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Investigating Sustained Participation in Open Design Community in China: The Antecedents of User Loyalty

Ruo-Yu Liang [1], Wei Guo [2], Ling-Hao Zhang [1,*] and Lei Wang [2,*]

[1] School of Design, Jiangnan University, Wuxi 214122, China; lryasa@tju.edu.cn
[2] School of Mechanical Engineering, Tianjin University, Tianjin 300072, China; wguo@tju.edu.cn
* Correspondence: wowo.zlh@jiangnan.edu.cn (L.-H.Z.); tjuwl@tju.edu.cn (L.W.); Tel.: +86-1386-185-7116 (L.-H.Z.); +86-1382-018-8225 (L.W.)

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Abstract: Understanding what drives user loyalty is a central theme in the research fields of open design community (ODC) and sustained innovation. Drawing on theories of network externalities and expectation disconfirmation, this paper develops a theoretical model reflecting the effect of determinants on user loyalty. The model is tested utilizing survey data amassed from 389 users of a typical ODC, Xiaomi Corporation's forum, in China. The major findings of our work as follows: First, satisfaction plays the most important role in explaining the user loyalty to ODCs, and disconfirmation of fan care is the most critical factor influencing user satisfaction. Second, the perceived network size exerts negative impact on user loyalty to an ODC. Third, impacts of different factors on user loyalty vary due to gender difference. This research advanced the knowledge in Open Design by demonstrating the antecedents of participant's loyalty towards ODC, and highlighting the motivations of individual's open design participation behavior.

Keywords: firm-hosted open design community; user loyalty; sustained participation; network externalities; expectation disconfirmation

1. Introduction

Since innovation may create new markets and profit growth possibilities, new product development (NPD) plays a crucial role in the survival and expansion of enterprises [1]. In traditional NPD process, most of the product ideas/designs are proposed by the designers and engineers of the companies. Nevertheless, numerous NPD projects failed because the products did not meet customers' expectations [2]. Some pioneer firms have realized the importance of consumers' needs and began to use customers as external innovation sources to increase the success rate of NPD [3]. For instance, Procter and Gamble (P and G) have initiated an online open innovation platform, named connect + develop (C+P), for NPD. P and G puts its needs (e.g., bottleneck issues the enterprise encounter during the process of product development) on C+P, and invites users to contribute knowledge, ideas and designs to solve these challenges [4]. With C+P strategy, P and G's NPD productivity has increased by almost 60%; and many of P and G's best-selling products are coming from C+P [4]. Hence, as important an innovation forces, users can exert significant impacts on the success of NPD.

In various industrial fields, "open innovation" strategy provides an approach for organizations/enterprises to enhance the flow of ideas across their boundaries [5–7]. The exploitation of open source software (OSS) is a typical application of open innovation. In the development domain of OSS, the source code of a program is publicly available and often shared through the Internet. The netizens with adequate skills can join their favored software exploitation projects,

and improve the design of existing code or contribute new code to facilitate the development of these projects [8]. The OSS projects are often implemented in the context of online communities; researchers, businessmen, and even hobbyists can initiate projects to develop software to satisfy their own needs [9]. Numerous well-known software products, such as Linux, were born in OSS communities. Most programmers contribute to these communities "for free", previous literature considered that sense of identification, enjoyment, and expectation towards software function, etc., play a positive effect on programmers' contribution behavior [8,10–13]. Many enterprises have recognized the economic value of OSS, and started to sponsor the development of OSS projects [8]. For example, Red Hat, an American multinational software company, developed a business model based on OSS. They sponsor the OSS projects and send their employees to work with the community members to produce open source code. Based on the OSS projects, Red Hat launched their own version of the software (e.g., Red Hat Linux), and sold subscriptions for the training, integration services, and support which assisted consumers in applying the OSS products of their version [14,15]. The open source business model has brought tremendous benefit to Red Hat. Similarly, in the field of open source hardware (OSH), developers have launched many OSH projects in online communities, such as RepRap (3D printing) and Arduino (single-board microcontroller); enterprises sponsored some of these projects and developed commercial versions of the OSH products [16–20]. So far, scholars have acknowledged that open source has important influences on the development of enterprises. However, since most of the open source projects were initiated by non-profit organizations or individuals in the context of third-party sponsored online forums, a large number of projects are loosely organized, and the development progress of products is slow and uneven. Enterprises have to invest time and human resources to find the projects with high economic value and assist initiators to organize and manage the projects. Thus, companies must take risks to sponsor the open source projects.

In order to reduce capital outlay, risk, and develop commercially valuable products, more and more companies launched their own online platforms to implement open innovation strategy [21]. There are two main options for enterprises to involve users in NPD projects: They may initiate an innovation contest platform or they can launch a firm-hosted open design community (ODC) [22]. The former is focusing on soliciting designs/ideas from crowds, where the participation motivation of individuals relies heavily on extrinsic rewards such as money payments [23,24]. The latter is developed based on online community, which encourages members to contribute contents and interact with others; within such communities, companies disclose the design-related issues they face via posts, and motivate external experts or users to contribute (via post text, images, and videos in forum) to solve these predefined design challenges [22,25–27]. For instance, P and G and LEGO have initiated online innovation contest platforms to acquire new designs/ideas; and Local Motors, Sony, and Ducati have launched ODCs to settle technical problems [21,22]. Nevertheless, a great number of enterprises did not create value from those ODCs [21]. Scholars suggested that the lack of individuals' sustained participation was the key reason for this result [28]. Thus, user retention or loyalty is of critical significance to the development of ODC.

The open-design movement in China was initiated in the early 2000s, a large number of enterprises (e.g., Haier, Midea) participated in this movement and launched ODCs. Among them, Xiaomi Corporation is a typical representative [1,3,29]. Xiaomi is a mobile Internet company focused on designing and manufacturing smartphones; it was founded in 2010 and has a market value of more than $30 billion today. The ODC (i.e., Xiaomi Forum) is one of the core competitiveness of Xiaomi Corporation, the forum has around 45 million registered users and over 65 percent of them are members with high degree of loyalty; Figure 1 shows the user interface of Xiaomi Forum [21]. With a legion of brand advocators (i.e., brand fans), Xiaomi gains plenty of valuable ideas and designs, which assist it to design cost-effective products [30,31]. Hence, open design exerts significant effects on the development of enterprises, and loyalty may play a significant role in facilitating user's sustained participation behaviors (e.g., design/idea/knowledge contribution).

In virtual environments (e.g., online communities), user loyalty is usually lower than in offline communities [32]. The relatively low switching cost induces a large number of migration behaviors in online communities. Individuals could change from one community to another with only a few simple steps. Therefore, operators should have a good understanding of the precursors of loyalty, and put more efforts in enhancing members' loyalty towards the community. Previous literature have probed the antecedents of loyalty in the context of social network sites and professional platforms (e.g., innovation contest platform) from multiple perspectives, however, as far as it has been understood, very little work has been done heretofore to explore the predictors of user loyalty towards ODCs. In addition, most of the studies in the research field of individual loyalty were carried out from a managerial perspective [33]; they have demonstrated the positive impact of some environmental issues (e.g., usefulness, complementary) and personal factors (e.g., trust, satisfaction, identification) on user loyalty [34–36]. While some other factors (e.g., interaction) and other types of communities (e.g., ODC) have not received sufficient attention.

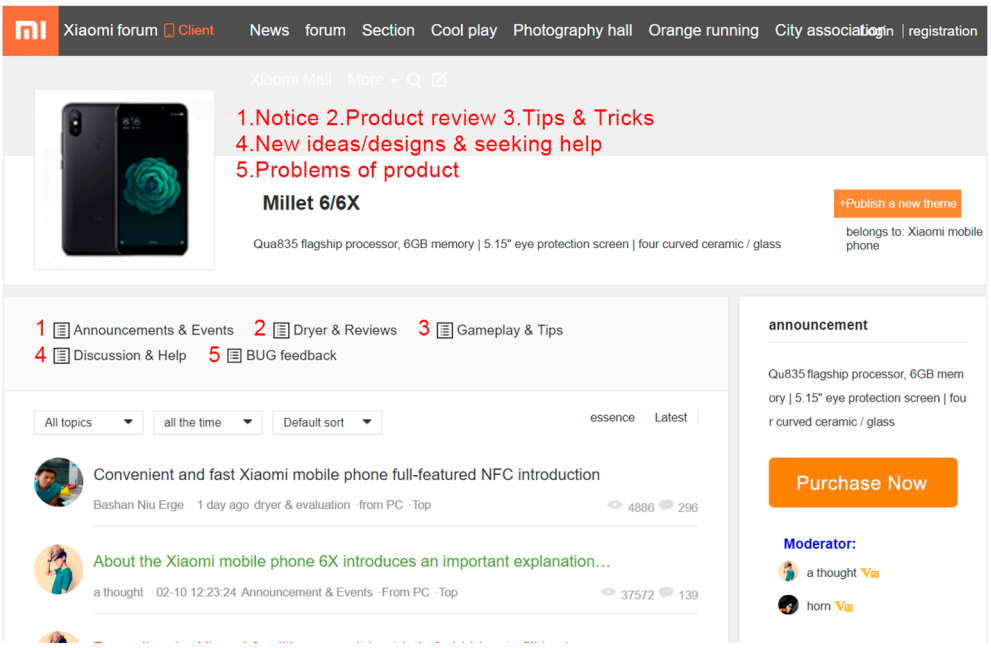

Figure 1. User interface of Xiaomi Forum (Section of MI6/6X).

We attempt to fill the literature gap. In this work, we aimed to probe the key factors determining user loyalty in the context of ODC. The main research questions include:

(1) What are the antecedents of user loyalty to ODC?
(2) Whether user perception of interaction with community managers (perceived respect and perceived fan care) play an important role in user loyalty to ODC?
(3) To what extent the user loyalty is affected by these factors?

This research is novel in that it considers user perception of interaction with community operators. And our results provide convincing evidence that perceived respect and perceived fan care significantly influence user loyalty to ODC. On the whole, this paper provides a new view on the precursors of user loyalty. The remainder of this work is organized as follows. Section 2 reviews the relevant literature on open innovation, user loyalty, and the Xiaomi Forum. Additionally, Section 3 proposes the hypotheses and research model. Next, the research methodology which includes constructs (i.e., latent variables) measurement, data collection and analysis, and results of hypothesis testing is described in Section 4. Then, the research results are discussed in Section 5. Finally, Section 6 draws the conclusions.

2. Theoretical Background

2.1. Open Innovation in the Context of Online Platforms

Enterprises that wish to implement open innovation will need to encourage individuals to contribute designs, ideas, and innovations. One method for companies to collect these resources is to run an innovation contest platform. Within the website firms post their needs (for products, technology, ecommerce, etc.) on certain sections, and users can find the need that is a match for their innovation through the retrieval system [23]. The managers will choose the best ideas/designs as solutions for their needs and pay the users for their contributions [24]. In order to get the reward, users will try their best to propose outstanding ideas to defeat the competitors. Prior literature confirmed that participation in such a context relies on the potential of reward rather than on the internal satisfaction of contributing [37]. Cuusoo hosted by LEGO, C+P hosted by P and G and OpenIDEO hosted by IDEO are typical representatives of innovation contest platform [3,4].

Another approach for companies to initiate open innovation is to launch an ODC [22,38]. Such community often starts out as customer support forum in that consumers exchange information (e.g., usage tips, attentions) of the enterprise's products/services and evolves into a channel by that users can propose suggestions on product modification and develop extensions [27,38–41]. Some of the good ideas contributed by the customers may be adopted by the company [38]. Additionally, the firms often post the problems they meet in the process of NPD, and motivate users to contribute contents (e.g., designs, ideas) to solve these issues. Additionally, ODC can also be used to help the enterprise to identify the lead users, whose needs will be general in a marketplace in the near future [42]. These users often contribute valuable ideas; and many firms, such as 3M and Xiaomi, invite them as external experts to participate in the NPD projects [43]. Although ODC is a widely used online platform for implementing open innovation, relatively little empirical work has been done to systematically explore the users' participation behavior in such context. Hence, more in-depth investigations are necessary.

2.2. User Loyalty to Open Design Communities

Since the last century, much attention has been paid to the concept of loyalty in the business literature [44]. According to Oliver's suggestion, loyalty is "individual hold a firm belief that she/he will reuse a preferred service/product constantly in the future, in spite of marketing efforts and situational influences having the potential to induce switching behavior" [45]. In a sense, loyalty decides the users' readopt intentions: if the individual is loyal to the providers, she/he will reuse their service/product, if not, the individual may not apply the service/product again. In addition, loyalty also exerts significant influences on the survival of ecommerce [44].

However, loyalty is not equivalent to readopt intention. To distinguish between the two concepts, we first introduce two types of loyalty: behavioral loyalty and attitudinal loyalty [46]. Behavioral loyalty refers to the readopt behavior, and attitudinal loyalty reflects repeat adopting intention. It is necessary to differentiate true loyalty from spurious loyalty, as users may reuse an online community while keeping a negative attitude to this behavior. Anderson and Srinivasan argued that e-loyalty is users' approving attitude to an e-business and results in readopt behavior [47]. Thus, user loyalty to ODC could be considered as a revisit behavior based on a positive attitude.

Literature on virtual community loyalty-related issues is quite limited. One of the research hotspots is the effects of interaction on individual loyalty. Some viewpoints of interaction (e.g., familiarity, similarity, expertise, benefits) were certified to exert positive impacts on user loyalty [33,48]. However, these studies seldom give consideration to the interaction between users and community managers. In this work, we seek to address the gap from the perspective of user psychological feeling. Additionally, the influence of the relationship between users and communities (e.g., commitment, engagement, trust, satisfaction) on loyalty is also the focus of academic research [49,50]. However, little knowledge has been obtained about the influence of network externalities and expectancy disconfirmation that have

been proven to have significant impact on loyalty to online social networks [51]. In this article, we also explore whether these factors have positive influences on participants' loyalty in ODC.

2.3. Open Innovation in Xiaomi Forum

User involvement in innovation is a key characteristic of Xiaomi [1,3,7]. When the company was created, the managers of Xiaomi emphasized the important role of customers in NPD, as Li Wanqiang, the Vice President of Xiaomi Technology Co., Ltd., said, "We attempt to identify the nuance of consumers' comments. Small changes can result in big effects. Without users' feedback, we cannot design a well-functioning product." [3]. A three-step method is conducted to implement the open design projects [3]: First, Xiaomi launched ODCs (i.e., Xiaomi Forum and MIUI Forum) to establish and strengthen relationships with customers. The operators have put great efforts (e.g., respond to their complaints properly, solve users' problems effectively, organize offline events) into developing stable relationships with users; and they try to transform users into fans of the brand [21]. Since the brand advocators can only use the spare time to participate in the online activities (some of the users just spend 30 min to an hour per day to interact with other members and contribute information in the ODC), Xiaomi needs a large number of fans to launch their innovation projects. Second, based on the fans' technical skills, Xiaomi divided them into four sub-groups, i.e., developers, spreaders, testers, and normal fans. Among them, developers can work with designers and engineers of Xiaomi to design new products, they are the members of honorable development team, and the number of developers is about 1000. Spreaders are not directly related to the product development. Their duty is to respond to community users' posts. Normal spreaders are required to spend at least an hour per day in the ODC to reply questions from customers [3]. Testers are responsible for testing the prototype of the product and composing test report. There are around 100,000 testers in Xiaomi's ODCs [3]. The rest users are normal fans. They contribute designs and ideas to assist the firm to improve the products, and vote on new functions to be developed. Third, Xiaomi organized internal development activities around users. During this process, Xiaomi collects the demands and ideas from the fans to plan the future features of the product, and the spreaders will release these features for community users to vote on. The features that receive the most votes will be developed in the new products. Developers will cooperate with the designers to exploit the products, and the testers will test the prototype and identify the issues. The spreaders will release the list of product issues, and the normal fans/regular users will share their ideas and solutions on how to solve these problems. Most products of Xiaomi were developed by this method, and one third of products' functions were coming from fans [1,3,29]. Although fans may receive material rewards from the enterprise, previous studies have verified that the main motives for individuals to participate in Xiaomi's NPD projects are internal factors, such as a sense of belonging, satisfaction, shared value, and social interaction ties [3,21,52]. Therefore, Xiaomi Forum is an ideal setting for the research of users' loyalty towards ODC.

3. Research Model and Hypotheses

3.1. Antecedents to the Formation of Loyalty: Open Design Community Identification and Satisfaction

Identification is a key factor in affecting individual's adoption behavior; it describes individual's sense of belonging to a certain organization. Identification is related to user psychological and emotional state, and an intense emotional attachment towards an online community is important to the formation of individual's continued usage intention [53]. Previous studies have confirmed that sense of belonging towards a group has a positive impact on user's sustained participation [54]. Identification has nearly the same effect as satisfaction on user loyalty; if the user is identified with a group, she/he will accept the group's views and purposes (e.g., product design) as her/his own [36]. Therefore, we suggest:

Hypothesis 1 (H1). *Identification with an ODC has a positive effect on user loyalty.*

The development of user loyalty is also affected by satisfaction, which originates from the evaluation of one's use of the services and applications (e.g., design tools) provided by the community and can lead to a concentrate of attention on specific goal [55]. Satisfaction may promote user's continuing intention towards the online community, many studies considered that the satisfied members tend to keep a long-term relationship with the community operators [56]. This relationship is stronger in online environments than offline environments [57]. DeLone and McLean argued that future intention in using information system is led by user satisfaction [35]. The marketing literature also provides proof for the positive influence of satisfaction on individual's emotional tendency towards business organization [58]. Thus, we state:

Hypothesis 2 (H2). *Satisfaction with an ODC usage has a positive effect on user loyalty.*

3.2. Antecedents to the Formation of Identification: Network Externalities

Network externality (also called network effect) is the effect described in economics that "a user can obtain more value or effect with the increase of users, services, or complementary products" [59]. Prior studies claimed that network externalities play crucial roles in facilitating user behavior of using information technology [60]. The network size may exert positive impacts on user's intention to take part in the activities of an online community [61]. Fiedler and Sarstedt's studies suggested that the identity-based group attachment can be predicted by the components of network externalities like network size, etc. [62]. Following Lin and Bhattacherjee's work, we select three factors, which are perceived network size, number of peers, and perceived complementarity, to measure network externalities [63].

Perceived network size refers to the individuals' knowledge about the present user scale of the ODC. Haslam argued that the group's membership size may have a decisive effect on the development of user's identification with the group [64]. When the size of ODC is large, users can expand their social networks, obtain more communication chances and gain a better understanding of the enterprise/brand, which may enhance participants' identification towards the community. Therefore, we suggest:

Hypothesis 3 (H3). *Perceived Network Size has a Positive Effect on ODC Identification.*

Number of peers reflects the quantity of the user's acquaintances that are using the same community. The individuals tend to coordinate and cooperate with the people they know to achieve common goals, such as design new products. If a member can interact or communicate with their acquaintances at any time in a community, she/he is more likely to use the website continuously, and in turn, identify with the community [65]. Conversely, if the user abandons the community, that may represents a decrease of the user identification of it. Hence, we state:

Hypothesis 4 (H4). *Number of peers has a positive effect on ODC identification.*

Perceived compatibility is a well-used factor in explaining user's behavioral intentions in the context of commercial information system. It refers to the user's perception that whether service/product provided by the enterprise is in line with the values, requirements and experiences of their own [66]. Some scholars' work indicated that compatibility has a significant impact on individual's evaluation and impression of the online forum [67,68]. Song et al. pointed that if the users' perceived compatibility is positive, they are likely to continue using the community and their identification with the website may be increased [69]. Consequently, we suggest:

Hypothesis 5 (H5). *Perceived compatibility has a positive effect on ODC identification.*

3.3. Antecedents to the Formation of Satisfaction: Expectancy Disconfirmation

When choosing services and products, consumers usually use their prior expectations about the products and services as a reference substance [70]. However, there is a gap between individual expectation and actual performance of service/product, and it is positive when performance out beyond expectations, or negative when performance lower than expectations [71]. This gap is referred to as expectancy disconfirmation [40]. Previous literature considered that expectation disconfirmation has important influences on the formation of individual satisfaction [72]. Bhattacherjee indicate that performance disconfirmation exert decisive effects on user's satisfaction towards online business platform [73]. Bhattacherjee and Premkumar's work revealed that the realized disconfirmation determines user satisfaction of information technology [74].

An ODC can bring many benefits to the enterprise, such as new product ideas, powerful marketing, promotion opportunities, etc. However, the dynamics of ODC can also exert adverse effects on the development of firms, such as promoting the formation of users' negative views towards the community [75]. Thus, companies must utilize effective management measures, such as guide public opinion and response to users' complaints properly, to maintain the positive opinions among the community members [76]. From the perspective of participants, the enterprises' responses represent their respect to participants. A quick, honest, and positive attitude may induce a positive disconfirmation, which will increase users' satisfaction. Accordingly, we state:

Hypothesis 6 (H6). *Perceived respect (disconfirmation of respect) has a positive effect on user satisfaction.*

A popular community not only provides substantive and honest feedback to participants, but also creates a homelike atmosphere, which may facilitate the formation of users' sense of belonging towards the forum. When fans/users feel that the enterprise cares about them, their satisfaction with the enterprise rises considerably [29]. The growth of customer satisfaction results in enhanced loyalty, which has important implications on users' further participation. Therefore, fan care may exert positive impact on user satisfaction, we state:

Hypothesis 7 (H7). *Perceived fan care (disconfirmation of fan care) has a positive effect on user satisfaction.*

Bhattacherjee's study suggested that usefulness have determinant effects on individual's satisfaction evaluation [73]. Hayashi et al. explored members' sustained participation in e-learning system, they found that perceived usefulness played an important role in promoting the development of user satisfaction [34]. Devraj et al. discussed the precursors of customer satisfaction and preference in the context of e-commerce system, they argued that satisfaction is the descendant of perceived usefulness [77]. These studies highlight the positive relationships between perceived usefulness and user satisfaction, hence, we suggest:

Hypothesis 8 (H8). *Perceived usefulness (disconfirmation of usefulness) has a positive effect on user satisfaction.*

Figure 2 depicts the research model proposed in our work.

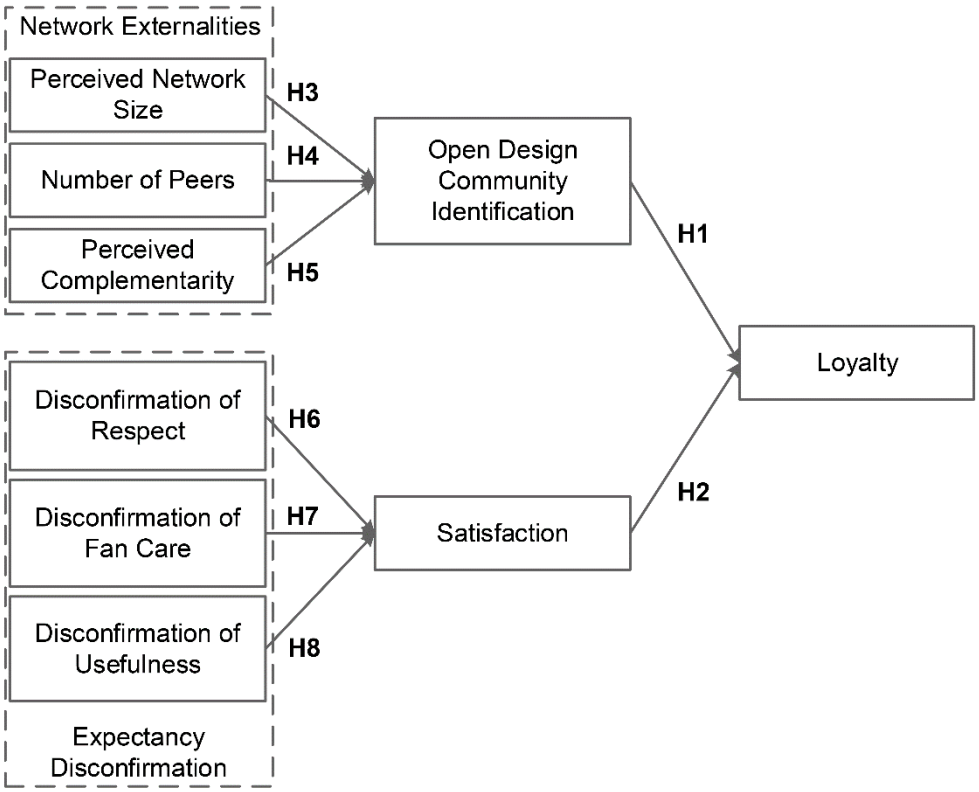

Figure 2. The research model.

4. Research Methodology

4.1. Instrument Development

Nine constructs (i.e., loyalty, open design community identification, satisfaction, perceived network size, number of peers, perceived complementarity, disconfirmation of respect, disconfirmation of fan care, and disconfirmation of usefulness) were measured in the study. The eight hypotheses provided statements that describe the correlations between the constructs of user loyalty and its antecedents. The measurement items were mainly adopted from previous research, as listed in Appendix A. Since the items are considered to be caused by the constructs, this work proposes reflective measures of loyalty. The items on the questionnaire were measured utilizing a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

4.2. Sample and Data Collection

A web-based survey was employed to empirically examine the research model. The data sample comes from members of Xiaomi Forum. We conducted a pre-test with 53 community users (fans of the brand) to validate the properties of the measurement items. The formal questionnaire was revised based on the users' comments and advice, and then, it was published on a well-known online survey platform named WJX (i.e., sojump) [21]. A topic post which provided the hyperlink to the online survey and explained the objective of the research was posted on the community. The netizens who complete the survey will have a chance to get an award. The survey lasted for a month and a total of 409 users participated in the survey. In order to assure the reliability of the survey data, only the participant who has been registered in the community for over six months can take part in the online survey. On account of the regulations established by the survey platform, the questionnaire that was finished less than a minute should be dropped, and the incomplete questionnaires couldn't be submitted. Additionally, the system can also check the participants' identities via their IP address to avoid potential replications. We scrutinized all responses and dropped the questionnaires that are contradictory in answers (e.g.,

the respondent chooses the opposite options in similar questions). Overall, 389 usable questionnaires were gathered for the analysis. Table 1 lists the statistical information related to these respondents.

Table 1. The statistical information related to these respondents.

Characteristics	Categories	Frequency	Percentage
Gender	Male	206	52.97
	Female	183	47.03
Age	Under 20	33	8.49
	20–29	248	63.67
	30–39	77	19.69
	40–49	24	6.11
	Over 50	8	2.04
Education	No formal education	1	0.34
	Primary education	4	1.02
	High school	32	8.15
	University students	102	26.15
	Bachelor	123	31.58
	Graduate students	86	22.07
	Master's/Ph.D. degree	42	10.70
Time spent using the community (per week)	Less than 3 h	69	17.74
	3–8 h	196	50.39
	8–15 h	113	29.05
	More than 15 h	11	2.83

A Harman's single-factor test was applied to examine the common method bias (CMB) [78]. The results suggest that the largest variance explained by a unitary factor is 31.31%, which indicate that no single factor can explain the majority of the variance. Thus, CMB is not a remarkable issue in our work.

4.3. Data Analysis and Results

Our research model and hypotheses were tested by the partial least squares (PLS) technique, which is a widely utilized tool for dealing with latent variable with multiple indicators in a unitary model. It maximizes the variance explained in the dependent variable, uses component-based estimation, is appropriate when data are abnormally distributed and is less demanding on sample size [79,80]. Additionally, PLS is the preferred method for exploratory research, theory development, and existed theory extension [79,80]. The main research goals in this work are to develop theory of loyalty and explain the variance of endogenous constructs. Hence, PLS is appropriate for our study. Following Chang's study, a two-step method was applied to conduct the analysis [81]: first, we evaluated the quality of the measurement model through validity and reliability test, and then we examined the hypotheses through the structural model. SmartPLS version 3.2, which was developed by Christian M. Ringle, Sven Wende and Jan-Michael Becker of Hamburg University of Technology, was used to implement the data analysis in this study.

4.4. Reliability and Validity

In this work, reliability, convergent validity and discriminant validity of all the latent variables were evaluated to validate the measurement model. Composite reliability and Cronbach's alpha are often utilized as measurement of internal consistency of items [82]. Table 2 reveals that all the values of composite reliability (CR) are above 0.8, and the Cronbach's alphas for the measured items are greater than 0.7, indicating adequate reliability [79]. Fornell and Larcker considered that when the average variance extracted (AVE) of all latent variables are higher than 0.5, and the factor loading of all items exceed 0.7, the convergent validity can be verified [83]. The results show that the AVEs of all constructs

ranged from 0.57 to 0.73; all factor loadings are above 0.7 (Tables 2 and 3), meeting the criterion of strong convergent validity. The discriminant validity was assessed utilizing two standards: the values of correlations among the latent variables should be lower than 0.85 and the squared correlations among all latent variables must be less than the corresponding AVE [83,84]. Table 3 shows the correlations among the constructs and square roots of the AVE. The results met both standards, which indicate the adequate level of discriminant validity.

Table 2. The descriptive statistics of the measure objects.

Dimension	Item	Loading	CR	Cronbach's alpha
Perceived Network Size (PNS)	PNS1	0.71	0.86	0.83
	PNS2	0.73		
	PNS3	0.70		
	PNS4	0.76		
Number of peers (NP)	NP1	0.71	0.84	0.82
	NP2	0.79		
	NP3	0.70		
	NP4	0.80		
Perceived complementarity (PC)	PC1	0.73	0.89	0.87
	PC2	0.87		
	PC3	0.76		
	PC4	0.90		
Disconfirmation of Respect (DR)	DR1	0.72	0.82	0.78
	DR2	0.80		
	DR3	0.71		
Disconfirmation of Fan Care (DFC)	DFC1	0.74	0.90	0.88
	DFC2	0.77		
	DFC3	0.81		
Disconfirmation of Usefulness (DU)	DU1	0.91	0.84	0.81
	DU2	0.88		
	DU3	0.70		
	DU4	0.73		
Open Design Community Identification (ODCI)	ODCI1	0.76	0.85	0.83
	ODCI2	0.88		
	ODCI3	0.89		
	ODCI4	0.72		
Satisfaction (SAT)	SAT1	0.87	0.87	0.85
	SAT2	0.72		
	SAT3	0.86		
	SAT4	0.75		
Loyalty (LOY)	LOY1	0.84	0.81	0.73
	LOY2	0.85		
	LOY3	0.81		
	LOY4	0.83		

Table 3. The factor correlation coefficient of the constructs and the square roots of average variance extracted.

	AVE	Latent Variable Correlations								
		PNS	NP	PC	DR	DFC	DU	ODCI	SAT	LOY
PNS	0.62	0.79								
NP	0.59	0.50	0.77							
PC	0.71	0.47	0.35	0.84						
DR	0.64	0.39	0.52	0.54	0.80					
DFC	0.73	0.34	0.50	0.50	0.39	0.85				
DU	0.57	0.40	0.49	0.46	0.47	0.32	0.76			
ODCI	0.68	0.47	0.53	0.47	0.50	0.42	0.44	0.83		
SAT	0.71	0.34	0.44	0.52	0.37	0.33	0.53	0.36	0.84	
LOY	0.65	0.34	0.43	0.37	0.41	0.43	0.37	0.51	0.49	0.81

Note: The square roots of the average variance extracted are exhibited on diagonal (in shade). To assure the discriminant validity, the values under diagonal must be less than those on diagonal.

4.5. Structural Model Analysis

To assess the hypotheses and research model, we employed the bootstrapping algorithm (sample size was 500) to measure the path coefficients and explanatory power of the structural model. The research results are shown in Figure 3; all hypotheses were supported by the path analysis except H3 ($\beta = -0.107$, $p < 0.01$). In addition, the predictive power of the model for the latent dependent variables was measured by R^2 values. As can be seen from Figure 3, the model explains 68.4% of variance in loyalty, 56.2% of variance in design community identification, and 60.3% variance in satisfaction. All R^2 values of the dependent construct are above 0.5, indicating acceptable predictive power of the research model.

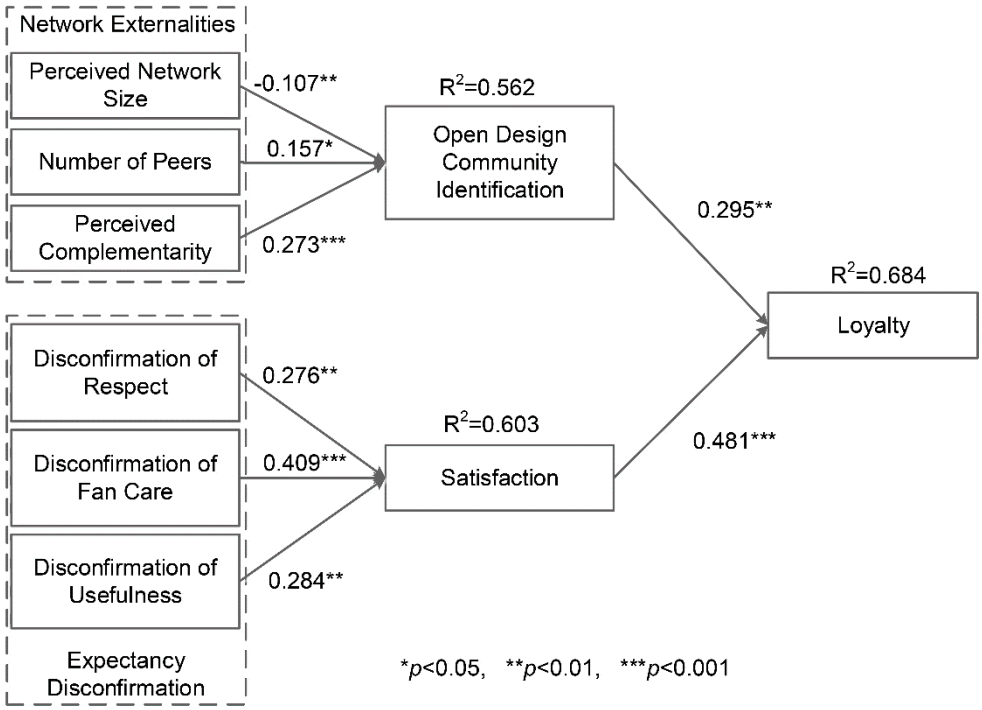

Figure 3. Structural model results.

5. Discussion

5.1. Correlations between Network Externalities, Expectancy Disconfirmation, Open Design Community Identification, Satisfaction, and Loyalty

The results indicate that network externalities, expectancy disconfirmation, open design community identification and satisfaction play important roles in user loyalty. Compared to network externalities, expectancy disconfirmation has a larger impact on loyalty. We apply indirect effects to assess the importance. The indirect influence of expectancy disconfirmation on user loyalty via satisfaction is 0.466 ($0.276 \times 0.481 + 0.409 \times 0.481 + 0.284 \times 0.481$), while the indirect effect of network externalities is 0.095. Similarly, satisfaction ($\beta = 0.481$, $p < 0.001$) is more important than open design community identification ($\beta = 0.295$, $p < 0.01$) in shaping user loyalty. Our results are inconsistent with Thomson's conclusion, which argued that identification may exert a stronger impact on user-company relationship than satisfaction [85]. A possible explanation is that most users of the ODC have identified with the brand or enterprise before they take part in the online activities (e.g., contribute designs/ideas, share knowledge). Identification may be the precondition for individuals' participation, but it has a limited effect on users' emotional tendency. Meanwhile, satisfaction may play a more significant role in fostering emotional connection between individual and ODC. If users' demands are fulfilled, they are very likely to have positive feelings towards the community and, in turn, enhance their loyalty.

In network externalities, perceived network size is found to exert negative influence on open design community identification ($\beta = -0.107$, $p < 0.01$), one possible explanation is that excessive users generated a great deal of useless information that impeded the daily communication among members. Users have to interact with other members frequently to manage the very large flow of information [86]; and large network size make users take more time and effort to maintain high quality relationships with others [87]. Perceived complementarity ($\beta = 0.273$, $p < 0.001$) has larger effect on open design community identification than number of peers ($\beta = 0.157$, $p < 0.05$). The result shows that members care more about community services than interactions with others in ODC. Since ODC is a type of professional online platform, most users join it with clear purposes, they tend to pay more attention on the features of the community, such as services, functions, etc., and the social expectations of these users are not as strong as the social network site members possess.

As for the predictors of user satisfaction, we find that disconfirmation of fan care is the most outstanding one ($\beta = 0.409$, $p < 0.001$). Positive disconfirmation of fan care induces a sense of belonging. Therefore, when fans feel that a community cares about them, their satisfaction with it rises considerably. Disconfirmation of respect ($\beta = 0.276$, $p < 0.01$) and disconfirmation of usefulness ($\beta = 0.284$, $p < 0.01$) play similar roles in promoting the formation of user satisfaction. Perceived usefulness represents an instrumental belief [88], while perceived respect has a significant effect on the changes of individual's internal emotions [89]. These results confirm that both practical value and emotional experience are decisive precursors of user satisfaction.

5.2. The Moderating Impact of Gender on Loyalty to ODC

In this study, the moderating impact of gender on user loyalty was also analyzed. The sample was divided according to gender, a sub-group of males (206 samples), and a sub-group of females (183 samples). To compare the effect of gender on the relationships between the independent and dependent variables, we applied *t*-statistics to analyze the path coefficients of the structural model of these two sub-samples [90,91]. The comparison results are shown in Table 4. The relationship between ODC identification and loyalty is significantly stronger for males ($t = 3.54$, male path coeff. = 0.367, female path coeff. = 0.202), while the correlation between satisfaction and loyalty is stronger for females ($t = 3.72$, male path coeff. = 0.411, female path coeff. = 0.574). Differences are also significant for other variables like number of peers, disconfirmation of respect, etc. The number of peers has stronger impact on ODC identification in female than in male. A possible explanation is that women may pay more attention to their social circle than men did, and the friendly atmosphere can encourage female

users to develop long-term relationship with the community [92]. However, the disconfirmation of respect has larger impact on satisfaction in men than women, which suggests that esteem may exert more effect on males' behavior intentions than on females'. These results confirmed the influence of gender, and highlight the differences of antecedents of loyalty between males and females in the context of ODC.

Table 4. Statistical comparison of paths.

Paths	Male	Female	Statistical Comparison of Paths
	Path Coefficients/(*t*-Values)	Path Coefficients/(*t*-Values)	
Open design community identification → loyalty	0.367 (2.35 **)	0.202 (2.01 *)	3.54 **
Satisfaction → loyalty	0.411 (2.88 **)	0.574 (3.61 **)	3.72 *
Perceived network size → open design community identification	−0.212 (−1.99 *)	−0.075 (−1.56)	4.31 *
Number of peers → open design community identification	0.093 (1.90)	0.342 (2.25 **)	5.23 *
Perceived complementarity → open design community identification	0.297 (2.19 **)	0.225 (2.02 **)	3.24 *
Disconfirmation of respect → satisfaction	0.514 (3.49 **)	0.246 (2.04 *)	4.85 **
Disconfirmation of fan care → satisfaction	0.355 (2.32 *)	0.543 (3.56 **)	4.07 *
Disconfirmation of usefulness → satisfaction	0.447 (3.02 **)	0.303 (2.20 *)	3.55 *

Note: ** $p < 0.01$, * $p < 0.05$

6. Conclusions and Limitations

This work proposes a research model for analyzing factors affecting user loyalty to ODC by combining network externalities and expectancy disconfirmation theory. The empirical analysis results provide good support for our research model.

The study findings provide several implications for the research of ODC and sustained innovation. First, although ODC has been a new hotspot of online community research, very little work has focused on the predictors of user retention or loyalty in such context. Hence, our paper contributes to literature by developing a research model, which includes identification, satisfaction, network externalities, and expectancy disconfirmation, to explore the precursors of user loyalty in ODC. The research results verified that most of the factors positively affect the development of loyalty, which may open up a new direction for future research on individual's sustained participation in online innovation platform. Second, scholars have acknowledged that the interactions among users may exert positive effects on the formation of loyalty. Nevertheless, prior research largely ignored the influences of interactions between users and community operators on loyalty. In order to fill this gap, we applied the theory of expectancy disconfirmation to probe the impacts of operator-related factors on loyalty. The empirical results show that disconfirmation of respect, disconfirmation of fan care and disconfirmation of usefulness significantly influence satisfaction, and in turn, affect the cultivation of loyalty. These findings provide foundations for further work on the effects of interactions between customers and managers in information system.

Some practical implications can be drawn from this paper. First, satisfaction was proved to be the most crucial factor in facilitating the formation of user loyalty. Disconfirmation of fan care exerts a stronger influence on satisfaction than other variables. Consequently, the design community operator should provide honest and sincere feedback as well as the best and affordable service to each

fan. This will increase fans' loyalty towards the community, promote meaningful interactions among them and enhance their willingness to contribute designs/ideas [29]. Second, number of peers and perceived complementarity have significant impact on ODC identification. Within the community, members have chances to meet new friends and widen their social circles through their friends or relatives [61]. Practitioners should develop more useful applications to facilitate communication among the users and reinforce users' identification to the community. Third, perceived network size exerts negative influence on user loyalty towards ODC. Overly frequent interactions may cause some difficulties in managing the flow of information [86]. Therefore, keeping a moderate community size, and reduce redundancy are very important for the development of the platform. Fourth, impacts of different factors on user loyalty vary due to gender difference. This finding recommends that ODC operators should provide personalized services according to user requirements and gender differences to improve user's experience.

Despite the valuable achievements, this study still has some limitations. First, our sample represents only Chinese-speaking users of ODC. Therefore, the results have limited generalizability to ODCs in diverse cultures. Future research will assess the availability of this study's results in different countries. Second, in our work, the data for all constructs were collected by respondent self-reporting; nevertheless, since the online survey was anonymous, the participants' self-reported items for the tenure and extent of usage could not be cross-validated, and their future online behavior could not be tracked. Further study may utilize supplementary data on individual's sequent acts to track their future adoption behavior accurately.

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Appendix A Measurement Items

Perceived Network Size (PNS) (adapted from [93])
PNS1: In my opinion, many people are using Xiaomi Forum.
PNS2: In my opinion, most product users of Xiaomi tend to use Xiaomi Forum.
PNS3: I think Xiaomi Forum has a big user base.
PNS4: I think the user group of Xiaomi Forum is getting bigger and bigger.
Number of peers (NP) (adapted from [93])
NP1: I think many friends around me use Xiaomi Forum.
NP2: I think most of my friends are using Xiaomi Forum.
NP3: I anticipate many friends will use Xiaomi Forum in the future.
NP4: I believe many friends or relatives will use Xiaomi Forum in the future.
Perceived complementarity (PC) (adapted from [93])
PC1: Xiaomi Forum is highly compatible with my mobile devices.
PC2: Xiaomi Forum is highly compatible with the websites I usually visit.
PC3: Xiaomi Forum is highly compatible with other open design communities.
PC4: Xiaomi Forum is highly compatible with the forum applications I usually use.
Disconfirmation of Respect (DR)
DR1: The quality and amount of Xiaomi Forum's feedback is better than I expected.
DR2: The sincerity of Xiaomi Forum's feedback is better than I expected.
DR3: The timeliness of Xiaomi Forum's feedback is better than I expected.
Disconfirmation of Fan Care (DFC)
DFC1: The concern provided by Xiaomi Forum is better than I expected.
DFC2: The welfare provided by Xiaomi Forum is better than I expected.

DFC3: Overall, the care from Xiaomi Forum is better than I expected.

Disconfirmation of Usefulness (DU) (adapted from [94])

DU1: The improvement of my interpersonal relations exceeds my expectation when using Xiaomi Forum.

DU2: The increase of my technical knowledge exceeds my expectation when using Xiaomi Forum.

DU3: The increase of my mobile phone maintenance and troubleshooting skills exceeds my expectation when using Xiaomi Forum.

DU4: I feel that the usefulness of Xiaomi Forum is better than I expected.

Open Design Community Identification (ODCI) (adapted from [51])

ODCI1: I identify with Xiaomi Forum.

ODCI2: When someone praises Xiaomi Forum, it feels like a personal compliment.

ODCI3: If stories in the media criticize Xiaomi Forum, I feel bad.

ODCI4: I feel that Xiaomi Forum's success is my success.

Satisfaction (SAT) (adapted from [95])

SAT1: I think that I do the right thing in using Xiaomi Forum.

SAT2: I'm pleased with my experience of using Xiaomi Forum.

SAT3: My decision to use Xiaomi Forum was a wise one.

SAT4: If I were to do it again, I would feel the same about using Xiaomi Forum.

Loyalty (LOY) (adapted from [73])

LOY1: I would say positive things about Xiaomi Forum to my relatives and friends.

LOY2: I would recommend Xiaomi Forum to someone who seeks my advice.

LOY3: If I could, I would like to continue using Xiaomi Forum in the future.

LOY4: I plan to continue using Xiaomi Forum in the future.

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