability [10–13], as some pyramid scheme organizations have violent features, which lead to serious consequences [14–18]. For these reasons, pyramid scheme is illegal in many countries in the world [19,20]. At present, many scholars have studied pyramid scheme organization mainly from three aspects: The first focuses on the harm of the pyramid scheme and examines its impact on economy, social ethics, and national security and stability. The second focuses on the operation mechanism, which typically discuss the operation mode of pyramid scheme and the difference between pyramid scheme and multi-level marketing as well as that between pyramid scheme and ponzi scheme. In addition, some literature also studies the characteristics and harms of the internet pyramid scheme [8,19].

However, although there is a large amount of literature on the pyramid scheme, there are two important gaps in the existing literature. First, few studies have discussed the micro-structure and operation mode of the pyramid scheme. Second, few studies have examined the network structure and dynamic interaction patterns of members recruited in a pyramid scheme. This paper intends to explore the classic micro-structure and endogenous interactive process from

* Corresponding author at: College of Systems Engineering, National University of Defense Technology, Changsha, 410072, China.
E-mail addresses: pihufeng@163.com (P. Feng), xin.lu@flowminder.org (X. Lu), zwgong26@163.com (Z. Gong), duoyongsun@sina.com (D. Sun).

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a recently revealed pyramid scheme, the "5.03" pyramid scheme, which was active in the Chinese city of Yongzhou (where the pyramid scheme activities were thriving in recent years). The "5.03" pyramid scheme involves 177 participants from seven communities, with 16 of them transferred for prosecution. The rest of the paper is organized as follows: In Section 2, we present and summarize related studies on pyramid scheme. In Section 3, based on the interview data, we describe the "5.03" pyramid scheme communication network and propose the problems to be resolved in this paper. In Section 4, we discuss what is the classic micro-structure in the communication network. In Section 5, we discuss the endogenous interaction process of the communication network of pyramid scheme organizations. In Section 6, we conclude the findings and discuss limitations and future work.

2. Literature review

2.1. Harmfulness of pyramid scheme organization

2.1.1. Pyramid scheme causes serious economic harm

At present, pyramid scheme is spreading rapidly around the world. In 1996, Better Business Bureau warned that pyramid schemes were "all over the country". In China, over 20,000 cases were investigated from 2005 to 2015 [2]. More than 5 million people were involved in tens of billions of yuan in a pyramid scheme organization alone [4]. In addition, similar news has also been reported in Albania [18], Russia [21] and Malaysia [22]. Many studies have reported that pyramid scheme seriously endangers social progress and economic development [19,23,24]. According to the Federal Trade Commission, participants in pyramid scheme expect financial returns that far exceed the investment, largely based on the fees paid by their subordinates. Bosley and Mckaege analyzed the operation mode of a pyramid scheme organization in Montana, they found that almost all of the participation behaviors were the result of the influence of communication relationship, and that the counties with a greater degree of economic contraction had a higher degree of participation [25]. Schiffauer thinks that pyramid scheme benefiting only a small number of investors, while increasing the financial difficulties of most participants and leading to serious social disputes [21].

2.1.2. Pyramid scheme brings serious social problems

In addition to economic losses, pyramid scheme also causes serious social impact [5–12]. In 1997, most Albanians lost their savings in two pyramid scheme organizations, these losses prompted civil unrest and threatened the stability of the national government [18]. Many studies report that pyramid scheme seriously endangers social progress and economic development [19,25]. Revenue opportunities were misrepresented in pyramid scheme, and many participants were harmed by exaggerated and illegal product claims [7]. Pyramid scheme also severely damages social integrity [5–9]. Some dealers even abuse their friends and family to make money, seriously harming social ethics [10–13]. Some pyramid schemes have cult-like cultures, which limit their members' ability to reflect the quality of the company's business practices [11,14,15]. In China, pyramid scheme organizations are associated with violent crimes which may even cause death [16,17].

2.2. The difference with other similar types of crime

There are many differences between pyramid scheme, multi-level marketing and ponzi scheme. As the development mode of the pyramid scheme in various countries is different, the differences between pyramid scheme and the other two modes of operation are also varying. Some researchers believe that pyramid scheme refers to companies recruiting distributors and making profits by selling products to participants which they neither need nor can sell [7,26–28]. The Federal Trade Commission (FTC) determined that the income of pyramid scheme personnel depends mainly on the number of distributors and products they sell, rather than the profits they receive after the goods are sold [16]. Keep and Vander define the pyramid scheme as a money-transfer scheme in which the predicted losses of the vast majority become winnings for a small minority at the top of the recruitment structure [29]. Tencent's report argues that the essence of the pyramid scheme is "ponzi scheme", in which the profits of those who make money come later, generally, if four conditions are satisfied, it can be identified as suspected pyramid scheme [19]. The Montana defines pyramid scheme as a sales plan in which a participant earn income derived primarily from obtaining the participation of other persons rather than from the sale of goods or services [25]. In 2004, FTC commission staff stated that the presence of product or service sales does not, by itself, indicate legitimacy and defined a pyramid scheme as a multi-level compensation system, they believed that mandatory product purchases is a guise by which some pyramid scheme create the illusion of scheme activity and seek to disguise recruitment rewards as scheme commissions [30]. Vander and Keep review case and proposed a threshold, which is defined as the proportion of recruitment rewards and wholesale price which can be attributable to production costs, to identify the difference between legitimate and illegitimate pyramid scheme firms [29].

2.2.1. The differences between pyramid scheme and multi-level marketing

Although some people think that pyramid scheme originate from or are only legitimate pyramid scheme [17–19], and some multi-level marketing companies operate in the form of pyramid scheme, there are still many differences between them: (1) Pyramid scheme organizations use fraudulent information to recruit new participants [1,23,31–33]; (2) The products sold by the pyramid scheme organization are seriously inconsistent with the actual value, and even no products can be sold [9,34–37]; (3) The income distribution mechanism within pyramid scheme organizations is extremely unfair, and most people are destined to lose all wealth [11,15,25,31–33].

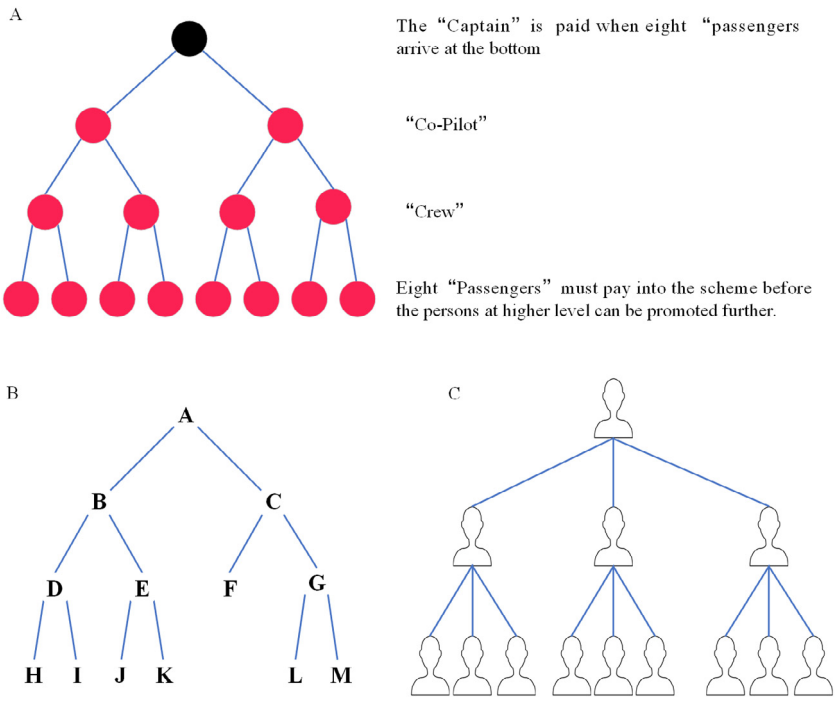

Fig. 1. The pyramid scheme organization structure. (A) Eight-ball model [42]. (B) The structure can be found in [22–24]. (C) The structure can be found in [19].

2.2.2. The differences between pyramid scheme and ponzi scheme

As a special form of business operation, pyramid scheme can be seen as a practice that is situated somewhere in between the common understanding of gambling and business [21]. Pyramid scheme and ponzi schemes are related in the sense that both of them are forms of financial fraud [37,38]. Some ponzi schemes can depend on multi-level marketing for popularizing them, thus forming a combination of the two [39,40]. While often confused with each other, pyramid scheme and ponzi schemes are distinct from each other. Pyramid scheme are based on network marketing, where each part of the pyramid takes a piece of the benefit, forwarding the money to the top of the pyramid. They fail simply because there are not enough people. Ponzi schemes are based on the principle of "Robbing Peter to pay Paul"—early investors are paid their returns through the proceeds of investments by later investors [20]. Pyramid and ponzi schemes may survive for several years, but sooner or later, when growth stagnates, they will collapse. In contrast to participants in ponzi schemes, participants in pyramid scheme are usually aware that their income is dependent on the recruitment of new investors and that they themselves must recruit additional investors, who will themselves recruit new investors, and so on. Pyramid scheme requires people to become its marketing agents and representatives, whereas ponzi schemes only requires investment [21].

2.2.3. The structure of the pyramid scheme organization

The most classic description of the pyramid scheme structure is the eight-ball model (also known as the Plane Game), which was a style of pyramid scheme active in the 1980s in North America and Europe [41]. The organizational structure of plane game is presented in Fig. 1. The common version of the system involved joining an "airplane" by spending some money to become one of eight "passengers" [42,43]. Already on the airplane were four "flight attendants" who were a step ahead, and two "co-pilots" next in line behind the pilot. Once a pilot collected $12,000 from passengers to retire, the group split into two "airplanes", with each co-pilot becoming the pilot of the new airplane, taking half the participants and promoting everyone a level. Bringing in new passengers sped up everyone's progression towards retiring as a pilot [42]. However, the structure of the scheme results in a participant losing the entire payment unless 64 new participants join [43]. In many literatures, the pyramid scheme structure was considered to be a multi-fork tree structure (pyramid-shaped structure). The most classic famous structure is the airplane game (also known as the eight-ball model), whose typical structure is shown in Fig. 1A.

In addition, there are many discussions about the structure of the pyramid scheme organization. However, in almost all the literatures, researchers believe that the organizational structure of the pyramid scheme organization is a multi-fork tree structure, its operation mode is a strict single-line connection, and the entire organization has a strict subordinate relationship. The multi-fork tree structure is illustrated in B and C.

Table 1
List of suspects who were transferred to prosecution in the "5.03" pyramid scheme organization.

Node number	Level	Node number	Level	Node number	Level
2	A2	25	A1	89	A1
3	A1	37	A1	135	A1
5	A1	41	A1	136	A1
7	A1	44	A1	137	A1
10	A1	59	A1		
17	A1	75	A1		

In summary, we can see that the current understanding of the structure of pyramid scheme organizations is relatively uniform, and they are considered to be multi-fork tree structures (or pyramid-shaped structure). In these studies, the research on pyramid scheme mainly focused on qualitative research, and a small amount of quantitative research focused on the definition of business model and the loses caused by pyramid scheme. Few studies refer to the structure and internal interaction mechanisms of pyramid scheme organizations.

3. Data description

3.1. The "5.03" pyramid scheme organization

The "5.03" pyramid scheme organization was detected on May 3, 2012, when it had expanded to a number of provinces. After a detailed review, 21 senior salesmen were detained and 16 of them were transferred for prosecution [44,45]. Entrants had to pay 3800 yuan to 69,800 yuan to purchase 1–21 copies of virtual products in order to obtain the qualification to join the "5.03" pyramid scheme organization after that they continued to develop new offline to get money according to the principle of relationship trust. The organization operated in the mode of "five levels and three levels", "three bonuses" and "one plus three". By fabricating all kinds of lies to "brainwash" new participants, senior salesmen lured them to buy more products. Once joined the organization, they were taught to develop new offline.

According to the share of virtual products, the organization divides people from bottom to top into five levels: E, D, C, B and A. The promotion of members of pyramid scheme organization can be divided into three stages: the first stage is the promotion of practice salesman to salesman, the second stage is the promotion of salesman to business manager, and the third stage is the promotion of business manager to business director. The practice salesmen are divided into E and D stages, the salesmen are divided into C1 and C2 stages, and the business managers are divided into B1, B2 and B3 stages, the business director is divided into A1 and A2 stages. The criminal suspects transferred for prosecution in "5.03" pyramid scheme cases is shown in Table 1.

4. Modeling and analysis

4.1. Pyramid scheme organization communication network construction

To construct the communication network of the "5.30" pyramid scheme members, we obtain anonymized mobile phone communication data from the prosecutor such that each user is paired with the properties of its role in the pyramid scheme, however, all identities of the data, including phone number, personal ID, etc., were removed before the process such that it is not possible to identify an individual person from the analysis. In this study, the communication data of seven days before May 3 (the day on which the pyramid scheme organization was detected) was collected and used to analyze the characteristics of the organization's communication relationship. An undirected and unweighted communication network with 177 nodes and 247 edges is then constructed.

4.2. Statistical properties of the communication network

Social network analysis theory provides a large number of effective indicators to access the roles of individuals in their social network. In order to gain a better understanding of the pyramid scheme network, we apply the following indicators: density, average distance, connectivity, transitivity and modularity. These five network attributes can describe the pyramid scheme network from multiple perspectives, which can help us understand the network structure and activity characteristics of pyramid scheme organizations.

(1) Network density. Network density is used to measure the ratio between the total number of actual connections between members in the network and the total number of maximum possible connections [46,47], which is used to characterize the closeness of the connections between nodes in a graph. Networks with high network density have more close connections between members; conversely, networks with low network density have fewer connections between members.

(2) Average distance. Average distance is the sum of the geodesic length between all nodes in the network divided by the number of node pairs [48]. If there is not any path between the two points, then we say that the distance between

the two points is infinite. The longer the average distance of the network, the more the pyramid scheme tend to be hierarchical, and the cross-layer contact within the group is weaker; The shorter the average distance of the network, the more the pyramid scheme organization tends to be agglomerated, and the connections between members in the group or between different layers are more common.

(3) Connectedness. Connectedness refers to the degree of accessibility between any nodes in the graph [49], which is used to measure the degree of connectivity of a network. The higher the network connectivity, the smoother the information exchanges among members. The lower the network connectivity, the more difficult and even impossible it is to exchange information between members.

(4) Clustering coefficient (Transitivity). The clustering coefficient is the likelihood of the connection between adjacent vertexes of the current vertex, sometimes referred to as transitivity [50]. The larger the clustering coefficient, the more closely the local members are connected; The smaller the clustering coefficient, the looser the relationship between the regional members.

(5) Modularity. The modularity is the ratio of the difference between the number of edges in a given community partition and the number of edges in the corresponding random network separated by the community to the number of edges in the network [51]. If the number of internal sides of the community exceeds the expected number based on chance, it is positive; otherwise, it is negative. Modularity reflects the concentration within the community. In general, the larger the value of the modularity is, the better the concentration of the network become.

4.3. Motifs analysis

According to the scope of the research object, network structure features are mainly divided into two categories: one is global statistical features, and the other is microscopic local structural features. As a typical frequent subgraph, the motif is the basic structure that can represent the local information of the network and the interaction mode of the elements between the nodes. Generally speaking, the frequently appearing motifs represent different network functions and features [52,53]. As a sub-graph hierarchy analysis, the motif has the function of function recognition of the corresponding organization and has significant functional features [54,55]. Gulbahce and Lehmann believe that the motif is one of the most basic topologies of the network, and motif mining is of great significance for analyzing the network structure [56]. Costa et al. also believes that the motif is an important structure which reflects the evolution of the network topology [57]. At present, network motif research has been applied to many fields such as biomedicine, intelligence information, sociology and computer science [58–62]. These studies further validate the relationship between network microstructure and network functions, that is, nodes can influence the global composition of the network through the subgraph structure formed by their neighbors.

4.4. ERGMs analysis

In order to gain a better understanding of the interactive characteristics of the communication network, we use the exponential random graph model (ERGM) to analyze the network. The exponential random graph model (ERGM) is a statistical method specifically for relational data. It explains the existence or absence of relationships in the network [63,64]. It identifies how the characteristics of the network members and larger social forces can explain or predict the observed patterns of relationships [64]. As a unique and effective network statistical tool, ERGM can be used to explain the observed network structural characteristics through statistical forms like logistic regression [65]. Compared with traditional regression models, the ERGM is constructed based on dependencies to generate various local structural configurations that reflect important social processes. It provides an effective tool to study network formation by explicitly modeling these configurations that may affect network and exogenous factors [66].

ERGM can be used to understand whether the formation of an observation network is due to some attribute characteristics of the network members or to the relationship model in the process of network formation, or both. The statistical form of the model is

$$\Pr(Y = y) = (\frac{1}{k}) \exp\left\{\sum_{A} \eta_A g_A(y)\right\} \tag{1}$$

where k is a constant to ensure that the probability is between 0 and 1 and that the sum of the probabilities is equal to 1, η_A is the coefficient of network configuration statistics, $g_A(\mathrm{y})$ represents various network configurations (statistics), When the network statistics of the fitting network are consistent with the network statistics of the observing network, $g_A(\mathrm{y})$ takes 1; otherwise, it takes 0.

For the "5.03" pyramid scheme organization, the model includes two attribute variables: community and the status of the indicted, which are used to compare the likelihood of establishing connections. It also includes structural factors (configuration) involving other connections in the network, such as geometrically weighted distribution (GWD), the geometrically weighted dyadwise shared partnerships (GWDSP) and the geometrically weighted edgewise shared partnerships (GWESP) [66,67]. The geometrically weighted distribution is used to reflect the decreasing degree distribution characteristics in the network, the geometrically weighted dyadwise shared partnership is used to get the number of binaries with shared partnerships, and the geometrically weighted edgewise shared partnership is used to obtain

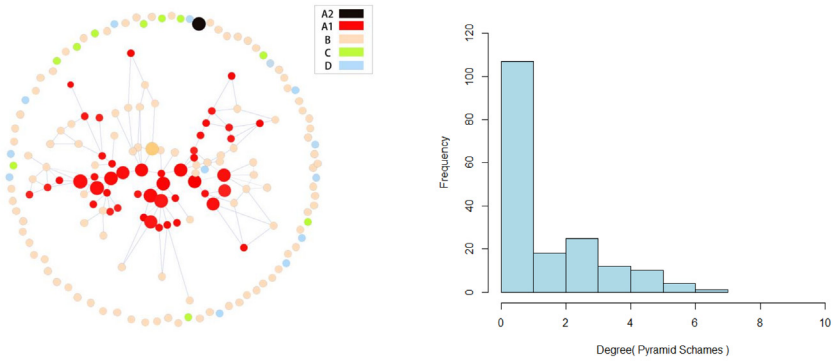

Fig. 2. "5.03" pyramid scheme organization network and the degree distribution. (A) Visualization of the communication network. Colors representing different levels in the pyramid scheme, and nodes of larger size are those transferred to the prosecution. (B) Degree distribution.

Table 2
Analysis of the characteristics of the communication network.

Index	Total number of nodes	Isolated node	Number of relationships	Average distance	Transitivity	Connectivity	Density	Modularity
Value	177	89	247	6.364	0.251	0.246	0.008	0.783

the transitivity and closure in the network [68,69]. These terms are interpreted as local structural processes such as expansiveness, transitivity, and structural equivalence, to adjust the degree distribution and to obtain transitive, dependent features [63,70].

For the dependence model, we use the Markov Chain Monte Carlo (MCMC) estimation to approximate the likelihood of the equation, so as to obtain general parameter estimation of ERGM [71]. In order to assess the model fitting results, we looked at the goodness-of-fit, and compared the observed network parameters for the simulated networks. The spectral goodness-of-fit (SGOF) captures the percent improvement a network model makes over a null model in explaining the structure in the observed data [72,73]. For the SGOF, 1000 simulations were used. For the MCMC estimation, the sample size was set at 5000 and the interval between samples at 1000.

5. Results

5.1. Statistical properties of pyramid scheme networks

The communication network and the degree distribution of the "5.03" pyramid scheme organization are shown in Fig. 1. As can be seen, the network has one large connected component and multiple isolated nodes. The degree distribution is heterogeneous, with a few nodes being connected with relatively larger number of communication counterparties. The communication network exhibits a hierarchical structure, and the relationship between the nodes show a "pseudo-tree" structure, that is, connections occur between the child nodes of the same parent node. In addition, the communication network also shows the cohesiveness, that is, there are many condensed subgroups, which are reflected in the star formation and closed loop state between group members at the same level. Therefore, it can be considered that there are a cross-level communication relationships and aggregation effect among members of the pyramid scheme organization.

In addition, it could be found that in the communication network, all the nodes of the A1 level were involved, and the nodes being sued which were all A1 level were all involved, except for the No.44 node. Interestingly, only the node-No.2 node of the A2 level does not exist in the communication network. Considering that it is impossible for such a large-scale annual meeting to leave the command of Node 2, it can be considered that Node 2 does not rely on or is unwilling to use communication means to issue various instructions and is very vigilant. Considering that these data come from the week before the annual meeting which is very important to the organization, through the analysis of the connectivity characteristics of the network, it can be concluded that pyramid marketing organizations do not rely on the communication network to complete organizational functions, but use other means (such as interpersonal relationships) to maintain the operation of the organization (see Figs. 2 and 4).

Analyzing the basic network concept of the network is elementary for the understanding of the pyramid scheme. The commonly used elementary network indicators are calculated according to Section 3.1, and the results are shown in Table 2.

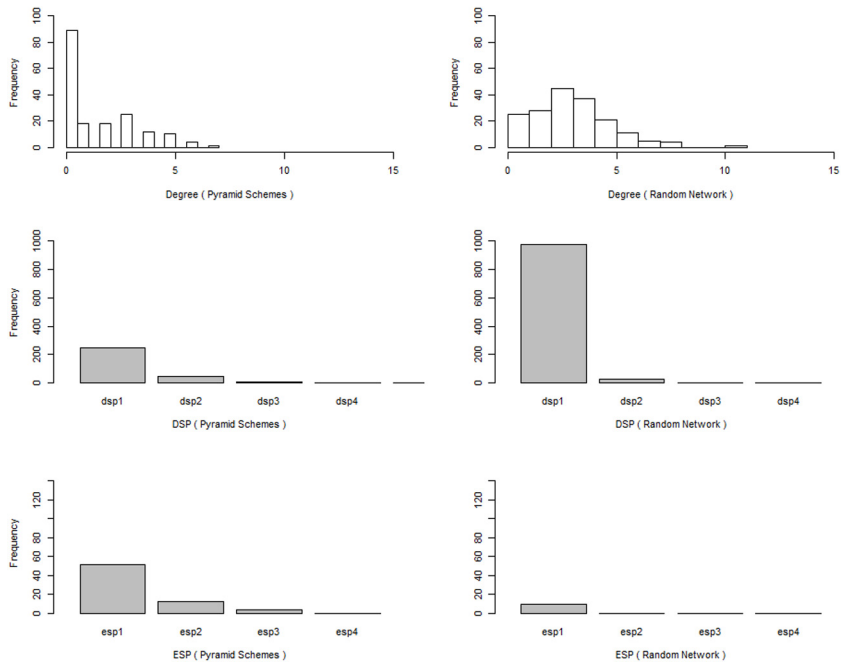

Fig. 3. Comparison of the degree distribution and shared partnerships in the observed communication relationships network (left) and random networks with the same size and density (right).

As shown in Table 2, the network density is 0.008, indicating that the communication network is a sparse network, reflecting that communication is not the main management method in the pyramid scheme network, and the communication relationship does not play an important role in the pyramid scheme organization. The average distance of the communication network is 6.364. For a network with 177 nodes, the communication network tends to be hierarchical, and there are fewer cross-level connections. The connectivity of the communication network is 0.246, indicating that the connectivity of the communication network is weak and the information exchange is not smooth enough. The transitivity is 0.245. Considering that the network density is 0.008, this indicates that there is a closed loop in the network and the communication network has a certain secretion type. The modularity is 0.783 (based on the Walktrap algorithm [74]), indicating that the communication network of the pyramid scheme organization has an obvious community structure.

5.2. Motif analysis

In order to further study the typical microstructure of the communication relationship network of the organizations, FANMOD, a software for motif analysis, is used to extract the motifs in network [75]. Taking into account the principle of organization construction (Section 2.1), we focus on the detection and analysis of the 3-node motif and 4-node motif, and the results are shown in Table 3.

We can summarize Table 3 with three main conclusions: First, almost all of the motifs in the table reflect structural closure. Therefore, it can be concluded that the communication network cannot be considered as a multi-fork tree structure and has strong closeness; Second, the motifs with higher p and Z values, such as No.13278, No.4958, No.8948910, No.19899128910, and No.17733316894, reflect the contact with the outside person. That is to say, in the communication network, the closeness of the edge and the connection with the outside coexist; Third, by analyzing No.2381, No.8948910, No.1084606, No.2133678, and No.1150364 motifs associated with the indicted persons, it is clear that these indicted persons act as bridges or cores roles in the organization. Considering the size of the network, it can be argued that the indicted persons have played a huge role in the communication network.

In some literature [9,15], the structure of pyramid scheme organizations is considered to be a typical pyramid-type (multi-fork tree) structure, nevertheless, any motif or combination of motifs in Table 3 does not present a multi-fork tree structure. Therefore, the communication network does not present the pyramid structure as mentioned above. Wasserman and Faust believe that there is a connection between network structure and network behavior, and nodes can influence the global composition of the network by forming subgraph structure with their neighbors [34]. Therefore, there are three main structural meanings of the aforementioned motifs (also the reason why the pyramid scheme organization network does not present a pyramid structure): (1) In a pyramid scheme organization, if there are two communication relationships among the three people, then they are inclined to establish another communication relationship to form a closed circle; (2) These small close circles tend to combine with each other to form bigger core structure of the network; (3) Participants tend to contact with participants in the same levels, and there are little cross-level contacts.

Table 3
Motif analysis result.

ID	Adj	Frequency	Mean-Freq	Standard-Dev	Z-Score	p-Value
238		9.7222%	0.056484%	0.0013323	72.551	0
2381		0.34722%	0.01512%	0.00065901	5.0394	0.001
13278		2.4931%	0.00087882%	8.7498e-005	284.83	0
4958		13.158%	0.099578%	0.0027103	48.18	0
8948910		0.36862%	0.00016911%	2.0182e-005	182.56	0
1256886		2.0537%	0.0014125%	0.00014851	138.2	0
1150398		1.4218%	0.0011921%	0.0001255	113.2	0
1084606		0.42127%	0.00053213%	6.3983e-005	65.758	0
8948910		9.0047%	0.062174%	0.0017471	51.185	0
2133678		0.31596%	0.00077561%	9.7386e-005	32.364	0
2133678		4.4234%	0.065376%	0.001899	22.949	0
1084606		1.8957%	0.031305%	0.00092284	20.203	0
13190438		0.42127%	0.017025%	0.00030622	13.201	0
1150364		0.52659%	0.02392%	0.00056831	8.8451	0
19899128910		0.32781%	5.9938e-006%	1.8954e-006	1729.5	0
17734316894		1.2148%	0.00068745%	7.1039e-005	170.91	0
2166143772		0.34709%	0.00039268%	3.643e-005	95.168	0
17735136086		0.86772%	0.00096732%	9.1651e-005	94.571	0
1141715822		0.92557%	0.0015017%	0.00013928	66.347	0
2199165980		4.9942%	0.028923%	0.00089338	55.579	0
2182388814		2.5067%	0.014128%	0.00045172	55.18	0

Note: "Frequency" denotes the frequency for the occurrence of each motif in the original network; "Z-Score" is the original frequency minus the random frequency divided by the standard deviation; and the p-Value of a motif is the number of random networks in which the motif occurred more often than in the original network, divided by the total number of random networks. Therefore, p ranges from 0 to 1 and the smaller p is, the more significant is the motif. Red node in the table represents that the person is transferred to the prosecution. The table excludes results for motifs with more than 7 nodes or less than 2 nodes, or with $Z-Score < 5$, or $p < 0.05$ and frequency $< 0.03\%$.

5.3. Analysis of exponential random graph models

(1) Analysis of basic statistic characteristic

The observed network is compared with the null model (random network). The results are shown in Fig. 3. It can be noted that there are significantly differences between the observed network and the null model. Consistent with the degree distribution characteristics exhibited by most observing networks, the degree distribution of the pyramid scheme network also indicates that it contains a large number of nodes with low centrality and a small number of nodes with high centrality. The observed network and the random network also show differences in the distribution of edgewise shared partnership and dyadwise shared partnership. In the observed network, more nodes have edgewise shared partnership and dyadwise shared partnership, while in the random network, a large number of nodes' shared partnership are concentrated around 1, and there are few other shared partnerships (see Table 4).

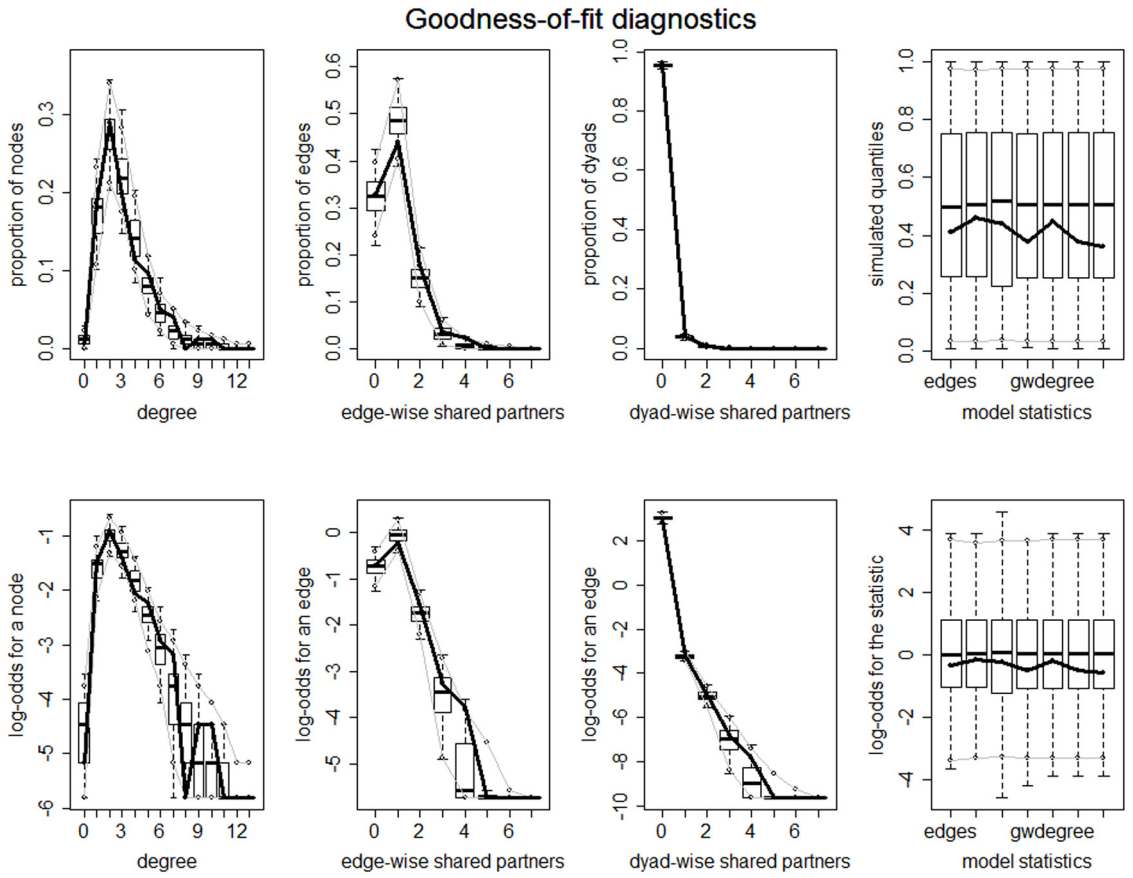

Fig. 4. Goodness-of-fit for measures from simulated networks based on the ERGMs. Top: proportions; bottom: log-odds. Black lines represent the observed value; gray lines and boxplots represent simulated network measures.

Table 4
ERGM analysis results.

Effects	Estimates	Std. Err.	MCMC %	Sign.
Edges	−2.94223	0.48941	0	***
Nodematch.convicted(Y)	1.30772	0.31956	0	***
Nodematch.convicted(N)	−0.75545	0.20206	0	***
Nodematch.community(S)	2.44857	0.27488	0	***
Gwdegree	−2.37801	0.30714	0	***
Gwesp.fix	0.70566	0.70566	0	***
Gwdsp.fix	−0.40520	0.06277	0	***
Signif.codes:	0: *** 0.001: ** 0.01: * 0.05:			
	AIC: 1873 BIC: 1919 Smaller is better			

In table 6.4, all P values are below 1e-04, and the coefficients of all statistical items show significance, so the model can be considered as a reasonable and convergent model. As shown in table 6.4, in the purely structural effects, Gwdgree's coefficient (B: - 2.87301; se: 0.30714) indicates that pyramid scheme participants are not more willing to establish communication relations with people with more communication links, Gwesp's coefficient (B: 0.70566; se: 0.14127) indicates that participants in pyramid scheme are willing to form closed triangular communication relations. In other words, existing communication relations are helpful to establish new relationships. For example, two friends or colleagues of the same person are more likely to establish communication links. In the actor relation effects, it is easier to establish a communication link between the transferred prosecutors (B: 1.30772; SE: 0.31856), In contrast, people who have not been transferred for prosecution have a much weaker willingness to establish contact (B: −0.75545; SE: 0.20206), People in the same community are also more likely to establish communication links (B: 2.44857; SE: 0.27488), Therefore, it can be considered that the communication network of pyramid scheme organizations has obvious homogeneity characteristics.

(2) Model fitting analysis

In Fig. 3, the thick black line represents the simulated networks, and the gray lines indicate 95% confidence interval of simulated network measures. When the black falls between the gray lines, the simulated networks have captured the characteristics of the observed network. Based on this simulation, although there are some drawbacks with the fit of edge-wise shared partners, the above results show that the simulation network can well explain the various statistics. In other words, this model is a stable model that can meet the modeling requirements and effectively account for this problem.

6. Conclusion and discussion

This paper applies social network theories to analyze the structural characteristics and endogenous processes of the pyramid scheme communication network. Anonymized data is used to construct the communication network, and the basic characteristics and micro-models of the communication relationship network are investigated by using the basic concept analysis and the motif analysis. The exponential random graph model (ERGM) is used to uncover influencing factors and endogenous processes of communication network formation.

A summation of the conclusions include, first, the communication network presents an obvious core–peripheral structure, indicating that members of the organization at the edge of the network do not communicate with each other by communication, in other words, communication is not the most important contact method in the pyramid scheme organization; second, the leader of the pyramid scheme organization is very vigilant and does not rely on or is unwilling to rely on the communication network to complete the management of the pyramid scheme organization; third, the communication network presents the characteristics of hierarchy and agglomeration, and the cross-community and cross-hierarchical connection among members is rare, fourth, the communication network is not a multi-fork tree structure, in the communication network, participants tend to establish another contact to make the group of departments form a closed circle; lastly, the communication network has obvious homophily, people in the same community or those who were also prosecuted tend to make connections with each other.

The above findings provide useful insights for the understanding of the formation of communication relationships in pyramid scheme organizations. These findings also provide some scientific basis for relevant law enforcement agencies to monitor the communication behavior of some suspected pyramid scheme organizations. However, there are still limitations in this study: first, this paper only studied the communication relationship network of a specific pyramid scheme organization, whether other pyramid scheme organizations or other kind of relationship networks also have the same characteristics still need to be explored; second, as the data is cross-sectional and incomplete, conclusions can only partially explain the characteristics of communication relationship network at the current stage, more comprehensive analysis may require large-scale panel data regarding the pyramid scheme organizations. Lastly, there are only a limited number of motifs is found in the study and the fitting analysis in ERGM may be fine-tuned with more complicated setting. Therefore, future research may explore a variety of pyramid scheme organizations, with more comprehensive social relationships that are not limited to phone communication, and more membership attributes, to achieve an improved model fitting and to help the discovery of more generalized structural and dynamic patterns for pyramid scheme organizations.

CRediT authorship contribution statement

Pihu Feng: Conceptualization, Methodology, Software, Writing - original draft, Validation, Data curation. **Xin Lu:** Methodology, Writing- reviewing. **Zaiwu Gong:** Visualization. **Duoyong Sun:** Methodology, Investigation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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