Analysis of sponsorship networks and cross-domain knowledge exchange: an empirical study on Zhihu

Tuotuo Qi, Tianmei Wang and Nuo Chen
School of Information, The Central University of Finance and Economics, Beijing, China

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Abstract

Purpose – This study aims to analyze the structural characteristics of knowledge exchange in Zhihu Lives to provide feasible suggestions for improving the creative enthusiasm of knowledge providers.

Design/methodology/approach – This paper uses the domain classification of Zhihu Lives to construct a cross-domain knowledge exchange network.

Findings – This research makes the following findings: the small-world effect exists in the sponsorship network and is conducive to enhancing the learning willingness of knowledge providers; significant sponsorships and strong learning willingness exist among knowledge providers; the knowledge exchange is obvious among the fields of education, reading and writing, business and lifestyle and the fields of music, film, games, art, the internet, science and technology, design, financial economy and occupation; and knowledge exchange is obvious among the internal fields of education, reading and writing, and business and life style, between the internal fields of music, film, and games and art and between the internal fields of the internet, science and technology, design, financial economy and occupation.

Originality/value – This study can provide practical suggestions for the following development of the platform by analyzing the special phenomenon of knowledge exchange in the present stage of knowledge exchange.

Keywords Zhihu Lives, Sponsorship network, Cross-domain, Knowledge exchange

Paper type Research paper

1 Introduction

Experts and scholars in the shared economy emphasize the untapped value of intangible assets (Botsman, 2014). Business models for collecting "idle" knowledge, experience and skills through online services based on social networks and redistributing (Finley, 2013) are collectively referred to as a knowledge-sharing economy. Given that the economic situation

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promotes the overall consumption level, users' acceptance of high-quality content and willingness to pay increased. Worth noting is that a large number of knowledge providers have already flooded into the knowledge-sharing economy markets, such as Quora Knowledge Prize (USA), Skillshare (USA), Zhihu (China) and Dedao (China), and their performances are changing how knowledge is shared in the global market (Zhang *et al.*, 2018a). The development situation of the knowledge-sharing economy in China is particularly evident. The year 2016 is known as the "first year of knowledge payment." In 2017, the scale of the knowledge payment industry in China was approximately 4.9bn yuan (iresearch, 2018). The trading volume of the knowledge-sharing economy is growing at a rate of 205% (SIC, 2017), indicating that the knowledge payment market's potential in China is significant.

In traditional virtual communities, people voluntarily contribute and consume knowledge for free (Bock *et al.*, 2005). In this case, knowledge contributors do not benefit from the money, and hitchhikers can gain the same knowledge as others (Wasko and Faraj, 2005). However, consumers may be overwhelmed by information overload, and the time cost of screening high-quality content is increasing.

The internet has changed the means of knowledge acquisition and participation in knowledge creation (Cellary, 2008). Knowledge sharing has entered the stage of paying for knowledge, which is typically based on paid questions and answers and real-time conversations. In the spiritual field, knowledge sharing is also called "consumption upgrading." A knowledge payment platform emphasizes the commodity attribute of knowledge and injects knowledge liquidation into the entire knowledge-sharing process, which helps improve users' efficiency of information screening and directly hits the pain point of unlimited information and limited energy.

Noted is that the key to the success of online knowledge communities is whether social professionals are actively involved in these websites (Wang *et al.*, 2017). As a whole, the development stage of the content side lags that of the platform side. The current emphasis on the development of the knowledge payment platform is establishing the ecology. In particular, certain knowledge payment platforms, such as Zhihu Lives and Himalayan FM, adopt the Professional User Generated Content model as their content side. Users play both provider and consumer roles and have the opportunity to rise to the key of leader. The self-cycling of content ecology is built. Therefore, incentives for providers to continuously produce high-quality content have become the core barrier of platform competition (iresearch, 2018).

As a special user group of the online community, social professionals on the knowledge payment platform play an important role in the social structure and possess valuable knowledge and skills. Although some studies effectively explained the external reputation and economic returns of online health communities (OHCs) experts, they ignored experts' internal returns (Guo *et al.*, 2017). Professional capital is a special, rare, lasting and valuable capital related to social professionals (Fullan *et al.*, 2015; Noordegraaf and Schinkel, 2011). Although most previous studies on professional capital focused on the importance of professional capital, our research extends its analysis to the perspective of professional capital exchange. Each knowledge provider can either produce paid knowledge for a profit or purchase paid knowledge produced by other knowledge providers. Purchasing behavior in this context is also known as sponsorship behavior. Thus, knowledge providers can achieve the purpose of knowledge exchange through the behavior of purchasing paid knowledge from each other and, finally, constitute a sponsorship network. Therefore, we aim to deeply investigate the intrinsic rewards of experts by analyzing the knowledge exchange behavior of social professionals.

2. Literature review

Because knowledge exchange, sharing and transfer involve many fields, concepts are often borrowed or used alternately, which leads to the confusion and ambiguity of concepts. Knowledge exchange is different from knowledge transfer and knowledge sharing. Knowledge transfer includes not only the knowledge sharing by knowledge sources but also the acquisition and application of knowledge by recipients. However, knowledge transfer is typically used to describe knowledge transfer among different units, departments or organizations, rather than individuals (Szulanski *et al.*, 2004). Knowledge sharing refers to providing task information and knowledge to help and cooperate with others to solve problems and develop new ideas (Cummings, 2004). Although "knowledge exchange" and "knowledge sharing" have been used interchangeably in many studies (Cabrera *et al.*, 2006), knowledge exchange includes knowledge sharing (or an expert providing knowledge for others) and knowledge seeking (or an expert seeking knowledge from others) (Wang and Noe, 2010). Therefore, in this study, we use the term "knowledge exchange."

Knowledge exchange between different fields is common. At present, information exchange in online social networks has attracted the attention of network researchers (Campbell and Kwak, 2010; Kumar *et al.*, 2010). Modern science is divided into different subdisciplines, and scientists are always limited to certain fields. However, currently, they must master multidisciplinary knowledge to solve complex problems, leading to cross-domain learning becoming increasingly common. Previous studies on cross-domain knowledge exchange mostly focused on citation analysis networks and interdisciplinary cooperation networks. When research involves many fields, it has the characteristics of interdisciplinary research (Huutoniemi *et al.*, 2010). Interdisciplinary cooperation inevitably leads to knowledge flow among different research fields, forming a unique network system with the domain as the node and knowledge flow as the edge.

The user behavior of the online knowledge community has been widely focused on by information system researchers. Many studies investigated various types of online communities, such as Wikipedia (Yang and Lai, 2010; Zhang and Wang, 2012), social Q&A sites (Khansa *et al.*, 2015; Li *et al.*, 2016; Lou *et al.*, 2013) and open-source software communities (Fang and Neufeld, 2009; Zhang *et al.*, 2013). The importance of members' contributions to the sustainable development of online communities has been fully validated (Khansa *et al.*, 2015; Li *et al.*, 2016; Lou *et al.*, 2013; Wasko and Faraj, 2005). However, few online knowledge communities succeed in motivating members to share knowledge continuously (Ma and Agarwal, 2007; Hung *et al.*, 2015).

The most significant challenge to promoting an online knowledge community is to maintain the continuous knowledge supply of its members (Chen and Hung, 2010; Chiu *et al.*, 2007). Therefore, understanding the motivation of knowledge sharing among members of the online knowledge community is very important. Previous studies proposed three important factors that affect knowledge sharing in virtual communities: personal incentives, technological factors and social factors (Hung *et al.*, 2015).

Cabrera *et al.* (2006) explained that individuals can share knowledge through perceived incentives. A lack of incentives is considered a major obstacle to cross-cultural knowledge sharing (Kam *et al.*, 2007). Establishing effective incentives is one of the most common ways to maintain community contribution behavior (Bock *et al.*, 2005; Garnefeld and Krebs, 2012; Hummel *et al.*, 2010; Kankanhalli *et al.*, 2005; Raban, 2008).

The incentive mechanism of the online knowledge community has been studied extensively. Cavusoglu *et al.* (2015) and Vasilescu *et al.* (2014) determined that the incentive mechanism of stack overflow promoted the value of voluntary participation. A badge in stack overflow by Anderson *et al.* (2013) can improve users' overall participation on the

website (Anderson *et al.*, 2013; J and F, 2011). In addition, most previous studies compared and analyzed the incentive effect of internal and external incentives. Previous studies involving online Q&A communities (Lou *et al.*, 2013) and open-source software development communities (Roberts *et al.*, 2006) found that external motivations (i.e. financial incentives) positively exaggerate participation contributions but that internal motivations may not be significantly associated with participation contribution. In Raban (2008, 2009), both intangible and tangible incentives have a significant positive impact on users' online contributions. Psychological and material incentives in online health-care communities can significantly increase doctors' online contributions (Wang *et al.*, 2017).

However, the current incentive system only attracts a few participants, and a considerable number of infrequent respondents are not attracted by the incentive system (Wang *et al.*, 2017). Prior studies indicated the importance of the user experience, especially the importance of social presence and dialog in e-commerce websites (Jiang *et al.*, 2009; Kumar and Benbasat, 2002). Even in the presence of financial incentives on Q&A websites, individual information providers are motivated by the dialog to some extent (Raban, 2008). However, no study has considered the importance of knowledge exchange among social professionals. Therefore, considering the incentive effect of the user experience, namely, knowledge exchange of knowledge contributors in the online knowledge-paying community, is necessary and can promote knowledge providers to make continuous contributions in the online knowledge-paying community. This study attempts to bridge this gap in our knowledge.

3. Data source and research methods

3.1 Data source

Zhihu (Zhihu.com), a multi-billion dollar unicorn and one of China's largest knowledge-sharing companies, creatively proposed a "Lives Session" to share knowledge, experience and skills. On Zhihu Lives (Zhihu.com/lives), knowledge providers use audio to engage in real-time dialog through the platform for approximately 1 h (Zhang *et al.*). Seventeen thematic areas are available: music, film and games, business, reading and writing, lifestyle, design, medical health, occupation, art, education, law, food, sports, science and technology, internet, travel, finance and economy and psychology.

This study captured sponsorship information among knowledge providers in all areas of Zhihu Lives by June 25, 2018. Sponsorship among 2,853 knowledge providers was acquired.

3.2 Research method

These related studies can be divided into three categories according to their research methods. First, a questionnaire survey was conducted to investigate knowledge-sharing communities (Bock *et al.*, 2005; Kankanhalli *et al.*, 2005). This type of research considers both external and internal incentives, and their impact on members' contributory behavior is studied. Empirical results verified the significant positive effects of internal incentives, but the effects of external incentives were inconsistent. Second, some studies discussed Q&A communities (Garnefeld and Krebs, 2012) and online learning communities (Hummel *et al.*, 2010) through experimental design. They only considered the impact of external incentives on contributory behavior and concluded that external incentives have a significant positive impact on users' online contributions. Third, using Web technology to collect public data from online communities for statistical analysis is another way to investigate this problem. Raban and other researchers explored members' contributions to Google Answers, an online community that helps users search for experts' information that others have online (Raban, 2008).

Previous studies mostly relied on the social capital framework (i.e. structure, relationship, cognitive dimension) of Nahapiet and Ghoshal (1998). However, when a community of practice is established, its members bring not only their knowledge, skills and abilities but also their social relationships. Some viewpoints of social network theory, such as structural holes in networks, are relatively underused and may improve our understanding of knowledge exchange in online knowledge communities. These theories may be useful because they recognize that members are not working, learning or sharing knowledge in isolation but are embedded in social networks. Therefore, by using the social network analysis method, this paper explores the knowledge exchange relationship between knowledge providers of online knowledge platform.

Zhihu Lives provides a good research scenario. We know that a sponsorship network exists for cross-domain learning in Zhihu Lives. Knowledge providers have a good grasp of skills and knowledge in their field. However, in the contemporary era, when they need various abilities, they need to add and promote the knowledge in their field and absorb knowledge nutrients from other fields. Therefore, knowledge providers act as participants to sponsor Lives in other fields. The Lives sponsored by knowledge providers of other knowledge providers leads to the exchange of knowledge, thus constituting a knowledge exchange network.

4. Data analysis and results

4.1 Analysis of sponsorship networks

Previous studies mostly analyzed the perceived usefulness of the platform from the perspective of consumers. This paper analyzed the usefulness of the platform from the perspective of social professionals – providers. Our findings provide insights for online knowledge community managers. Effective measures can be taken to retain social professionals and ensure the continuous supply of the seed content on the platform (Zhou, 2018).

In online communities, one of the main reasons for members' knowledge seeking is learning (Wasko and Faraj, 2000). One characteristic of knowledge is positive feedback: more knowledge reserve brings more demand for new knowledge. Because of the cognitive curiosity of highly skilled people, they need more new knowledge than do people with low skills (Cellary, 2010). Members with high goal orientation in performance may be more concerned with showing their ability and effective implementation and simultaneously avoiding risks and negative judgments (Dweck and Leggett, 1988). Therefore, knowledge seeking may be regarded as the learning process of seekers. Knowledge providers with stronger goal orientation in learning may view knowledge seeking as a learning opportunity to understand other people's views on the topics in which they are interested, which may further stimulate creativity (Wang and Noe, 2010). In Zhihu Lives, the willingness to learn can be measured by the number of live times that knowledge providers sponsor other knowledge providers. For this purpose, we propose the following research question.

RQ1. Is there general sponsorship among Live's knowledge providers? If so, how does the intensity of the sponsorship affect the learning willingness of the knowledge providers?

All knowledge providers on Zhihu Lives are regarded as the rows (or columns) of the sponsorship network, and the sponsorship network among knowledge providers is constructed. By June 25, 2018, Zhihu Lives had 2,853 knowledge providers.

$$A_{2853\times2853} = \begin{bmatrix} a_{1,1} & \cdots & a_{1,2853} \\ \vdots & \ddots & \vdots \\ a_{2853,1} & \cdots & a_{2853,2853} \end{bmatrix} \quad (1)$$

Among them, a_{ii} represents the number of times that knowledge provider i sponsors knowledge provider j. The sponsorship network is a directed value network.

By drawing the sponsorship network, we find 19,621 sides in the network. Therefore, a sponsorship exists between knowledge providers. To clearly illustrate the sponsorship network, only knowledge providers with node degree $\geq$100 are selected, as is shown in Figure 1.

4.1.1 Small-world effect of sponsorship networks. Watts and Strogatz (1998) stated that networks with larger aggregation coefficients and smaller average path lengths have small-world effects. In the sponsorship network, the average distance is approximately 4; that is, the average distance between all pairs of nodes is 4. The clustering coefficient is 0.061; that is, the average probability of two nodes connected to the same node being also connected in the network is 0.061. Compared with the electric power network (average distance 18.7, clustering coefficient 0.08) (Watts and Strogatz, 1998), the average distance of the sponsorship network is 3.988, which is far shorter than that of the electric power network. The clustering coefficient is 0.061, which is the same as that of the electric power network, indicating that the sponsorship network has an obvious small-world effect. Because of the characteristic of local denseness, the small-world effect of sponsorship promotes the formation of a trust mechanism among network knowledge providers, facilitates the establishment of internal sponsorships, better promotes the flow of knowledge and information transmission among knowledge providers and further strengthens the learning willingness of knowledge providers.

4.1.2 Characteristics of learning willingness in sponsorship networks. The average weighted out-degree and in-degree of the sponsorship network is 8.685, which indicates that the average number of sponsoring (or being sponsored) per knowledge provider is approximately eight to nine times. Because knowledge providers hold approximately 11 Lives on average, a strong sponsorship can be considered to exist between Lives knowledge providers, which reflects the strong learning willingness of knowledge providers as a whole.

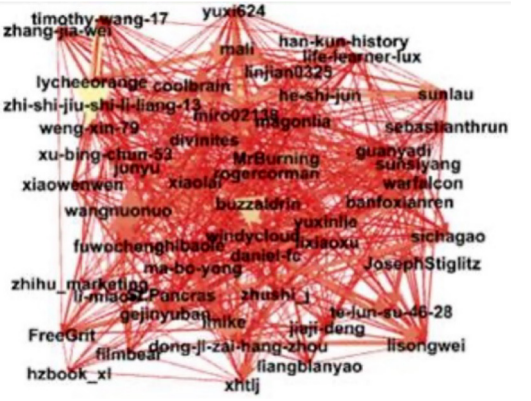

Figure 1.
Sponsorship networks with degree $\geq$ 100

The weight of the sponsorship network side represents the number of times that knowledge providers i sponsor knowledge providers j, which intuitively reflects the "one-to-one" learning willingness among knowledge providers. The sponsorship network has 19,621 edges, and the weight of the edges reflects the number of times a single knowledge provider sponsors. Table 1 and Figure 2 show that we can find that a sponsor for one time is the largest; however, when the weight of the edge is 2, the number of sponsorships with a corresponding intensity drops sharply to 2,593, and the dotted line shows the trend in the change. Given the increase in the edge weight, the sponsorship of corresponding intensity tends to be zero, indicating that the one-time sponsorship of knowledge providers i sponsor other knowledge providers j is more common, reflecting the weak willingness to continue learning from the same knowledge provider. The analysis of the weight of the edge shows that the "one-to-one" relationship between knowledge providers is weak, reflecting knowledge providers' tendency to learn from different knowledge providers.

4.2 Analysis of cross-domain knowledge exchange

Members of the online knowledge community have different professional skills, thus providing an effective platform with diversified sources of information (Park *et al.*, 2014). Therefore, interactive learning among individuals in online communities may exist in an organization or in the form of professional networks that transcend organizational boundaries (Brown and Duguid, 1991, 2001). Moreover, members share their ideas with others, which further promotes creativity (Oldham, 2003). Presently, most of the excellent research results have horizontal characteristics that penetrate many different disciplines

Edge weight	≥1	≥2	≥3	≥4	≥5	≥6
Number of directed edges	19621	2593	968	552	362	263
Visual proportion of edges	100	13.22	4.93	2.81	1.84	1.34
Edge weight	*≥13*	*≥14*	*≥15*	*≥16*	*≥17*	*≥18*
Number of directed edges	24	14	9	7	5	5
Visual proportion of edges	0.12	0.07	0.05	0.04	0.03	0.03
Edge weight	*≥7*	*≥8*	*≥9*	*≥10*	*≥11*	*≥12*
Number of directed edges	117	69	49	41	35	31
Visual proportion of edges	0.6	0.35	0.25	0.21	0.18	0.16
Edge weight	*≥19*	*≥20*	*≥21*	*≥22*	*≥23*	*≥24*
Number of directed edges	5	2	2	1	1	1
Visual proportion of edges	0.03	0.01	0.01	0.01	0.01	0.01

Table 1.
Numbers of directed edges corresponding to edge weight

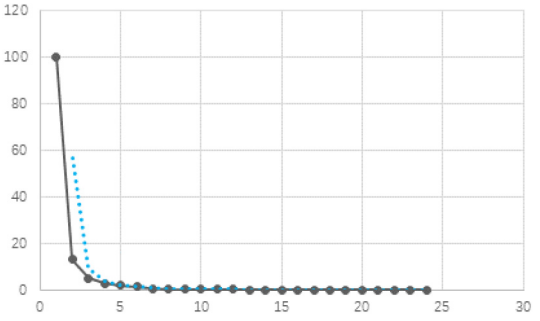

Figure 2.
Number of directed edges that vary with edge weight

(Cellary, 2010). Therefore, the cross-domain knowledge search of Lives knowledge providers is conducive to the innovation and supply of high-quality seed content.

Given the background of the knowledge community, this paper studies the relationship between reciprocal norms and knowledge sharing. The norm of reciprocity, a dimension of social capital (Nahapiet and Ghoshal, 1998), refers to the knowledge exchange that both sides consider being fair. The results of the research on online professional community reciprocity norms indicate that participating in knowledge sharing in an online practice community has been found to increase experts' internal satisfaction, making them realize the obligation to reward the knowledge acquired from the forum and help the community make progress (Hew and Hara, 2007; Lin, 2007; Wasko and Faraj, 2005; Wasko and Faraj, 2000). Chiu *et al.* (2007) found that reciprocity norms are positively correlated with personal knowledge sharing. Therefore, cross-domain knowledge exchange can promote the creation of seed content for knowledge providers as an incentive factor. Therefore, we propose the following research question.

RQ2. How do Lives knowledge providers exchange knowledge across domains? Further, how can the enthusiasm for the creation of Lives knowledge providers be enhanced?

4.2.1 Construction of cross-domain knowledge exchange network. Because Zhihu Lives has 17 domains, 17 nodes exist. Cross-domain knowledge exchange network G can be constructed. Note that the direction of sponsorship is adopted, which is opposite the direction of knowledge flow; that is, "the knowledge provider who belongs to domain i sponsors the knowledge provider who belongs to domain j" is equivalent to "knowledge flows from the domain in which knowledge provider j belongs to the domain in which knowledge provider i belongs."

$$\mathrm{G} = \begin{bmatrix} g_{1,1} & \cdots & g_{1,17} \\ \vdots & \ddots & \vdots \\ g_{17,1} & \cdots & g_{17,17} \end{bmatrix} \tag{2}$$

Among them, $g_{i,j}$ refers to the total times that the knowledge providers belonging to domain i sponsor the knowledge providers belonging to domain j, which is equivalent to the total inflow of knowledge from domain j to domain i.

Take "music, film and games, business, reading and writing, life style, design, medical health, occupation, art, education, law, food, sports, science and technology, internet, travel, financial economy, psychology" as the row (or column) of Matrix G. Finally, Matrix G is obtained and is visualized as in Figure 3. To observe the relationship between areas with high sponsorship frequency, the network is filtered, and Figure 4 is obtained.

Density and average degree are used to describe the number of connections of the network node. The density of the valued directed network is calculated using formula (3). The average number of sponsorships by knowledge providers in different fields is 141, which indicates that cross-domain knowledge exchange exists.

$$m_{direct} = \sum V_k / N(N-1) \tag{3}$$

To be noted is that Matrix G cannot be directly used to analyze the characteristics of knowledge flow in a domain network for the following reasons: the number of knowledge providers and Lives in different fields is different, making the sponsorship among different

$$G = \begin{bmatrix}
676 & 44 & 152 & 215 & 39 & 35 & 144 & 178 & 178 & 18 & 53 & 72 & 102 & 274 & 43 & 90 & 115 \\
195 & 68 & 73 & 116 & 32 & 49 & 122 & 48 & 110 & 36 & 23 & 53 & 99 & 213 & 23 & 146 & 69 \\
148 & 28 & 197 & 131 & 29 & 59 & 154 & 117 & 196 & 41 & 21 & 70 & 123 & 191 & 14 & 108 & 118 \\
300 & 101 & 265 & 448 & 101 & 223 & 360 & 203 & 448 & 27 & 123 & 189 & 242 & 463 & 123 & 245 & 328 \\
82 & 39 & 89 & 132 & 154 & 31 & 162 & 82 & 123 & 8 & 31 & 16 & 82 & 268 & 19 & 71 & 82 \\
49 & 27 & 81 & 116 & 21 & 145 & 106 & 30 & 130 & 29 & 30 & 77 & 80 & 151 & 14 & 84 & 110 \\
327 & 150 & 362 & 478 & 199 & 225 & 795 & 207 & 536 & 117 & 110 & 212 & 283 & 927 & 81 & 527 & 301 \\
211 & 26 & 100 & 105 & 46 & 41 & 94 & 183 & 113 & 13 & 21 & 38 & 80 & 156 & 27 & 75 & 60 \\
408 & 99 & 381 & 439 & 116 & 238 & 630 & 206 & 1032 & 65 & 74 & 196 & 474 & 870 & 88 & 539 & 431 \\
48 & 18 & 52 & 51 & 7 & 27 & 96 & 23 & 68 & 103 & 20 & 21 & 21 & 77 & 5 & 68 & 28 \\
23 & 9 & 18 & 70 & 13 & 14 & 32 & 20 & 31 & 6 & 57 & 11 & 30 & 45 & 9 & 49 & 26 \\
96 & 32 & 63 & 84 & 7 & 31 & 63 & 40 & 97 & 6 & 18 & 143 & 60 & 176 & 16 & 59 & 82 \\
96 & 49 & 130 & 152 & 31 & 95 & 222 & 77 & 199 & 14 & 41 & 66 & 336 & 402 & 34 & 149 & 142 \\
272 & 110 & 245 & 293 & 116 & 96 & 391 & 95 & 347 & 34 & 74 & 118 & 303 & 1534 & 57 & 394 & 197 \\
55 & 26 & 58 & 144 & 23 & 46 & 122 & 39 & 74 & 34 & 31 & 51 & 51 & 130 & 113 & 98 & 59 \\
171 & 70 & 103 & 220 & 36 & 84 & 281 & 77 & 177 & 95 & 69 & 92 & 157 & 309 & 37 & 665 & 93 \\
73 & 14 & 110 & 104 & 28 & 72 & 134 & 53 & 202 & 15 & 28 & 36 & 105 & 162 & 19 & 56 & 333
\end{bmatrix}$$

Figure 3.
Matrix G

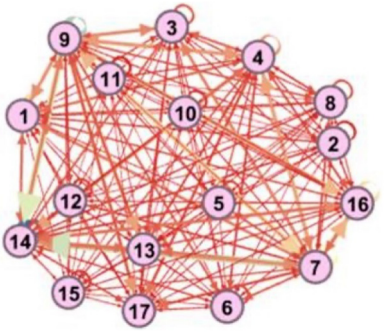

Figure 4.
Primitive cross-domain knowledge exchange network between knowledge providers

fields incomparable. This problem can be solved through standardization. We can observe from the matrix that the maximum value of the element is "internet–internet," which is 1,534. Each element of Matrix G is divided by the maximum value of 1,534, as shown in formula (4).

$$W = [w_{ij}] = [g_{i,j}/1534] \tag{4}$$

Matrix W is obtained by standardization as follows (Figure 5).

In this way, Matrix G is standardized to Matrix W. The elements in Matrix W represent the intensity of the sponsorship in one area by others. Matrix W eliminates the influence of the number of knowledge providers and Lives and makes comparable the knowledge exchange relationship among different fields.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.441	0.029	0.099	0.140	0.025	0.023	0.094	0.116	0.116	0.012	0.035	0.047	0.066	0.179	0.028	0.059	0.075
2	0.127	0.044	0.048	0.076	0.021	0.032	0.080	0.031	0.072	0.023	0.015	0.035	0.065	0.139	0.015	0.095	0.045
3	0.096	0.018	0.128	0.085	0.019	0.038	0.100	0.076	0.128	0.027	0.014	0.046	0.080	0.125	0.009	0.070	0.077
4	0.196	0.066	0.173	0.292	0.066	0.145	0.235	0.132	0.292	0.018	0.080	0.123	0.158	0.302	0.080	0.160	0.214
5	0.053	0.025	0.058	0.086	0.100	0.020	0.106	0.053	0.080	0.005	0.020	0.010	0.053	0.175	0.012	0.046	0.053
6	0.032	0.018	0.053	0.076	0.014	0.095	0.069	0.020	0.085	0.019	0.020	0.050	0.052	0.098	0.009	0.055	0.072
7	0.213	0.098	0.236	0.312	0.130	0.147	0.518	0.135	0.349	0.076	0.072	0.138	0.184	0.604	0.053	0.344	0.196
8	0.138	0.017	0.065	0.068	0.030	0.027	0.061	0.119	0.074	0.008	0.014	0.025	0.052	0.102	0.018	0.049	0.039
9	0.266	0.065	0.248	0.286	0.076	0.155	0.411	0.134	0.673	0.042	0.048	0.128	0.309	0.567	0.057	0.351	0.281
10	0.031	0.012	0.034	0.033	0.005	0.018	0.063	0.015	0.044	0.067	0.013	0.014	0.014	0.050	0.003	0.044	0.018
11	0.015	0.006	0.012	0.046	0.008	0.009	0.021	0.013	0.020	0.004	0.037	0.007	0.020	0.029	0.006	0.032	0.017
12	0.063	0.021	0.041	0.055	0.005	0.020	0.041	0.026	0.063	0.004	0.012	0.093	0.039	0.115	0.010	0.038	0.053
13	0.063	0.032	0.085	0.099	0.020	0.062	0.145	0.050	0.130	0.009	0.027	0.043	0.219	0.262	0.022	0.097	0.093
14	0.177	0.072	0.160	0.191	0.076	0.063	0.255	0.062	0.226	0.022	0.048	0.077	0.198	1.000	0.037	0.257	0.128
15	0.036	0.017	0.038	0.094	0.015	0.030	0.080	0.025	0.048	0.022	0.020	0.033	0.033	0.085	0.074	0.064	0.038
16	0.111	0.046	0.067	0.143	0.023	0.055	0.183	0.050	0.115	0.062	0.045	0.060	0.102	0.201	0.024	0.434	0.061
17	0.048	0.009	0.072	0.068	0.018	0.047	0.087	0.035	0.132	0.010	0.018	0.023	0.068	0.106	0.012	0.037	0.217

Figure 5.
Matrix W

The network is directed; however, block model analysis requires an undirected network. Therefore, the symmetrical processing of networks is needed. To be noted is that symmetric processing is an irreversible process, and some information in the network is lost. In this paper, the mean method is selected and the formula to process matrix W is as follows:

$$S = [s_{ij}] = [(w_{ij} + w_{ji})/2 \tag{5}$$

By symmetry, Matrix V is obtained as follows (Figure 6).

4.2.2 Characteristics of cross-domain knowledge exchange. Some fields occupy a very important position in knowledge outflow, and other fields occupy a very important position in knowledge inflow. Also, some values of the knowledge inflow and knowledge outflow are the same. The fields that tend to knowledge inflow indicate that knowledge providers belonging to this field are more likely to sponsor certain fields; the fields that tend to knowledge outflow indicate that they are more likely to attract the attention of knowledge providers. Here, the block model is used to analyze the knowledge exchange.

The block model is a simplified representation of a relational network, which reflects the general characteristics of a network structure. Actors subordinate to the same status have the same or similar connections to other status actors. The main steps to building a block model are as follows. First, to partition the actors – dividing them into different positions – the commonly used methods are CONCOR and hierarchical clustering. Second, the value of each block is determined according to the connection density of the submatrix of the social relation matrix, which is a one-block or a zero-block. Presently, six criteria are considered useful: complete fitting method, zero-block standard method, one-block standard method, alpha-density index method, maximum standard method and average standard method.

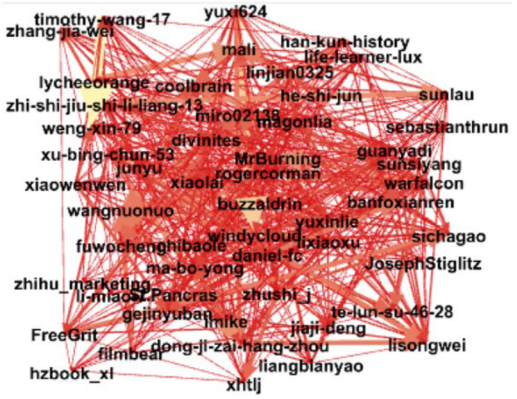

Figure 6.
Symmetric matrix V

Among them, the alpha-density index method is the most commonly used, and the average density of the entire network is generally used as the critical value.

The CONCOR method is used to assign similar actors to the same position. A total of six positions were obtained (as indicated in Table 2). Through observation, the domains within each position are found to be relevant, supporting to a certain extent the applicability of the CONCOR method in this research problem. Because of a certain degree of relevancy within the statuses, we generally summarize fields belonging to status β_1 as "basic skill demand"; status β_2 as "high-end entertainment demand"; status β_3 as "high-end skill demand"; status β_4 as "physical fitness demand"; status β_5 as "basic entertainment demand"; and status β_6 as "extra demand."

Density tables are used to summarize the relationship between statuses. The calculation results are shown in Table 3.

The mapping matrix can induce the relationship between and within statuses. Rules for constructing the block model represent the alpha-density criterion. Using the mean criterion:

$$\overline{x} = \sum_{i=1}^{g} \sum_{j=1}^{g} x_{ij} \Big/ g^{*}g \tag{6}$$

The density of the entire cross-domain knowledge exchange matrix is 0.092. If the submatrix of the social relation matrix corresponds to the relationship between actors in status β_k, and the actors in status β_l are greater than or equal to the density of the entire cross-domain knowledge exchange matrix, the block is defined as a block. Otherwise, it is defined as a zero-block, as shown in formula (9). Thus, the mapping matrix and the simplified graph of the cross-domain knowledge exchange relationship can be obtained (as shown in Table 4 and Figure 7).

β_1	β_2	β_3	β_4	β_5	β_6
Education	Music, film and games	Internet	Medical health	Food	Law
Reading and writing	Art	Science and technology	Psychology	Travel	
Business		Design	Sports		
Lifestyle		Financial economy			
		Occupation			

Table 2.
Block model statuses

$$b_{kl} = \begin{cases} 1 & \overline{x_{kl}} \geq 0.092 \\ 0 & \text{the other} \end{cases} \quad (7)$$

Considering the overall structure of the relationship between statuses, we find that the relationship model between the sets of statuses is a center-edge structure (Snyder and Kick, 1979), which includes the core status β_1. The marginal positions β_2 and β_3 depend on this core position but not on each other, reflecting the "elite" and "dependents" in Live.

Because statuses β_2 and β_3 are only connected to β_1, statuses β_2 and β_3 are "tree nodes" (Richards and Skelton, 1989). Status β_1 and statuses β_2 and β_3 are two-way links. Therefore, status β_1 is a liaison on the network (Richards and Skelton, 1989) reflecting the mutual sponsorship and reciprocity among domain knowledge providers between status β_1 and statuses β_2 and β_3, which leads to their knowledge exchange. In other words, "basic skills demand" links "high-end entertainment demand" and "high-end technology demand" as a bridge. The inflow and outflow of knowledge occur among "basic skill demand," "high-end entertainment demand" and "high-end technology demand." In addition, statuses β_4, β_5 and β_6 are self-reflexive for three cohesive subgroups, namely, "basic skills demand," "high-end entertainment demand" and "high-end technology demand." The internal domain frequently

Table 3.
Density table of cross-domain knowledge exchange relationships

Status	β_1	β_2	β_3	β_4	β_5	β_6
β_1	0.168	0.104	0.151	0.084	0.037	0.029
β_2	0.104	0.203	0.084	0.038	0.023	0.017
β_3	0.151	0.084	0.229	0.068	0.037	0.035
β_4	0.084	0.038	0.068	0.075	0.018	0.014
β_5	0.037	0.023	0.037	0.018	0.034	0.011
β_6	0.029	0.017	0.035	0.014	0.011	0.067

Table 4.
Mapping matrix of cross-domain knowledge exchange relationships

Status	β_1	β_2	β_3	β_4	β_5	β_6
β_1	1	1	1	0	0	0
β_2	1	1	0	0	0	0
β_3	1	0	1	0	0	0
β_4	0	0	0	0	0	0
β_5	0	0	0	0	0	0
β_6	0	0	0	0	0	0

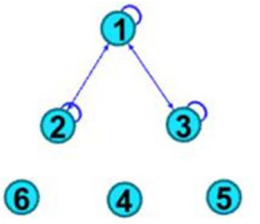

Figure 7.
Simplified diagram of cross-domain knowledge exchange relationships

sponsors each other, and knowledge obviously flows in and out of the internal domain. Knowledge providers in all fields of status tend to sponsor each other, and a strong phenomenon of knowledge exchange exists that further supports the rationality of status classification.

However, we find that although the internal domains of statuses β_4, β_5 and β_6 are relevant to a certain extent, the three positions are neither out-degree nor in-degree – they are isolated points (Richards and Skelton, 1989). That statuses β_4, β_5 and β_6 are neither reflexive nor related to any status, indicating that knowledge providers in all fields with the three statuses of "physical fitness demand," "basic entertainment demand" and "extra demand" do not exchange internal knowledge and do not exchange knowledge with other fields. This situation reflects knowledge providers in all fields belonging to this status as relatively isolated, probably because knowledge providers belonging to statuses β_4, β_5 and β_6 in various fields focus only on their fields and have no interest in other fields. Alternatively, knowledge providers belonging to statuses β_4, β_5 and β_6 are busy in the medical, fitness, law and other industries, whereas knowledge providers who hold travel and food themes tend to enjoy life and spend less time using the internet.

5. Discussion

Compared with the simple online Q&A platform, the knowledge payment service model is heavier and more customized. Therefore, we can provide practical suggestions for the following development of the platform by analyzing the special phenomenon of knowledge exchange in the present stage of knowledge exchange.

The sponsorship network matrix of Zhihu Lives shows that knowledge providers' overall learning willingness is strong. However, the "one-to-one" learning willingness is weak, reflecting that knowledge providers tend to learn from different knowledge providers. Moreover, the small-world effect of the sponsorship network explains the strong learning willingness among knowledge providers to a certain extent. Through the analysis of a cross-domain knowledge exchange network, we find that cross-domain knowledge exchange exists in Zhihu Lives. As a "liaison," "basic skill demand" links "high-end entertainment demand" with "high-end skill demand" knowledge providers and receives the common attention of knowledge providers from the two statuses representing "high-end entertainment demand" and "high-end skill demand," indicating that "basic skill demand" is more likely to be favored by knowledge providers and occupies a very important position in cross-domain knowledge exchange. At the same time, a clear sponsorship exists among the three internal fields, indicating that the internal knowledge exchange is obvious. Because cross-domain knowledge exchange can be used as an incentive to promote the sustainable use of the platform by knowledge providers, personalized recommendations and accurate marketing for various fields will assist in enhancing the sustainable contribution and use of the platform by knowledge providers. It is helpful to further stimulate the creativity and enthusiasm of knowledge providers by recommending Live, which belongs to "basic skills demand" for those who hold "high-end entertainment demand" and "high-end skills demand." In addition, because the three positions belong to the cohesive subgroup, further enhancing the frequency and quantity of mutual recommendations of Lives in the internal field will become an important breakthrough in stimulating knowledge providers to create seed content. Ultimately, influenced by reciprocal norms, knowledge providers will return sponsored knowledge providers by hosting Live, thus promoting the sustainable use of the platform of knowledge providers.

However, no knowledge exchange exists among the status of "physical fitness demand," "basic entertainment demand" and "extra demand" and any other status, and no knowledge exchange exists between internal fields, which are isolated points. Therefore, we cannot simply recommend Lives to stimulate the creativity and sustainability of knowledge providers who hold three statuses. Future research can analyze the influence of other factors (e.g. the concerning relationship among knowledge providers, scores, and evaluation content) on the motivation of knowledge providers.

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Further reading

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Corresponding author

Tianmei Wang can be contacted at: wangtianmei@cufe.edu.cn