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REGULAR ARTICLE

A bottom-up simulation on competition of online interpersonal communication platforms

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Abstract

The competition of interpersonal communication platforms is a complex process affected by various factors. This paper aims to simulate and analyze this process from a bottom-up perspective. Individual platform selection serves as the micro-foundation for the study. The evolution of online interpersonal communication networks, and innovations proposed by online interpersonal communication platforms, would also impact this process by affecting individual selection on those platforms. Three scenarios were designed for this study to simulate typical modes of competition. In this regard, the simulation results were compared to practical cases. Taken together, this bottom-up simulation model could reproduce and anticipate the applied competition process associated with such platforms. Based on this model, it was found that, in any case, one online interpersonal communication platform will eventually monopolize the market, either partly or entirely. The late entrant platform, comprising a major innovation, tends to fail when competing with the incumbent monopoly due to "network externalities." Even when two competing platforms continue to propose innovations, and they will alternately lead the competition due to those innovations, this type of replacement of their competitive positions in the market may only occur a few times and then disappear completely.

Keywords Bottom-up simulation · Internet platform competition · Social network service (SNS) · Network externalities · Internet platform innovation

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1 Introduction

Nowadays, the Internet is ubiquitous. An interesting and widespread phenomenon is the existence of large firms, whose platforms have significantly more users than their competitors, nearly monopolizing regional or national markets in each Internet service domain. For instance, in the USA, the big four—Google, Amazon, Facebook, and Apple—are known as GAFA (Miguel and Casado 2016), and in China, the big three—Baidu, Alibaba, and Tencent—are known as BAT (Keane 2016). Platforms such as Facebook, Tencent's QQ, and WeChat belong to social networking services (SNS), enabling their users to construct and maintain social relations in cyberspace (Jung and Lee 2011). According to previous research (Ellison et al. 2006; Hargittai 2007; Fogel and Nehmad 2009), a substantial proportion of the population in many countries, who rely heavily on SNS platforms for social engagement, spend a significant amount of time on those platforms.

Today's SNS platforms provide many functions, including presenting personal opinions and feelings on things (Tang and Hew 2017), sharing photographs and videos (Gibbs et al. 2015), searching for specific information and knowledge (Zahn et al. 2010), learning how to complete procedural tasks (Lee and Lehto 2013), and even browsing content shared by others just for fun and killing time (Ellison et al. 2006). It is believed that the most fundamental and important function of those SNS platforms is facilitating interpersonal communication, especially with acquaintances (Ellison et al. 2007), while other functions are essentially related to this. Moreover, the success experienced by Facebook and WeChat is inconceivable without this fundamental function. Therefore, this paper mainly discussed the competition between online interpersonal communication platforms (hereafter, OICPs) and the most popular and well-known SNS platforms, including Facebook, WeChat, QQ, Line, and Skype, were roughly attributed as relevant platforms in this discussion.

Certainly, many papers have examined the competition between OICPs and other types of Internet platforms. In addition, many factors determining the competitive situation and result have been revealed. First, the number of users of an Internet platform may heavily influence its future competitiveness (e.g.Rohn 2013; Haucap and Heimeshoff 2014; Borsenberger 2015; Baran and Stock 2016). This tendency can be explained by the concept of "network externalities" proposed by Rohlfs (1974), which describes the situation where users may obtain more benefits from a particular product with increased user quantity, complementary products, or services. Principally, those Internet platforms serve as matchmakers between different platform users (Evans and Schmalensee 2016). They facilitate the exchange of goods, services, currency, or information to create different types of value, such as generating economic benefits for their users, fulfilling their specific needs, reducing their negotiation frictions, and saving time (Parker et al. 2016). Network externalities are directly related to the total number of users on those Internet platforms with only one market side (such as those OICPs). For all platform users, a large user base will increase the probability of forming valuable contacts (Haucap and Heimeshoff 2014). Meanwhile, for those Internet platforms with distinct market sides (e.g., Amazon, eBay, and Taobao), the cross-side network effects (Hinz et al. 2020) describe the situation whereby more sellers attract more buyers and vice versa. The users on each side (i.e., the buying and selling sides) will enjoy network externalities from the increase in the number of users on the other side. Consequently, in many Internet service domains, users prefer to join the platform with the largest number of users, leading to a quasi-monopoly competition structure in those domains. Moreover, according to Caillaud and Jullien (2003) and Jullien (2005), a quasi-monopoly competition structure efficiently maximizes the benefits derived by platform users.

Second, many researchers emphasize platform innovation as a critical competitive factor (e.g., Dimmick et al. 2004; Fietkiewicz and Lins 2016; Miguel and Casado 2016; Li et al. 2017). By offering new and promising functions or designs, an OICP can give its users more satisfaction and opportunities for gratification that are essential to attracting and preserving those users (Li et al. 2017). It is quite common that a new OICP with some new functions or designs enters this domain and competes with incumbent platforms based on those innovations (Jung and Lee 2011; Kuchinke and Vidal 2016; Li et al. 2017). Moreover, top OICP holders, such as Facebook and Tencent, always spend a relatively high amount on R&D annually, developing new platform functions to maintain their competitive advantage (Miguel and Casado 2016; Yang et al. 2016).

In addition, there remain many other factors that may all play a role but cannot be discussed in this paper due to space limitations. These factors include the selection of competition strategies by platform holders (Kuchinke and Vidal, 2016); customized services beyond the basic communication function, based on learning from user data (Hagiu and Wright 2020); and policy regulation on OICPs (Mansell 2015).

The competition of OICPs is a complex process along with the expansion of the total number of Internet users, the evolution of online interpersonal communication networks, and the continued roll-out of platform innovations. Many factors, including those discussed above, can affect that process, and these factors act in different ways while sometimes overlapping each other. From a bottom-up perspective, the fluctuation of different OICP users and the changes in the competitive positions of OICPs at the macroscopic level can be the results of platform adoption and abandonment at the microscopic level (Holland 1995; Fu et al. 2015). In this manner, once in a while, a user may change its OICP selection, and an OICP's total number of users will be counted based on each user's platform selection instead of setting its current variation as a function of its previous value. The benefits of this bottom-up model are easily understood. For example, it presents a condensed version of the real world that covers individual platform selection, the entrance of new users and OICPs, the expansion and adjustment of the online interpersonal communication network, the emergence of platform innovations, and the fluctuation of different platform adopters. Importantly, it can demonstrate many representative scenarios on OICP competition that have occurred or are likely to occur. Some competition strategies for OICP holders will be explored by analyzing those scenarios.

The rest of this paper is organized as follows: In Sect. 2, the definitions and theoretical foundations of the components of the simulation model are presented. In Sect. 3, the simulation model is proposed, and the rules of individual platform selection, the evolution mechanism of online interpersonal communication networks, and details of key scenarios are specified. In Sect. 4, the simulation results are analyzed and linked to some practical cases. Finally, discussions and conclusions are presented in the last two sections.

2 Definitions and theoretical foundations of the components comprising the bottom-up simulation model

There are three key components comprising the bottom-up model on OICP competition: individual OICP selection, the evolution of online interpersonal communication networks, and platform innovations. Their definitions and theoretical foundations will be presented before the creation of the simulation model.

First, individual OICP selection includes both platform adoption and platform abandonment. Individual platform adoption does not mean registering a platform account or installing the platform client program on a particular computer or a mobile phone. The adopter should also continuously use the platform for communication since the long-term development of those platforms and their competitiveness relies heavily on their adopters' continuous use, while the impact of ephemeral and inactive accounts on these facets is minimal (Chang and Zhu 2012; Chen et al. 2015).

An individual's basic motivation for adopting an OICP is that the specific platform should afford desired interpersonal communication. Though a user may have hundreds of contacts on their platform's friend list, it is believed that only a small portion of their acquaintances (Hartmann and Wanner 2016) or intimates (Kim et al. 2014) on the list can encourage the individual to maintain their continuous use of that platform. If those contacts leave the platform, the individual will abandon it. In reality, it is very common that a user has frequently contacted acquaintances or intimates who adopt different platforms, which may cause so-called multi-homing (i.e., a situation where a user adopts several platforms simultaneously) (Haucap and Heimeshoff 2014). OICP holders seldom force platform adopters to only use their platforms. Therefore, such multi-homing costs are minimal, limited to installing the program and adding friends.

Parallel to individual OICP adoption, individual platform abandonment is described in this paper as the situation where a platform user stops continuously using that platform, therefore becoming inactive. However, the user may still keep the account and log in occasionally. The most direct reason for individual platform abandonment is that all the frequently contacted acquaintances or intimates on the platform user's friend list have abandoned that platform, making the individual's continued presence on that platform useless. Moreover, the case proposed by Fu et al. (2015) occurs more frequently, whereby a multi-homing user simultaneously adopts two functionally similar platforms: Platforms 1 and 2. In this case, the user 1 day finds that all their frequently contacted acquaintances or intimates either adopt Platform 1 solely or adopt both platforms. In such a circumstance, the user is likely to abandon Platform 2, as keeping Platform 1 is enough to guarantee their online communication with all their acquaintances or intimates. This example is similar to cases where customers prefer "one-stop shopping" instead of visiting several places, thereby seeking to save time, money, and energy (Novelli 1989) and get more convenience (Felker Kaufman 1996).

An exception to those platform abandonment rules occurs for high viscosity users (Shi and Ma 2012; Xue et al. 2017). These users favor one specific platform over all others. It is common to see that many successful and previously successful SNS platforms have a percentage of extremely loyal users (Li et al. 2016; Xue et al. 2017). In some extreme cases, the favored platform may have no obvious advantages over others. Meanwhile, abandoning it would never result in losing any desired contacts. These users will still log in frequently and try to use the platform as much as possible. This situation accounts for the fact that some dying SNS platforms still have tens to hundreds of thousands of active users though their market shares are very low.

Second, the online interpersonal communication network (hereafter, OICN) constantly expands and self-adjusts instead of remaining unchanged. When mentioning OICN, this paper refers to the entire online communication network, comprising all users linked by all OICPs. It is commonsense that the total number of global Internet users has been increasing continuously from its inception to the present day, like the total number of OICP users in each country and globally (e.g.CACS 2020, 2021). This trend is also accompanied by the expansion of the OICN, and every year, many people begin using OICPs as replacements for some face-to-face conversations (Michalec and Leszek 2009). The joining of those new OICP adopters may also impact the OICN structure in many facets. For example, previous research by Li et al. (2009), Xu and Liu (2010), Liu and Chen (2011), and Furtenbacher and Császár (2012) revealed that SNS user networks usually exhibit a scale-free feature in which a few nodes have myriad links while most of them are poorly connected. This situation occurs because people tend to establish contacts with those who already have many links, and those hubs have a higher probability of receiving links from new adopters. Finally, when more and more new adopters enter, some hubs with extremely high connectivity appear (Barabási and Albert 1999).

Besides joining new adopters, the communication relationships between existing platform users would also be adjusted with time. Some people, previously unknown to each other, may add each other to their friend list and communicate frequently. Meanwhile, some frequently contacted acquaintances or intimates may rarely contact or even unfriend each other (Boyd and Ellison 2007; Quercia et al. 2012). In every era, some current OICN links will disappear. Meanwhile, some new links will emerge, and this adjustment seems random from an overarching perspective.

Third, through innovation, an OICP may obtain a competitive advantage for a period. Numerous examples showed that a new function or design helps an OICP establish a place in the market or even take over the leading position. For example, Skype fused peer-to-peer (P2P) and voice-over-Internet-protocol (VoIP) technologies to provide its users with high-quality voice telecommunications at an extremely low cost, which gave Skype a strong competitive advantage over other VoIP service providers, driving the platform to successfully penetrate the markets of more than a hundred countries (Rao et al. 2006). Line developed its stickers based on emoticons introduced in the late 90s to deliver messages easily. Those Line stickers, built from diverse characters with specific backgrounds and stories, are very effective in expressing different kinds of meanings that are difficult or inconvenient to express in words, thereby facilitating Line's emergence as the most popular chat app in Japan and preferred among youngsters in many Asian countries (Jessica and Franzia 2017). Facebook incorporated “Open API[1]” into its business model in 2007, allowing third parties to create applications on the platform. According to Jung and Lee (2011), this innovation gave Facebook a radical increase in users, shortening its competitive gap with MySpace (the market leader at that time) and significantly contributing to it later recording a competitive lead over MySpace.

OICPs become increasingly homogeneous, although platform innovations are introduced every few months or years and seem to emerge continuously. This trend occurs because it is relatively difficult to protect the innovations made by Internet platforms, and most of those innovations will be imitated directly or implicitly by their competitors. Even the very few innovations that are challenging to be replicated can be obtained through platform acquisitions (Fu et al. 2015; Luiro 2018). For instance, all those previously mentioned specific platform functions or designs can be located on most current OICPs (e.g., Facebook, WeChat, QQ, and Line), and it is taken for granted that an OICP should have such functions or designs. In summary, the competitive advantages created by platform innovations would have a period of validity until competitors imitate those platform innovations.

3 The bottom-up simulation model

3.1 Basic assumptions and frame

First, some basic assumptions derived from the previous theoretical discussion are listed hereunder:

1. A person adopting an OICP means that they will use the OICP frequently, and when they become an inactive adopter, they actually have abandoned that platform. The basic motivation for individual platform adoption is maintaining the adopter’s communication with their frequently contacted acquaintances or intimates. Platform abandonment may occur only when this behavior will not result in the user losing any of those contacts. A proportion of platform adopters have strong viscosity to some platforms and will never abandon their favorite platforms under any circumstance.
2. As active platform adopters and frequent communications between platform adopters play essential roles in OICP competition, those ephemeral OICP users and temporary communication links between platform adopters will be ignored. It was prescribed that each node of the OICN denotes an adopter frequently using at least one platform. Each link of this undirected network denotes that its two end nodes frequently communicate with each other via any platform. The OICN is constantly expanding following a scale-free law of degree distribution. A proportion of current links will disappear in each epoch (simulation time step) while some new links will emerge, as the frequent communication relationships between platform adopters will be adjusted with time.

[1] http://en.wikipedia.org/wiki/Open_API.

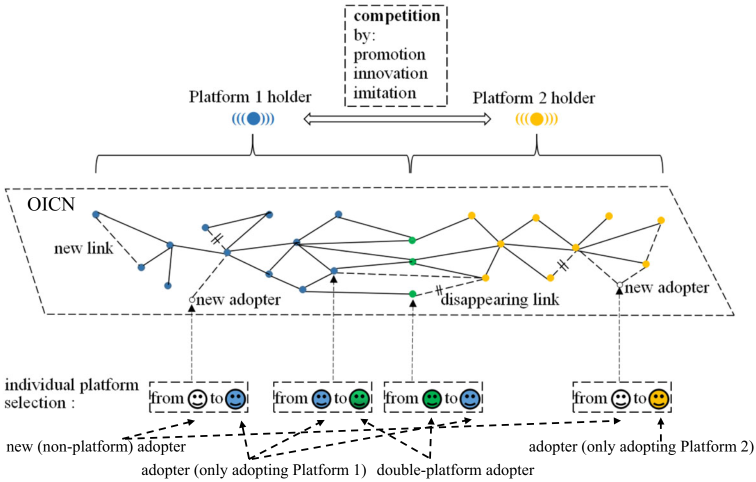

Fig. 1 Frame of the bottom-up simulation model

3. Platform innovations will give OICPs new functions or designs, making them better than their competitors in a given period (called the "platform innovation-effective period" in this paper). During this period, the innovative platform will never be abandoned by its adopters; however, due to imitation by competitors, all platforms will become homogeneous when this period has passed.

Based on those assumptions, we built the bottom-up simulation model (see Fig. 1 for its frame). Individual platform selection takes the bottom position, where an individual decides on platform adoption and abandonment according to the platforms selected by their frequently contacted acquaintances or intimates, the quality of those platforms, and their personal platform preference. The evolution of the OICN is more macro than micro-oriented and positioned higher in this model, describing how new adopters join this network and how existing platform adopters adjust their frequent communication relationships in each simulation time step. Finally, platform holders focus on propagation and promotion to quickly attract many early adopters to build the initial userbase when their platforms first enter the market. After that, they try to improve the quality of their platforms through innovation or imitation.

3.2 Model construction

3.2.1 Individual platform adoption and abandonment rules

The most basic component of this bottom-up simulation model is the adoption and abandonment of individual platforms. In this regard, the specific rules are defined as follows:

$$
\text{one will}\begin{cases}
\text{Adopt a new platform, if anyone of its neighbors adopts only the} \\
\text{platform it does not adopt, or it is attracted by the propagation} \\
\text{and promotion of the new platform.} \\
\\
\text{Abondon a present platform, if} \\
\begin{cases}
\text{that would not result in losing of any contacts with its neighbors,} \\
\text{and it does not have strong viscosity to that platform,} \\
\text{and that platform is no better than the platform it would preserve.}
\end{cases} \\
\\
\text{Maintain the status, otherwise.}
\end{cases} \tag{1}
$$

Here, a node of the OICN is also an OICP adopter, while their neighbors in that network denote frequently contacted acquaintances or intimates. The platform adoption rule takes place in two cases: The first is when a node initially gets a new neighbor who adopts a different platform due to the new node's joining (see white nodes in Fig. 1) or link adjustment mechanism (see the blue node and the orange node just linking by a new link in Fig. 1). The second case occurs when a new OICP first enters this market, at which point many nodes may want to try due to its propagation and promotion. The platform abandonment rule is more rigorous and complex than the platform adoption rule. For example, consider the green node at the bottom of the OICN in Fig. 1. That node adopted Platforms 1 and 2 because its two neighbors just adopted different platforms. The link between it and one of its neighbors (the orange node) now disappears, and it no longer needs Platform 2 to communicate with that neighbor, so it will consider abandoning Platform 2. Furthermore, the green node should not have strong viscosity to Platform 2. A proportion Pv ($Pv << 1$) of the total population will be selected, and each one will be randomly assigned a high viscosity to one platform. These nodes will never abandon their preferred platforms. Moreover, Platform 2 should not be better than Platform 1 at this moment, or in other words, it is not under Platform 2's innovation-effective period. Otherwise, this abandonment will be rejected because it will miss the green node with new functions or designs. All three conditions are indispensable. If all are fulfilled, Platform 2 will be dropped by the green node, and it will become a blue one, as shown in Fig. 1. As a node's platform selection or modification will influence that of other nodes, in each simulation time step, every node's platform selection result will be individually and repeatedly updated until none changes its platform selection.

3.2.2 Evolution mechanism of the OICN

In each simulation round (namely, a run of the simulation program from start to end), an OICN with N_0 nodes would be initialized in the beginning. Each node would be connected to m ($m << N_0$) other randomly selected nodes. Therefore, there were N_0 OICP adopters in the beginning, and each had m frequently contacted acquaintances or intimates as their neighbors in this undirected network. Then, in each simulation time step, a new node i will be added to this network, and m existing nodes will be chosen as its direct neighbors, according to the degree of all existing nodes. For those m new links of node i, an existing node j with degree d_j that has not been connected to it ($j! \leftrightarrow i$) may have a chance to receive one. In this regard, the probability is

$$\underset{j,j!\leftrightarrow i}{Pr} = \frac{d_j}{\sum_{l!\leftrightarrow i} d_l}. \tag{2}$$

(From here until the end, we use subscripts (e.g., i, j, and l in Eq. (2)) to denote the variations in those variables (e.g., Pr and d in Eq. (2)). This node adding mechanism will produce a scale-free network (Barabási and Albert 1999), where the fraction of nodes with degree k follows a power-law distribution:

$$P(k) \sim k^{-\gamma}. \tag{3}$$

Finally, this simulation round will be terminated when the total number of platform adopters N reaches $N_{\max}$.

In each simulation time step, a proportion Pc ($0 \le Pc < < 1$) of links will be randomly selected and removed from the OICN. Then, an equal number of new links will be randomly added between pairs of unconnected nodes to represent the adjustment of the frequent communication relationships between platform adopters in the real world. As those links of the OICN denote frequent communication relationships between OICP adopters, a low Pc value reflects a relatively stable platform adopter's frequent communication structure, while a high Pc value indicates a turbulent one.

3.2.3 Design of simulation scenarios

Besides the OICP holders' competition behaviors, such as promotion, innovation, and imitation, the initial competition situation should also be considered. For instance, an OICP that entered the market when SNS platforms first appeared may encounter very few newly established competitors, or even no competitors, while such platforms entering this market today would only face an incumbent monopolist, and the competition results would be different. Therefore, three simulation scenarios associated with different competitive behaviors of platform holders and initial competition situations were designed to reflect cases in the real world.

Scenario 1 describes that two homogeneous OICPs come into the market when these kinds of platforms first emerge and compete with each other. At the beginning of the simulation, each node randomly selects one of the two platforms (Platforms 1 or 2), and all nodes modify their platform selections according to the individual platform's adoption and abandonment rules (1). Then, in each simulation time step, a new platform adopter will join the network, its first platform selection will be set to mirror its first neighbor (see those white nodes of the OICN in Fig. 1), and all nodes must update their platform selections after the joining of the new node. In this scenario, no platform holder will make innovations. In brief, this scenario is designed to observe the competition of two homogeneous platforms at the same starting point.

Scenario 1 was designed to review the competition between MySpace and Facebook, which is usually viewed as a typical case where the late entrant finally defeated the leading incumbent. However, MySpace started its business in August 2003, only 6 months before the establishment of Facebook. When Facebook entered this market, MySpace was far from being a monopolist. Though MySpace and Facebook later became universal SNS platforms, the groups they initially targeted for propagation and promotion differed. The most successful strategy for MySpace in its early days was donating money to assist clubs, bands, and parties in Los Angeles, which attracted many small offline communities (usually under 1000 people). The initial adopters of Facebook were mainly college students, which later expanded to high school students and corporate employees. Therefore, it could be deemed that the two platforms entered this market nearly simultaneously. They separately expanded their membership to establish their market segments until they became universal SNS platforms, competing with each other. All of these developments essentially coincided with the setting of Scenario 1.

Scenario 2 was designed to study how a late entrant OICP with a major innovation competes with the incumbent monopolist. It was prescribed that only Platform 1 existed initially, and all nodes, including those initial ones and those that joined later, will adopt this platform until time step $Ti - 1$. At time step Ti, Platform 2 enters the market with a major innovation, and a proportion Pi of randomly selected nodes will immediately adopt Platform 2 due to its initial propagation and promotion. Since Platform 1 has already dominated this market, those initial Platform 2 adopters are always double-platform adopters instead of adopting only Platform 2, which is the main difference from Scenario 1. The innovation of Platform 2 makes it better than Platform 1 in the next Ct time steps (including time step Ti), during which Platform 2 will never be abandoned by its adopters. After Platform 2's innovation-effective period, Platforms 1 and 2 will become homogeneous in function and design, and from then on, no platform will make further innovations.

The most significant design of Scenario 2 was to set the initial adopters of the late entrant platform as double-platform adopters. It coincided with the fact that the late entrant has to grab users from the incumbent monopolist instead of persuading those who have never used an OICP to have a try. The corresponding practical case is the competition between QQ (it also involved WeChat) and Fetion in China. QQ is an instant Internet OICP launched by Tencent in February 1999. Later, in 2002, it became the largest SNS platform in China. In early 2007, Apple introduced the iPhone, which enhanced the smartphone market, sparking the increased importation of Internet services from computers to mobile phones. In the middle of this year, China Mobile launched Fetion, a short message service (SMS)-based instant OICP. Fetion's main user interface resembled a simplified version of QQ, which omitted many of QQ's relatively unimportant functions. Fetion was easy to get started, as almost every new adopter had previously used QQ. In those days, when it came to QQ, people generally thought it was Internet software instead of a smart mobile application. For Fetion, people viewed it as the first successful instant OICP combing Internet and mobile network applications in China (Hao et al. 2013). The simulation in Scenario 2 would reproduce the competition between QQ (WeChat) and Fetion.

In addition, because it is challenging for a late entrant OICP to survive in the market, let alone catch up with the incumbent monopolist, two improved market entrance strategies for the late entrant platform (Platform 2 in this scenario) were designed. In this regard, at time step *Ti*, Platform 2's initial adopter selection strategy was switched from random selection to selecting nodes with the highest degrees or localized diffusion (Shao et al. 2015). The former (named the "hub first" strategy) refers to the Platform 2 holder prioritizing persuading those OICN hubs to adopt this platform and using their influence to popularize it. The latter (called the "localized diffusion" strategy) refers to the Platform 2 holder first randomly persuading a node to adopt the platform, then persuading its OICN neighbors under its help, and then neighbors of its neighbors. Simulations would detect a better strategy under the same initial adoption proportion of Platform 2.

Finally, Scenario 3 was developed to observe the competition process and result when the incumbent monopolist and the late entrant are efficient in innovating. This scenario was the same as Scenario 2 before the termination of the first innovation-effective period for Platform 2, and then, the two platforms began to propose innovations alternately and repeatedly. They would alternately enjoy the privilege that the innovative platform under its innovation-effective period would not be abandoned in any instance. Those alternate innovation-effective periods reflect the main difference between Scenarios 3 and 2 and the focus of this study's observation and analysis.

Those platform innovations in Scenario 3 could stand for small and incremental improvements that appear more frequently in reality than some rare major innovations. This scenario is more consistent with today's OICP competition landscape. Today, every platform, whether big or small, new or old, tries to adjust its user interface and gradually add new interesting functions. However, these improvements would seldom become major innovations. The corresponding practical case for Scenario 3 is the brief appearance of Bullet Messenger in China. Beijing Kuairu Technology launched that app in August 2018, and its name is a metaphor for the speed and smoothness of its message sending and receiving processes, likened to that of flying bullets. The innovation brought by Bullet Messenger was smoothly combining voice, text, picture, and video to form a message (Li 2018). Though that innovation might not be a major one, its adopters all felt very comfortable with it, according to reviews and comments. Considering the market strength of its main competitor WeChat, Bullet Messenger offered an additional bonus for its adopters. Finishing tasks, including staying online, joining a group and chatting, and letting one's friends use the app, could generate a bonus whose upper limit was ¥2000. The innovation of Bullet Messenger, together with its promotion, brought its registered accounts to eight million nearly 20 days after its launch. It was once ranked number one based on Apple SNS app download rankings (Karthik 2018). However, Bullet Messenger soon collapsed, and the simulation in Scenario 3 will reveal the reason behind its failure.

3.3 Execution procedure of the simulation program

In a word, this bottom-up simulation model tried to reproduce the competition process of OICPs in the real world with the most straightforward rules and instructions. Figure 2 illustrates the execution procedure of the program designed according to the bottom-up simulation model.

4 Simulation results

The simulation program was written in Object-C and run on the Swarm platform. Before analyzing the simulation results, those parameters defined in previous parts are listed in Table 1. In the following analysis, the values of some parameters would be changed to observe their impact on the competition process of OICPs, while other parameters remained the same as default values.

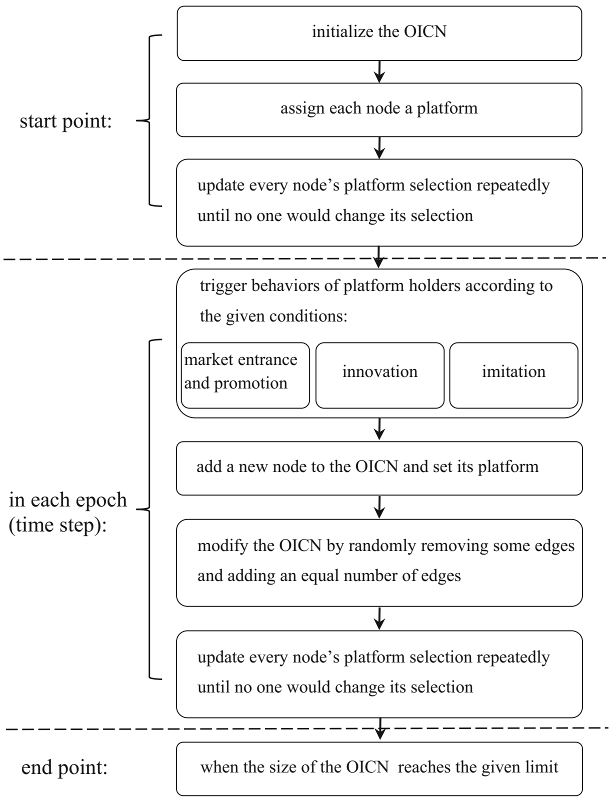

Fig. 2 Execution procedure of the simulation program

Table 1 Simulation model parameters

Symbol	Default Value	Scenario	Description
N_0	500	All three scenarios	The initial node number of the OICN
$N_{\max}$	10,000	All three scenarios	The final node number of the OICN
m	5	All three scenarios	The initial degree of OICN nodes
Pc	0.1	All three scenarios	The proportion of links to be removed and added in each time step
Pv	0.05	aLl three scenarios	The proportion of nodes with a high viscosity to some platforms
Ti	1000	Scenarios 2 and 3	The time step when Platform 2 joins the market
Pi	0.1	Scenarios 2 and 3	The proportion of nodes adopting Platform 2 immediately at time step *Ti*
Ct	1000	Scenarios 2 and 3	The length of the innovation-effective period

4.1 Simulation results in scenario 1

Scenario 1 was designed to study the competition between two homogeneous OICPs simultaneously entering the market. In this scenario, it was found that those evolutionary curves reflecting the proportion of different platform adopters might change from round to round under the same initial parameter values. Thus, several representative ones were chosen and presented in Fig. 3. The first three (Fig. 3a–c) represented the cases where there was no adjustment of the OICN except new node join ($Pc = 0$) and no person with a high viscosity to any platform ($Pv = 0$). Figure 3a reflected the case where, initially, one platform (Platform 1) had a dominant advantage in the proportion of platform adopters, and the initial proportion of solo Platform 1 adopters was even higher than the proportion of double-platform adopters. It was subsequently observed that though the proportion of double-platform adopters experienced a short rise, it was surpassed by that of solo Platform 1 adopters and began to decline continuously. In Fig. 3b, Platform 2 exhibited an obvious but not dominant advantage, as the initial proportion of double-platform adopters was the highest among the three proportions. Then, it was shown that the period for which the proportion of double platform adopters was the highest lasted longer than that in Fig. 3a. The proportion of adopters who only adopt the leading platform increased continuously, while the other two proportions decreased. This outcome was similar to that of Fig. 3a. The difference was that Platform 2 was the leading platform in this round. In Fig. 3c, the two platforms were initially evenly matched, and then, they alternately led until the gap was open. During the entire simulation process (it was stopped when the total node number reached $N_{\max}$), the proportion of double platform adopters was always the highest among the three.

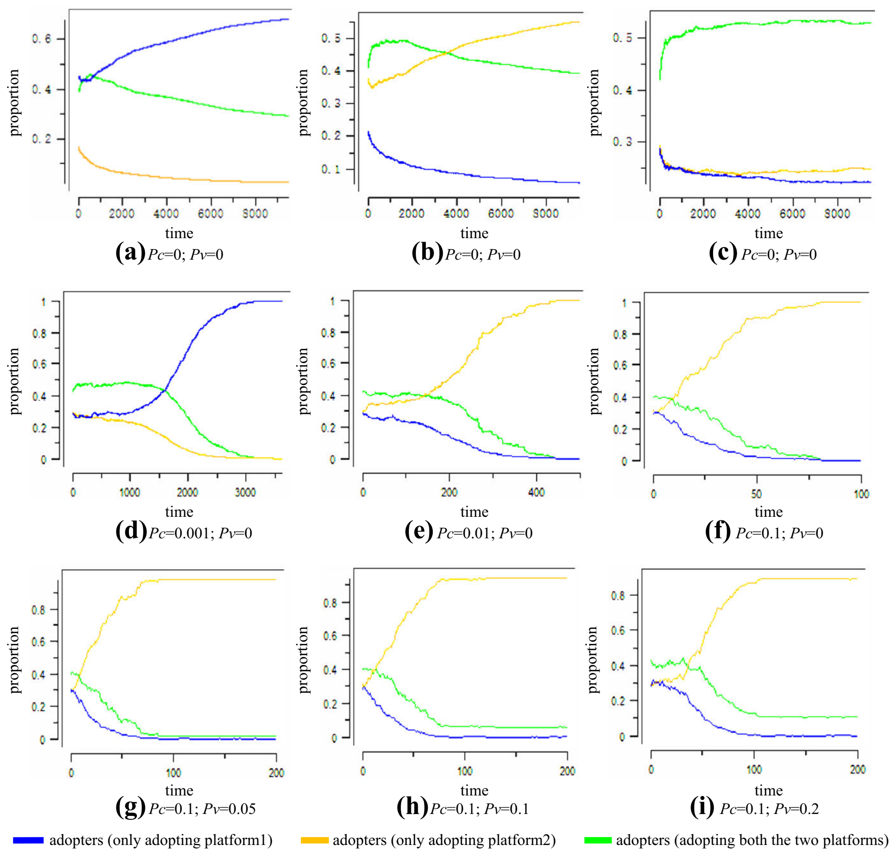

Fig. 3 The evolutionary curves of platform adopter proportion in Scenario 1

From Fig. 3a–c, it could be seen that the initial platform adopter proportions influenced the following evolutionary process. If the gap between the two platforms was large enough, it seemed quite difficult for the laggard to catch up with the leading platform. Furthermore, the gap tended to enlarge with time, by which it was deduced that the laggard platform would, sooner or later, be expelled out of the market. However, the extinction of the laggard platform was not observed during the simulation process.

Next, we discussed a more complex case whereby platform adopters might adjust their frequent communication relationships with other existing platform adopters in each time step ($Pc > 0$), but no one had a viscosity to any platform ($Pv = 0$). We found that increasing the Pc value may accelerate the platform competition process, and now the extinction of the laggard platform could always be observed. As the platform competition process in Fig. 3c seemed slower than those in Fig. 3a and b, its initial OICN was preserved. Figure 3d–f presents those evolutionary processes starting from the same initial OICN (generated by the simulation in Fig. 3c) but under different Pc values. From them, we found that the length of the entire competition process (from the beginning to the extinction of the laggard platform) might always decrease with

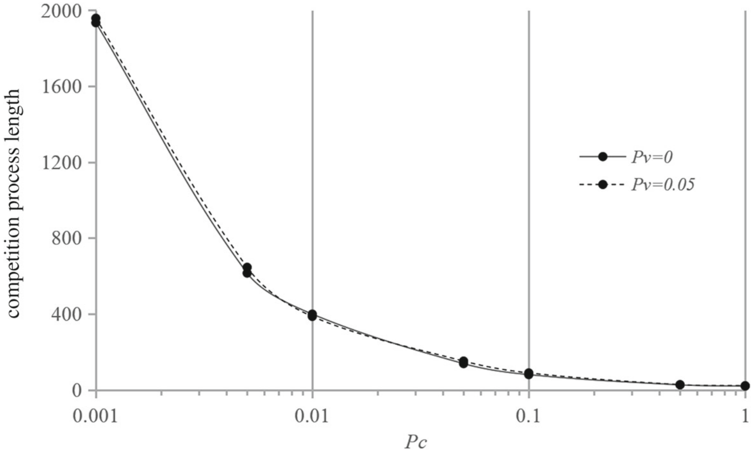

Fig. 4 The length of OICP competition processes under different *Pc* values. The results were obtained from the average of 100 simulation rounds. The laggard platform would never be thoroughly expelled from the market when *Pv* was above zero. In this case, an entire competition process was judged to end when the proportion of adopters using only the laggard platform first touched zero

the increasing *Pc* value. Figure 4 further exhibits the results from simulations with different initial OICNs, which also verified this finding.

Comparing Fig. 3d with e and f, we could conclude that even starting from the same initial OICN, the evolution results could vary from round to round, and the laggard platform at the beginning might also have a chance to turn the tide.

Finally, in Scenario 1, user viscosity was considered. It was observed that the direct effect of introducing *Pv* into this model was to avoid the extinction of the laggard platform. For comparison, in Fig. 3g–i, the simulation still started from the OICN generated by the simulation in Fig. 3 c, and *Pc* was set to its default value. In Fig. 3g–i, when those evolutionary curves came into the final stable state, the proportion of adopters who used only the laggard platform (Platform 1) fluctuated close to zero, indicating that nearly all of those adopters with a high viscosity to this platform also adopted the other platform (Platform 2). In all these three sub-graphs, the final proportion of double-platform adopters was near the half of *Pv*, from which we could deduce that those adopters with a high viscosity to the laggard platform mainly constituted the final double-platform adopters.

In conclusion, Scenario 1 revealed that when two homogeneous OICPs simultaneously entered the market, one would eventually partly or entirely monopolize this market. Furthermore, adjusting the frequent communication relationships between platform adopters might accelerate the platform competition process, while user viscosity would avoid the extinction of the laggard platform. However, parameters such as *Pc* and *Pv* seemed exogenous to the platform competition process, and it was difficult for those platform holders to change them directly.

Next, we reviewed the competition between MySpace and Facebook. It is well known that MySpace reached its peak in 2006 when its page view began to surpass Google and Yahoo, becoming the largest US website at that time. In 2007, Facebook began to experience a radical increase in users, shortening its gap with MySpace. Finally, the number of visits to Facebook in the US began to exceed MySpace at the beginning of 2009, and the gap widened gradually. According to the simulation results in Scenario 1, when two homogeneous OICPs simultaneously entered the market, both the initial leading and laggard platforms had a chance to win the competition. Further, the probability of victory for the initial laggard platform is not low. Today, people tend to attribute Facebook's victory to the improper intervention in MySpace's operations by its parent company, its excessive pursuit of profits, its lack of good technicians to maintain the quality of its website, and even Facebook's "Open API" policy, which pulled many users from MySpace. However, it should be emphasized that compared with those concrete reasons mentioned above, the initial competition situation of the two platforms played an essential role. MySpace was only a temporary leader instead of a quasi-monopolist when Facebook entered this market. If, at that moment, Facebook's main competitor was similar to today's Facebook, even if its advantages, its competitor's disadvantages, and other conditions all remained the same, surpassing such a competitor seemed impossible.

4.2 Simulation results in scenario 2

Scenario 2 discussed the competition between the incumbent monopolist and the late entrant with a major innovation. As the incumbent already monopolized the market before the late entrant's appearance, the latter had to persuade the former's adopters instead of persuading those who had never adopted an OICP. Two key factors might directly impact the competition result: the initial proportion of adopters the late entrant could persuade (denoted by *Pi*) and the length of its innovation-effective period (denoted by *Ct*). Figure 5 presents the evolutionary curves under different *Pi* and *Ct* values. For comparison, we let all simulations start from the same initial OICN.

From Fig. 5, increasing *Pi* and *Ct* values would help the late entrant platform turn the tide. Therefore, it was deduced that if the *Pi* or *Ct* values were sufficiently high, the late entrant would eventually catch up with the incumbent monopolist. However, in practice, it is quite common that a late entrant OICP with new functions or designs achieves rapid growth in users soon after inception, only to, 1 day, experiences sharp declines until it disappears from the field of view (the same as in cases of Fig. 5a, b, and d). In contrast, we seldomly observed in practice that the late entrant finally won the competition with the incumbent monopolist (described by the sub-graphs of Fig. 5 except a, b, and d). In this regard, the underlying reason is the difficulty for the late entrant to increase *Pi* or *Ct* values.

Pi denotes the proportion of adopters who immediately adopted the late entrant platform at its initial appearance. This proportion is associated more with the announced publication, propagation, advertisement, and promotion with a bonus instead of common diffusion from person to person. When faced with a relatively mature OICP market and an incumbent monopolist, even persuading one percent of the present adopters to try the new platform requires a considerable amount of money, and letting *Pi* take the value higher than 0.1 may only make sense in computer simulations. As for *Ct*, it is used to denote the length of the effective period for the late entrant's platform

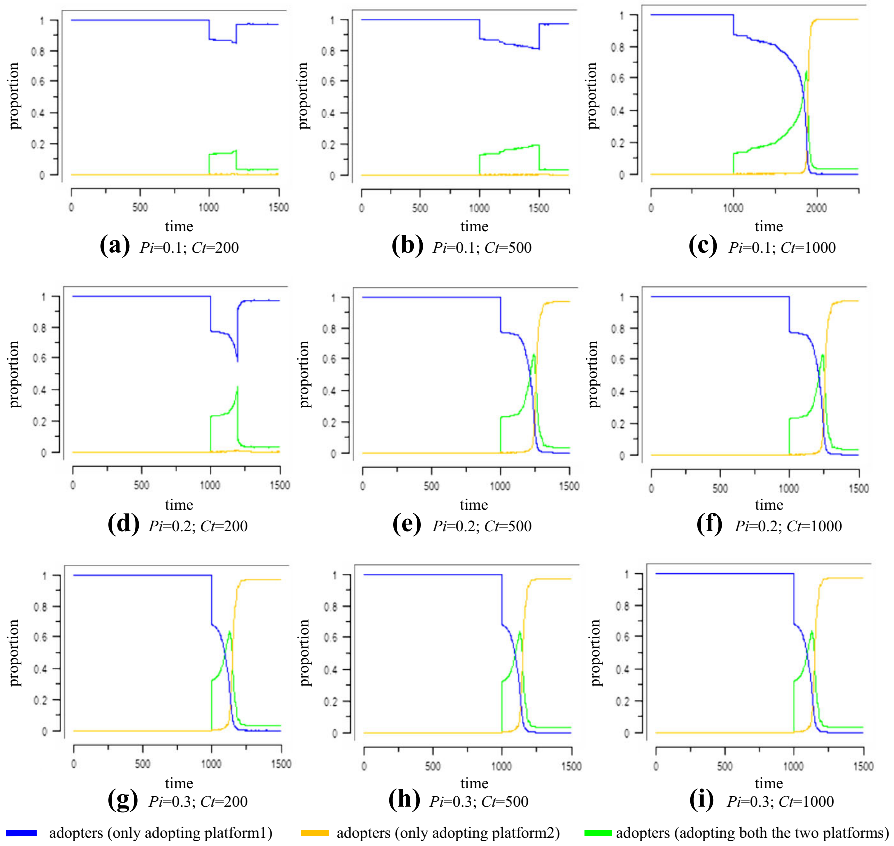

Fig. 5 The evolutionary curves of platform adopter proportion in Scenario 2

innovation. It is mainly determined when the competitor (the incumbent monopolist) would begin to pay attention to and further imitate that innovation while the late entrant may have little impact thereon. All of these can explain why the late entrant seldom wins the competition. Therefore, some competition strategies for the late entrant must be explored.

As mentioned previously, the OICN, in reality, may follow a scale-free law of degree distribution, and the node-adding mechanism was also designed to produce such network structure in simulations. Figure 6 shows the distribution of the power-law exponent γ estimated at the 1000, 2000, 4000, and 8000 time steps, and those estimates were calculated by the robust method given by Barabási and Albert (1999):

$$\gamma = 1 + N \cdot \left(\sum \ln \frac{d_i}{d_{\min}} \right)^{-1}, \tag{4}$$

where N denotes the present node number of the OICN, and $d_{\min}$ is the minimal node degree. The power-law distribution would lead to the situation where a few nodes have

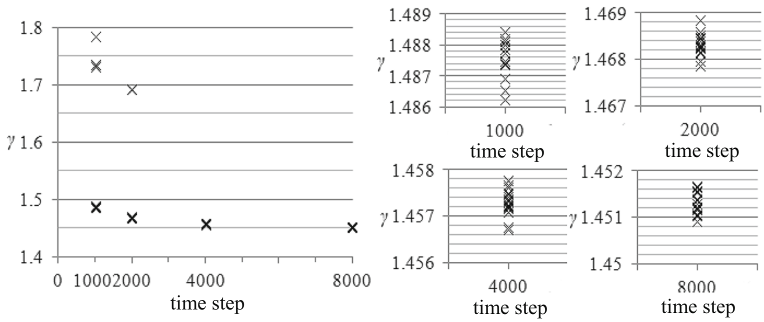

Fig. 6 Scatter diagram of the power-law exponent γ estimates at different time steps. Twenty simulation rounds were randomly selected, and at each specific time step, those estimates were calculated according to their present OICNs

an extremely high degree; therefore, it is wise for the late entrant platform holder to grasp those high-degree nodes with its limited promotion resource and make good use of their "hub" attribute to improve the diffusion of its platform.

By observing all sub-graphs in Fig. 5, we found that the proportion of double-platform adopters began to increase sharply soon after the entrance of Platform 2. However, the proportion of solo Platform 2 adopters would remain very low until the proportion of double-platform adopters was sufficiently high. The absence of solo Platform 2 adopters hinted that during this period, the whole OICN was mainly supported and maintained by Platform 1. Platform 2 was more likely to supplement Platform 1 just to provide the innovative function or design that Platform 1 did not have. The size of the online communication sub-network supported by Platform 2 was very limited. Therefore, it was believed that for Platform 2 holders, providing rewards to its early adopters to let them persuade their frequently contacted acquaintances or intimates to try this platform might help foster and enlarge its online communication sub-network and might further contribute to its competition against the incumbent monopolist.

Based on the above observations, two market entrance strategies for Platform 2 holders, named the "hub first" strategy and "localized diffusion" strategy, were designed and applied in simulations to observe their validity. Two indicators were used: $Ct_{\min}$ denotes the necessary length of the innovation-effective period for the late entrant platform to guarantee that it catches up with the incumbent monopolist. This indicator could be measured from the entrance of Platform 2 to the time step when it first catches up with Platform 1 (indicated by the horizontal ordinate of the intersection of blue and orange lines in Fig. 5c, e–i). The other indicator $PS2_0$ denotes the proportion of solo Platform 2 adopters just after the entrance of Platform 2 and the following individual platform modification. This indicator also indirectly reflects the size of the online communication sub-network supported by Platform 2 after its initial propagation and promotion. As shown in Fig. 7, when Pi was relatively low, both the two market entrance strategies would accelerate Platform 2's catch-up with Platform 1 in adopter proportion and shorten the necessary length of the innovation-effective period for Platform 2 ($Ct_{\min}$). When $Pi = 0.1$, the acceleration effect of the "hub first"

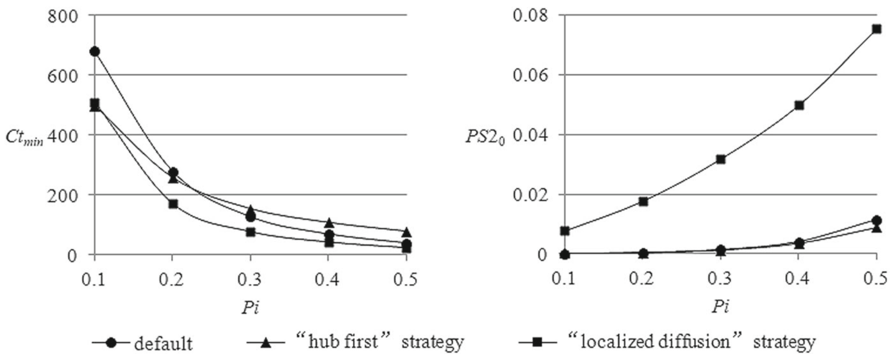

Fig. 7 Comparison of two indicators under the default circumstance and improved market entrance strategies of the late entrant. The results were based on an average of 100 simulation rounds

strategy seemed a little better than that of the "localized diffusion" strategy. However, when *Pi* increased, the acceleration effect of both strategies became more insignificant. As for $PS2_0$, the "localized diffusion" strategy worked very well at any specific *Pi* value. Under this strategy, the proportion of solo Platform 2 adopters at $Pi = 0.1$ was even higher than values at $Pi = 0.4$ under the default circumstance and "hub first" strategy. All of these confirmed our anticipation that the "localized diffusion" strategy tended to help the late entrant platform establish and expand its online communication sub-network and further accelerate its catch-up with its competitor. Though the "hub first" strategy performed not so well at relatively high *Pi* values, the validity of both strategies was still announced. The experience shows that *Pi* is usually very low in practice. If a new OICP holder in the real world could immediately persuade more than 20% of the total users to try this platform at its first appearance, who would be persuaded seems unimportant.

In conclusion, Scenario 2 showed that increasing the initial adopter proportion *Pi* and the length of the innovation-effective period *Ct* is essential for the late entrant platform to catch up with the incumbent monopolist. If one of them is sufficiently high, the surpassing will certainly occur. However, it is challenging for the late entrant platform holder to, in reality, exert sufficient influence on its initial adopter proportion and its innovation-effective period. Although the late entrant platform holder adopts the "hub first" or "localized diffusion" strategy was proven to be effective by simulations, the surpassing still rarely happens in the real world.

Let us review the competition between QQ (WeChat) and Fetion in China. Due to the major innovation, porting high-quality OICP functions from computers to smart mobiles, in the 4 years that followed (from 2007 to 2011), Fetion continuously held first place in China's domestic mobile SNS market, and its active monthly users gradually increased to 82 million in 2011. All these gave China Mobile (the holder of Fetion) an illusion that Fetion's competitive advantage and customer growth would continue in the next few years. It neglected the fact that QQ had 721 monthly active users in 2011, and though most of them were computer users, they still had great potential to become mobile SNS users. In the same year, Tencent launched WeChat to compete in the mobile SNS market. WeChat nearly had all the merits of Fetion in function and design. It allowed its adopters to import their QQ friend relationships smoothly, which perfectly retained the network externalities of QQ for those adopters. One year later (in 2012), WeChat's monthly active users reached 160.8 million, far surpassing Fetion's approximately 90 million users; meanwhile, Fetion stopped its rapid growth and began to decline. Finally, in 2016, Fetion's main service was shut off. In a word, the major platform innovation gave Fetion nearly 4 years' protection to let it grow and develop (the innovation-effective period could be counted from its inception in May 2007 to the launch of WeChat in January 2011). Later, it lost that protection, and its main competitor's network externalities destroyed it in a shorter time frame.

4.3 Simulation results in scenario 3

Scenario 3 was designed to study the impact of continuous and alternate platform innovations on the competition process of OICPs. We envisioned observing the alternation of platform innovations leading to the alternation of their proposers' competitive positions, and we would further analyze the condition for its appearance. In this scenario, for simplicity, it was prescribed that all innovations proposed by both platforms have the same length of innovation-effective periods (denoted by *Ct*). Its influence was observed by keeping other parameters as default. From Fig. 8a, it can be seen that when the *Ct* value was relatively low, those alternate platform innovations might only create some fluctuations of platform adopter proportions but would never change the dominant position of the incumbent monopolist (Platform 1). Once the gap reduction mainly caused by the initial propagation and promotion of the late entrant (Platform 2) was exhausted, that platform would have no chance to catch up with the incumbent monopolist (Platform 1).

We then increased *Ct* gradually, and it was demonstrated that for some medium *Ct* values, the evolutionary process experienced a period during which both platforms alternately led the competition. However, that period would not last very long. Finally, a platform would slash its competitor thoroughly (this winner could be any one of the two), and the loser would never turn the tide (see Fig. 8b for reference).

The previous scenario (Scenario 2) had shown that if the length of the innovation-effective period was sufficiently long, the late entrant would, sooner or later, take the place of the incumbent monopolist. Here, a complete global platform replacement process is defined beginning from the state where there are the most solo leading platform adopters, a few double platform adopters, and nearly no solo laggard platform adopters. It ends at the state where there are the most solo previous laggard platform adopters, a few double platform adopters, and nearly no solo previous leading platform adopters. Meanwhile, that process should be under an innovation-effective period of the initial laggard platform. Sparked by Scenario 2, it was inferred that in this scenario, if *Ct* was high enough to allow any complete global replacement process of both platforms, an evolutionary process, whereby the two platforms would lead the competition alternately and none of them would dominate the market forever, could be observed. That hypothetical evolutionary process could be described as a late entrant with some platform innovation coming into this market. During its innovation-effective period,

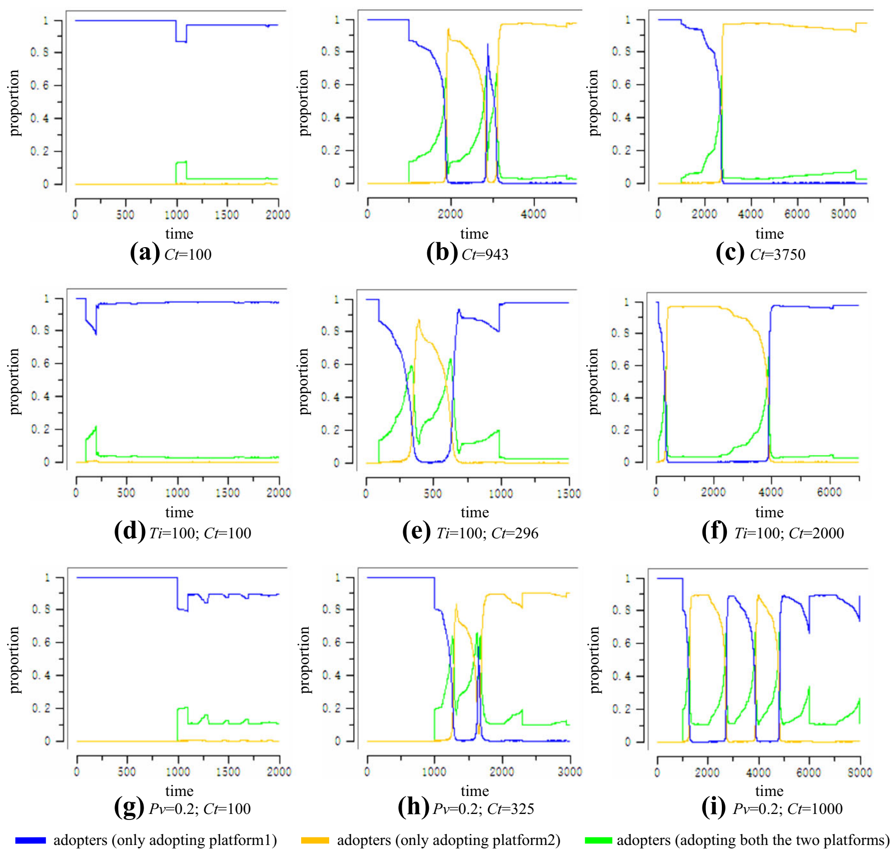

Fig. 8 The evolutionary curves of platform adopter proportion in Scenario 3

this platform gradually caught up with, and finally almost destroyed, the incumbent monopolist. Then, the previous incumbent monopolist also proposed an innovation and did the same work. This type of alternation would continue indefinitely. Unfortunately, that hypothetical evolutionary process could not be observed in simulations when *Ct* was relatively large, and other parameters took the default values. Most cases are like that in Fig. 8c.

By further observations, we found that the length of a complete global replacement process would increase with the size of the OICN. More concretely, the earlier this process began, the smaller its starting OICN is, the fewer time steps it tended to take. According to this, the market entrance of Platform 2 was brought forward by setting $Ti = 100$, and the evolutionary processes are presented in Fig. 8d–f. Comparing these sub-graphs with Fig. 8a–c, we could see that the results were not different from $Ti = 1000$, when *Ct* took relatively low and medium values. However, when it took some relatively high values, we could observe one more complete global replacement process after the near extinction of Platform 1 (see Fig. 8f for details). Meanwhile, once this process took place, Platform 2 tended to lose the chance to catch up with Platform 1 again.

Considering the starting and ending states of a complete global replacement process, we found that increasing the *Pv* value would lead to an increment of the initial proportion of the laggard platform and a decrement of the final proportion it had to reach, thereby decreasing the total length of such a process. Therefore, we increased the *Pv* value to 0.2, meanwhile keeping other parameters as defaults, and the simulation results were presented in the last three sub-graphs of Fig. 8. Figure 8g shows that the alternate platform innovations might never change the two platforms' competitive positions when *Ct* was relatively low. Moreover, the fluctuation caused by this alternation had a decreasing trend as the simulation time passed (though not so strict), indicating that during the same length of innovation-effective periods, the proportion gap narrowed by those innovations of the laggard platform became increasingly smaller. This outcome indirectly confirmed the inference that the length of a complete global replacement process would increase with the size of the OICN. In Fig. 8i, we could observe many complete global replacement processes until the length of such a process had become higher than *Ct* and the competitive position alternation finally disappeared.

Finally, we recorded the length of those complete global replacement processes from many simulation rounds at specific *Pv* values and specific starting time steps, and the results are averaged and presented in Fig. 9. We found that the length of a complete global replacement process would increase with its starting time step for any specific *Pv* value. In other words, if the size of the OICN is still expanding, those complete global replacement processes will become increasingly longer. Once they far surpassed the innovation-effective period length *Ct*, the alternation of platform competitive positions would disappear forever.

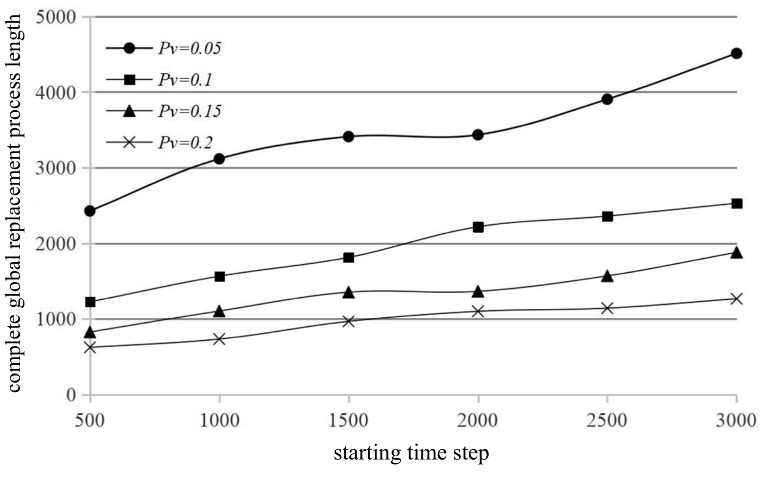

Fig. 9 The average length of those complete global replacement processes. The results are an average of 100 simulation rounds

In conclusion, in a scenario where the incumbent monopolist and the late entrant are both innovative, and they propose innovations alternately, the late entrant tends to never catch up with the monopolist, and soon be expelled from the market when the innovation-effective period is relatively short (when *Ct* is relatively low). If the innovation-effective period is long enough to allow the two platforms to replace their competitive positions, a complete global replacement process could be observed. Those complete global replacement processes will be shorter if the proportion of high-viscosity adopters is higher (if *Pv* is higher). As the size of the OICN is continuously expanding worldwide, those processes will become increasingly longer. Therefore, there is no permanent alternation of platform competitive positions for any substantial *Ct* value. Finally, a winner will partly or entirely monopolize the market and take all.

Today, the competition between OICPs is consistent with Scenario 3 in that both the incumbent monopolist and the late entrant are eager to propose small and incremental improvements continuously. As those improvements are easy to be imitated by competitors, their innovation-effective periods are relatively short. Hence, the case presented by Fig. 8a, d, and g that the late entrant will never catch up with the monopolist and soon be defeated is common. The outcome of the competition between Bullet Messenger and WeChat further confirmed that. Only 6 months after the launch of Bullet Messenger, there was nearly no news about this platform, and it quickly faded out of the public eye. When interviewed about Bullet Messenger, many of its adopters still praised it for its smooth message compiling mode and insisted on it, but they also complained that people rarely used it. When those Bullet Messenger adopters tried to persuade their friends to try, the most frequent reply was "WeChat is enough."

5 Discussions

First, we would like to emphasize the good qualities of using the bottom-up simulation approach to analyze a complex process such as the competition of OICPs. As shown, it can consider multiple factors (including user quantity, platform innovation, OICN structure, and user viscosity) and their simultaneous interactions. Meanwhile, it grasps the main aspects of this process (individual platform selection, the evolution of OICN, and the competition behaviors of OICP holders). It presents them in a simple way to understand and assess them. Importantly, some representative OICP competition scenarios from reality could be reproduced and demonstrated by simulation outputs. By further modifying the values of some parameters, cases that may not be directly observed in practice could be explored, such as how a late entrant OICP with a major innovation could defeat the incumbent monopolist, and for two OICPs proposing innovations continuously and alternately, whether long enough innovation-effective periods could allow the eternal alternation of their competitive positions.

The main limitation of this bottom-up simulation model is that its parameter values may not be the same as reality. Given the complexity and tremendous dynamism of the competition between OICPs in the real world, this limitation seems inevitable. For example, today, the size of OICNs in big countries, such as the USA and China, usually counts hundreds of millions. It is impossible for ordinary computers to allow such a massive number of nodes. This bottom-up simulation model was just a model of the real world. When considering computer memory capacity and the program runtime, all simulation rounds would be terminated when the node number of the OICN reached 10,000. We believed that this size of the OICN was already enough to present characteristics of real competition processes of OICPs in most cases. For other parameters, such as *Pc* (the proportion of OICN links to be adjusted in each time step) and *Pv* (the proportion of OICP adopters with a high viscosity to their preferred platforms), the setting of their default values should have referred to some empirical investigations. However, we found that their real values might vary with adopter groups and OICPs by interviews with many OICP operators. We tried to change their values to observe and analyze their impacts on simulation results in addition to setting their default values. If, in the future, there is literature reporting that some of their values are universal in the real world, we will adjust their default values accordingly.

This paper's discussion on Internet platform competition was mainly limited to the competition between different OICPs, and the simulation results showed that one platform would finally monopolize the whole market in any case. However, some interesting questions would emerge, such as what the winner will do next after monopolizing the OICP market in a country or place. Will it just be satisfied with maintaining its monopoly position in this market? Or will it further enter other related Internet service domains? The following two cases on cross-domain competition between Tencent (the holder of WeChat) and other top Internet platform holders may give some hints.

The demand for online video conferencing services is increasing due to the COVID-19 pandemic, lockdowns, and stay-at-home policies. Alibaba (one of the big three Chinese Internet companies, whose global market share for its online shopping platform, Taobao, had already surpassed Amazon and eBay in 2020) launched the online office platform DingTalk in December 2014 and added the online video conference function several years before the COVID-19 pandemic. Tencent proposed the online video conferencing platform, Tencent Meeting, in December 2019 to deal with the online conference demand caused by this pandemic. Online conference users began to increase sharply in February 2020, as the government asked the Chinese people to work and learn at home after the Spring Festival holiday. Both DingTalk and Tencent Meeting provided complete online video conference functions at that critical time. Moreover, the quality of those two platforms was almost the same. However, today, Tencent's number of active users has already surpassed DingTalk, which entered the online video conferencing service domain much earlier. Both Tencent and Alibaba tried to take advantage of the reputation and influence of their main platforms (WeChat of Tencent and Taobao of Alibaba) to attract new adopters in a new domain. The competition result would depend on whose main platform could attract more users faster in that new domain. In this specific aspect, the best OICP performed better than the best online shopping platform in China.

Let us focus on the short video social service domain rising in recent years. TikTok has taken first place in China and has won rapid user growth in the USA and many European and Asian countries. Tencent entered this domain by adding a short video item to the panel of WeChat. In its short video browsing interface, those short videos are divided into three categories, namely those from the accounts followed by the current account, browsed by WeChat friends, and recommended by the platform, which is very like that of TikTok (its three categories are those from local accounts, from the accounts followed by the current account, and recommended by the platform). The video switching modes of both platforms are also the same (all by sliding up and down). Both Tencent and ByteDance (the holder of TikTok) chose to penetrate each other's main domains based on their main domains. At present, it is still difficult to distinguish between victory and defeat. When a TikTok adopter wants to establish frequent communication relationships with someone they follow, they will request that person to add WeChat friends via the private message function provided by TikTok. If successful, the private message function of TikTok will be abandoned. Meanwhile, WeChat's short video function cannot replace TikTok due to its insufficient number of short videos and its undeveloped recommendation algorithm. However, all these disadvantages will be improved gradually when more WeChat adopters try this short video function (WeChat could hint to its adopters that their friends are watching or liking some videos to attract them to have a try). If someday all these disadvantages associated with WeChat short videos disappear, TikTok will directly face the incredibly huge network effects of WeChat.

The above two cross-domain competition cases hinted that the platform monopolizing the OICP market might have a competitive advantage when it enters other Internet service domains. Actually, in China, we have countless times witnessed that Tencent entered a new Internet service domain and then eliminated the incumbent mainstream platform based on the influence of WeChat. Tencent's main domain (OICP domain) contributed significantly to this. The first section emphasized that facilitating individual online communication is the most fundamental function of SNS platforms. Today, this frequently used function seems indispensable to every person. If an OICP monopolizes this market in a country like WeChat in China, the user account may evolve into another kind of ID card for people, while its influence will permeate many aspects of people's lives instead of being limited to the OICP domain. People tend to use that OICP and its related products or services on various occasions, explaining why Tencent has such a competitive advantage in its cross-domain competition with Alibaba and ByteDance.

6 Conclusions

This paper mainly focused on the competition between OICPs based on a bottom-up simulation model, which emphasized that individual platform adoption and abandonment behaviors at the microscopic level would essentially impact and determine the competition process and result at the macroscopic level. Every OICP adopter might have several frequently contacted acquaintances or intimates due to work or daily life. Maintaining online communications with them was its basic and direct motivation to adopt and continuously use such platforms. Meanwhile, if an OICP was enough to maintain such communications, it would abandon other homogeneous platforms due to the consideration of saving time, money, and energy or chasing convenience. The bottom-up simulation model represented the substantial influence of network externalities by introducing this simple mechanism that an OICP with more adopters would have a higher probability of being adopted and less likely to be abandoned.

The design of the three scenarios reflected the situations that two homogeneous OICPs competed with each other when this kind of platforms first came into the public eye, that a late entrant with a major innovation competed with the incumbent monopolist during the following days, as well as that both the incumbent monopolist and the late entrant continued to propose many small innovations to compete in recent days, respectively. The simulation results showed that when two homogeneous OICPs entered the market simultaneously, one would monopolize this market sooner or later, and the other would be almost extinct. The adjustment of the frequent communication relationships of platform adopters would accelerate the competition process, while platform user viscosity might avoid the complete extinction of the laggard. For the late entrant platform with a major innovation to challenge the incumbent monopolist, it would help to increase its initial adopter proportion by promotion and extend its innovation-effective period, though difficult to be conducted. The "hub first" strategy and the "localized diffusion" strategy would be effective for the late entrant when its initial adopter proportion was relatively low. The latter was more efficient in constructing its online communication sub-network. For the case that the incumbent monopolist and the late entrant alternately introduced many small innovations, it was even more difficult for the late entrant to turn the tide. Meanwhile, even if we deliberately increased the length of the innovation-effective period to any large value in simulations, a forever-lasting process that the two platforms alternately led the competition may not be observed. In a word, there always exists an OICP at last partly or entirely monopolizing the whole market, in any case and any place. The competitive advantages brought by major or incremental platform innovations always have a period of validity. Compared with the network externalities produced by the huge user quantity of the monopolist, all kinds of innovations seem very weak.

Since it is inevitable in any country that the service domain for online interpersonal communication will be finally monopolized or quasi-monopolized by only one platform, the government should recognize this fact. Further, the government should enhance the awareness and supervision of the monopoly OICP's operations and prevent it from chasing profit at the expense of its adopters' rights (e.g., obtaining the adopters' consumption habits through improper use of their chat records). As for the permeation of some new domain by the monopoly OICP holder via first imitating the mainstream platform in that domain and then destroying that platform with the network effects borrowed from the OICP, the government should restrict this approach because of its unfairness and potential to stifle innovations in that domain. A feasible approach is to legislate and prohibit the monopoly OICP holder from binding the main function of some other domain to its OICP with a user interface similar enough to the mainstream platform in that domain. Even more radically, the monopoly OCIP holder could be forbidden from letting adopters register and login to its newly established platforms in different domains with the OICP accounts. Finally, it is unwise for those new entrant OICPs to challenge giants, like today's Facebook or WeChat, in their main domain. Even if the platform innovations they proposed are prominent, they usually still cannot escape the fate of being erased when the innovation-effective period is over. The monopoly OICP holder may sometimes acquire those new innovative entrants at a reasonable price, and they should pursue and seize such an opportunity to exit this market.

6.1 Notes

The model can be found at https://www.comses.net/codebases/0997bc88-d8e9-4af8-8b72-ee1d3f1fba7f/releases/1.1.0/.

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