Information Systems Review
Vol. 20, No. 1 March 2018 http://dx.doi.org/10.14329/isr.2018.20.1.137

# 플랫폼의 소셜로그인 서비스(Authing Service): 보안과 편의 사이의 적절성

# Authing Service of Platform: Tradeoff between Information Security and Convenience

**유 은 솔** (Eun Sol Yoo) 고려대학교 경영대학 석박사과정
**김 병 조** (Byung Cho Kim) 고려대학교 경영대학 교수, 교신저자

## 요 약

소셜로그인 서비스(authing service)는 온라인 플랫폼들간의 연결을 더욱 용이하게 함으로써 온라인 플랫폼 생태계에 긍정적인 영향을 미치고 있다. 소비자들은 추가적인 로그인 없이 다른 플랫폼으로의 접근이 가능해졌으며 플랫폼들은 다른 플랫폼들로부터 잠정적인 소비자들을 유치할 수 있다는 점이 이점으로 작용한다. 하지만 보다 쉽게 다른 플랫폼에 접속할 수 있는 소셜로그인 서비스는 플랫폼 생태계의 보안을 취약하게 만들고 있다. 즉, 플랫폼들 간의 연결이 많아질수록 소비자들의 편의성은 높아지는 반면에 플랫폼의 보안은 취약해진다. 그러므로 본 연구는 소셜로그인 서비스의 편의성과 보안의 상반관계를 고려하여 플랫폼이 결정해야 하는 적절한 수준의 소셜로그인 서비스를 제시하였을 뿐만 아니라 소셜로그인 전략이 전체적인 플랫폼 생태계에 미치는 영향에 있어서는 게임이론법을 적용하여 분석하였다. 본 연구를 통해 제시한 결과는 다음과 같다. 첫째, 소비자들의 해킹에 대한 기대손실이 낮은 경우, 플랫폼 생태계 전반의 구성원 수는 증가하게 된다. 둘째, 소셜로그인 서비스에서 소비자가 증가할 경우, 연결된 플랫폼들(joint sites)은 소비자들로부터 더 많은 이익을 창출할 수가 있다. 마지막으로, 소비자들의 해킹에 대한 기대손실이 낮은 경우, 플랫폼 제공자들은 플랫폼의 보안과 관련된 노력이 필요하다. 본 연구에서 소셜로그인 서비스를 제공하는 플랫폼 기업들에 대한 연결성과 보안에 대한 방법을 제시하였고, 이외에 전체플랫폼을 분석, 관리하는 정책담당자에게 정책적인 방향을 제시하였다.

*키워드 : 플랫폼, 네트워크 외부성, 소셜로그인 서비스, 게임이론*

## Ⅰ. Introduction

Recently, there has been growing interest in connectivity in online platforms. Platforms prefer to link each other for their own benefits; for example, sharing information of their members, increasing potential consumers though connection, and dominating small rival platforms. The connection among platforms creates

---

† This work was supported by the Institute for Business Research & Education (IBRE).

a big ecosystem of connectivity. One of the services that facilitate linkage among platforms is the authing service in the platform. An authing service, which is also called an authentication service, verifies "a claimed identity in the form of a pre-existing label from a mutually known name space as the end-point of a channel" (Glass *et al.*, 2000, p. 3). An authing service allows a platform to easily access data on other platforms and enhance sharing capabilities, and leads to positive spillover effects on competing applications (Li and Agarwal, 2016).

With regard to the consumers, use of an authing service provides additional value to them and enhances the ease of use for connected platforms. While platforms expand their ecosystem through an authing service, the members of these platforms can enjoy easy access to log in without exerting extra effort. Moreover, such connectivity allows platforms to access the data of platform members and thus, makes platform members less irritated to enter their subscription information. Moreover, despite the possible security risks, many users find the convenience of electronic access from personal computers irresistible (Rabkin, 2008).

However, connectivity can give rise to threats to security in the following way. As progressively more platforms are connected to each other, they become more vulnerable. For example, FourSquare was used to hack into Twitter through Twitter's authing service, which is used by FourSquare. Ryan Holmes (2016), the CEO of a social media company Hootsuite, which was in a partnership with FourSquare, stated that the platform was hacked through the site that provides the authing service.

The security versus convenience dilemma has become one of the biggest issues facing information security (Kim and Park, 2012), with the "lock it all down" mentality present in many organizations today (Cantafio, 2004). The more consumers are provided with authing services, the more the number of platforms providing these services grows, and thus, the higher is the convenience. However, the higher the number of platforms that provide authing services, the higher is their vulnerability, that is, the presence of negative network externalities. Thus, there is a clear trade-off between the convenience of using authing services and platform security.

Despite the importance of balancing authing service and security levels, far too little attention has been paid to the appropriate level of platform connectivity. This study proposes a sophisticated game-theoretic model to find the appropriate strategy to balance platform authing service and security. In this study, we analyze the implications of two different mechanisms of mitigating customer and platform risks with respect to authing services, that is, how to balance security and convenience. We develop a model that extends the literature on information security and provide a framework to answer the following questions. 1) What is the optimal level of authing service for a platform? 2) How do authing service strategies impact the overall participants in a platform ecosystem? To answer these research questions, we use a game-theoretic analysis to capture the tradeoff between the convenience of authing services and the resulting security vulnerability. This approach has an advantage of ensuring mathematical tractability, and makes it possible to verify the validity of balance between convenience and security. In addition, it allows us to demonstrate the intuition behind both negative and positive externalities and the effects of the interaction between these two.

Our study contributes to the literature in the following ways. First, this study presents a game-theoretic approach to the current online authing phenomenon, not only regarding the positive externality of the platform ecosystem but also that of the negative externality. Second, this study adds to the two-sided platform literature that applies platforms' authing services. In terms of practical implications, this research could help practitioners determine proper levels of effort and the extent to which to link to other platforms. Furthermore, this study has implications for policymakers on how to adopt policy strategy while considering the overall platform ecosystem.

The rest of the paper is organized as follows. The next section provides background literature on models of two-sided markets for authing service and security. Section III presents an analytical model, followed by an equilibrium analysis in Section IV. Section V discusses the theoretical and practical implications of the results as well as the limitations of the model and future research prospects.

## Ⅱ. Literature Review

Existing studies have mostly focused on the positive spillover and positive network externality. Li and Agarwal (2016) empirically showed that a photo-sharing platform integration strategy would positively impact platform-based ecosystems with regard to not only the first-party applications but also the overall application ecosystem. Huang *et al.* (2013) showed that by comparing platform integration before and after, third-party developers have more power to protect individuals copyrights and patents. However, the authors focused only on the spillover and network effects of platform integration, which represent only their positive side. Platform authing services, which connect the overall platform ecosystem, are closely related to security problems, which are the negative aspect of platform integration. This study differs from previous studies by analyzing the tradeoff between the positive and negative aspects of platform connectivity.

Authing services are used to ensure security, but they also increase the risk of security problems. Wang *et al.* (2013) showed that nowadays, an increasing number of platforms are being linked together, which poses a threat to security. Furthermore, Jeun *et al.* (2012) demonstrated that in the current ecosystem of platforms, authing services are not secure; hence, the authors emphasized a more enhanced password system. Through an authing service, multiple points of access are available on a platform. Which means that there could be a higher probability of being hacked. Feng *et al.* (2012) claimed that securing sensitive data and accessing it from mobile devices make user authing services a problem of paramount importance. According to the authors, the conflict between security and usability is a challenge for user authing services on mobile devices. However, both studies demonstrate only how to change the password system, not how to manage the security of the current password system. Thus, this study demonstrates how to manage the right level of authing service.

Previous studies have tended to focus on management within security. While some have studied the security issues related to patching liability (August and Tunca, 2006; August and Tunca, 2011; Kim *et al.*, 2011), others have focused more on the cost of security, convenience, and security risks. Tam *et al.* (2010) focused on the tradeoff between security and convenience. They found that this tradeoff could be positively influenced by imposing a time frame factor, that is, whether a change in the password would take place immediately or in the future. Kim and Park (2012) showed that consumers misperceive security quality given observable convenience. The authors argued that consumers' misperception of security quality could be explained by a zero-sum heuristic. According to Grosse and Upadhyay (2013), security and usability problems are intractable; therefore, it is time to give up on elaborate password rules and look for a better alternative. The authors suggested new types of password systems to find the right one that could be linked to the current ecosystem. Previous studies have suggested a new or enhanced security system.

Several studies have focused on the role of policy in security. Kim and Oh (2016) reported that as a result of privacy policies, high levels of privacy trust would increase the willingness to provide personal information in e-commerce. Chai *et al.* (2015) studied the individual perspective on privacy and claimed that government policies have a positive effect on the protection of privacy by a user. An *et al.* (2015) found that pressure by policymakers positively influences the management of risk in information security. You *et al.* (2015) used privacy calculus theory to demonstrate the smartphone users' dilemma concerning privacy issue, focusing on the impact of policy on the balance between security and the convenience of authing services. Security includes risks and vulnerability as well as costs.

Existing studies on platform security have mostly relied on analytical modeling to study the strategic interactions between platform owners and consumers. For example, Grossklags *et al.* (2008) investigated the optimal protection and insurance levels for securing a platform by using game theoretic analysis. Kwiat *et al.* (2015) also used game theory to show the problem of negative externalities in cloud computing, whereby the security of one member affects that of another. Furthermore, Cavusoglu *et al.* (2008) used an analytical model to find a socially optimal time-driven patch management strategy, placing a tradeoff between the costs of attacks and those of patching. Different from most previous studies, Tam *et al.* (2010) analyzed the psychological behavior of users though a web-based survey and an experiment to show the trade-off between security and user convenience.

To this end, platforms should address a more important question of how to manage the level of security. As more platforms are linked to each other, the main platform becomes vulnerable. It is vital not only to study the security of linked platforms but also to manage the level of security. Therefore, it is necessary to examine ways to manage the connections between platforms. This study not only focuses on the positive aspect of platform integration, such as spillover effect and consumer convenience, but also examines its negative aspects, such as security problems. Considering these facts, and to keep the analysis simple, we employ a game theoretical model to concentrate on the issue of convenience versus security risk in authing services. In particular, we abstract entirely from prioritization issues in order to focus on the characteristic of authing services.

## Ⅲ. The Model

We extend the approach of Economides and Tag (2012) to study authing services of platforms, specifically, the optimal security level in a two-sided platform. We assume that there are three players in the two-sided market: consumers, joint sites, and the main platform. This modeling setup is common in the traditional two-sided market literature when modeling monopoly (Armstrong, 2006; Hagiu, 2007). The consumers are individuals who are considering joining the main platform that may use an authing service. If a consumer joins the main platform, she has no choice, but to use the authing service. Joint sites are linked platforms that use an authing service offered by the main platform. The main platform connects consumers with joint sites through its authing service. By using the login process of the main platform, consumers can log in to the connected joint sites without directly logging in to the individual joint sites. For example, Naver and Facebook are the main platforms that provide an authing service to joint sites, such as Foursquare, which Facebook users can log in by using their Facebook ID and password.

We assume that both consumers and joint sites simultaneously choose to join within the main platform. We also assume that the authing service will increase the risk for both the consumers and the joint sites when the main platform is hacked. This assumption is reasonable because the higher are the number of joint sites connected to the main platform, the higher are the chances of the main platform getting hacked.

## 3.1 Consumers' Utility

This study analyzes the main platform's efforts in the provision of an authing service. For example, improving the main platform's security, checking the level of security of each linked platform, and increasing convenience for consumers who use the authing service constitute part of the main platform's efforts. $e$ represents the effort level of the main platform for security enhancement. $\alpha e$ denotes the consumers' utility gain at the platform's effort level $e$, where $\alpha$ is a scale parameter. $\theta_c$ is a scale parameter that captures the negative network externality of consumers and $n_j$ is the number of joint sites that use the main platform's authing service. The greater are the number of joint sites that exist, the higher is the chance of the main platform being hacked, which leads us to denote network externality as $\theta_c n_j$.

The expected utility of a consumer who joins the main platform with effort level $e$ is

$$U_c = v_c + \alpha e - \theta_c n_j \tag{1}$$

where $v_c$ is the value of the main platform to a consumer. We assume that $v_c$ is uniformly distributed in [0, 1]. Consumers whose utility is positive, join the main platform. <Table 1> shows the notations used in this study.

〈Table 1〉 Notations

| Parameter | Description |
|---|---|
| $v_C$ | Value of platform to consumer |
| $v_j$ | Value of platform to joint sites |
| $n_C$ | Number of consumers |
| $n_j$ | Number of joint sites |
| $\theta_C$ | Negative network externality on consumer-side |
| $\theta_j$ | Negative network externality on joint site-side |
| $\alpha$ | Utility gain from security enhancement |
| $\beta$ | Positive network externality on joint site-side |
| $A$ | Fee of advertisement |
| $C$ | Cost for security enhancement |
| $E$ | Effort of platform for security enhancement |

## 3.2 Joint Sites' Utility

The utility derived from joint sites is specified as

$$U_j = v_j - \theta_j n_j + \beta n_c \tag{2}$$

where $v_j$ is the value that a linked platform derives from authing using the main platform. We assume that $v_j$ is uniformly distributed in [0, 1]. Joint sites are heterogeneous in terms of the value they derive from the main platform. $\theta_j n_j$ captures the negative externality on the joint sites, where $n_j$ is the number of joint sites. $\beta$ is a parameter that captures cross-side network externality, which increases with an increase in the number of consumers $n_c$. Thus, $\beta$ is the value derived by a linked platform of an additional consumer connected to the main platform, which means that joint sites' utility increases as more consumers choose the same platform. In addition, we assume that each linked platform is an independent monopolist in its own market, that is, the linked platforms do not compete with each other. Joint sites that have an expected utility greater than zero are connected to the main platform by the authing service.

### 3.3 Demand

In this two-sided market, the demand from joint sites for authing services depends on the expected number of consumers who join the main platform. This outcome is because more joint sites tend to link an authing service with the main platform if there are more expected consumers. Moreover, the demand from both consumers and joint sites is affected by the expected number of joint sites. The expected loss is higher when the main platform is hacked if the number of joint sites is high. When the expected number of consumers is $n_c^e$ and the expected number of joint sites is $n_j^e$, the marginal consumer who is indifferent about joining the main platform has the following utility:

$$1+\alpha e-\theta_c n_j^e=n_c \tag{3}$$

The marginal joint site that is indifferent between linking to an authing service with the main platform and not linking to the authing service is determined by the following condition:

$$1-\theta_j n_j+\beta n_c^e=n_j \tag{4}$$

The equilibrium at which both consumers and joint sites have their expectations fulfilled is when $n_c^e=n_c$ and $n_j^e=n_j$. The number of consumers who join the main platform and the number of joint sites that join the authing service are then given by the solution of equations (3) and (4);

$$n_c=\frac{-\theta_c+(1+e\alpha)(1+\theta_j)}{1+\beta\theta_c+\theta_j} \tag{5}$$

$$n_j=\frac{1+\beta+e\alpha\beta}{1+\beta\theta_c+\theta_j} \tag{6}$$

Positivity of demand requires the condition, $(1+e\alpha)(1+\theta_j)>\theta_c$.

## Ⅳ. Results and Analysis

### 4.1 Market Equilibrium under a Monopoly

The monopolistic main platform sets the effort level $e$ to maximize profit. The main platform faces the problem of choosing an optimal $e$ to maximize

$$\pi=A(n_j+n_c)-ce^2 \tag{7}$$

where $A$ is the advertisement fee and $c$ is a cost parameter for the effort level $e$. We assume that the main platform collects advertisements fees from those seeking to advertise on, for example, the linked platform and other platforms. This advertisement fee is affected by the number of consumers who join the main platform and the number of joint sites that use the authing service provided by the main platform.

As the two sides affect each other simultaneously, it is difficult for the main platform to reduce its effort level, as doing so could lead to fewer consumers joining the main platform, which in turn could lead to fewer joint sites using the authing service. Thus, the optimal level of $e$ for the monopolist becomes

$$e^{M^*}=\frac{A(\alpha+\alpha\beta+\alpha\theta_j)}{2c(1+\beta\theta_c+\theta_j)} \tag{8}$$

By substituting equation (8) in equations (5) and (6), we can obtain the number of consumers who join the main platform and the number of joint sites that join the authing service when the platform profit is maximized under monopoly.

$$n_c^M = \frac{\begin{array}{c}-2c\beta\theta_c^2 + 2c(-1+\beta)\theta_c(1+\theta_j) + (1+\theta_j) \\ (2c + A\alpha^2(1+\beta) + (2c + A\alpha^2)\theta_j)\end{array}}{2c(1+\beta\theta_c+\theta_j)^2} \tag{9}$$

$$n_j^M = \frac{\begin{array}{c}(1+\beta)(2c + A\alpha^2\beta + 2c\beta\theta_c) \\ + (A\alpha^2\beta + 2c(1+\beta))\theta_j\end{array}}{2c(1+\beta\theta_c+\theta_j)^2} \tag{10}$$

In addition, the maximal profits of the monopoly main platform become

$$\pi = \frac{\begin{array}{c}A^2\alpha^2(1+\beta+\theta_j)^2 + 4Ac(2+\beta-\theta_c+\theta_j) \\ (1+\beta\theta_c+\theta_j)\end{array}}{4c(1+\beta\theta_c+\theta_j)^2} \tag{11}$$

## 4.2 Market Outcome under Monopoly

To examine the changes of players' participation level, depending on the expected loss of the consumer in the monopolistic platform condition, we differentiate the number of players into consumers' expected loss. This leads to the following proposition.

***Proposition 1***

*When the expected loss of consumers decreases, more consumers and joint sites participate in the platform. Conversely, if the expected loss of consumers increases, the numbers of both consumers and joint sites joining the platform decrease.*

**Proof.** See the Appendix.

Proposition 1 indicates that lowering the expected loss of consumers leads to an increase in the number of total members. When consumers perceive little danger in using the authing service, more consumers tend to use it. This tendency eventually leads to an increase in the number of joint sites, considering that more are likely to join when there are more players on the other side of the platform. In addition, the joint sites discover that the consumers' expected loss is not high and thus, they anticipate that more consumers will join the authing service, which in turn will draw more joint sites to the main platform. Therefore, to increase the number of participants, it would be effective to reduce the expected loss of consumers. Conversely, when the expected loss of consumers increases, the total number of both consumers and joint sites joining the main platform decreases. This is reasonable because the riskier joining is, the less consumers and joint sites would want to join the main platform. This finding is consistent with Yenisey *et al.* (2005) in that perceptions of weak online security could have negative consequences due to consumers' trust. In addition, with fewer consumers participating in the main platform, there would be less incentive to join the authing service. Consequently, the bigger the expected loss is for consumers, the less consumers would join, and owing to the small number of consumers in the platform, joint sites would not likely join the authing service.

To show the changes of players' participation level, depending on the expected loss of joint sites in the monopolistic condition, we differentiate the number of consumers and joint sites into the loss of joint sites. As we conduct the analysis, we find that changes in the players' participation level differ according to the range of the cost parameter and the condition of the expected loss of consumers. From this outcome, we suggest the following proposition.

***Proposition 2***

*At equilibrium, the impact of network externality and cost on the numbers of consumers and joint sites are as in the following Tables:*

**Proof.** See the Appendix.

Proposition 2 shows that when the cost of the effort level is moderate (see <Table 2>) and the expected loss of consumers is quite low, the total participation decreases as the joint sites' risk increases. This finding is related to whether a monopoly platform places more interest in the consumer or the joint site. The monopoly platform obtains more benefit from the consumer side, and if the expected loss of consumers is relatively low, the platform does not have much motivation to increase its effort level even if the cost of effort is not high. Moreover, when the cost of effort level is moderate (see <Table 3>) and the consumers' perceived risk is high, as the expected loss of joint sites increases, the number of total participants increases. This can be explained by the main platforms' effort level. When both the expected loss of consumers and joint sites are high, the main platform increases its effort to attract more participants on each side. The platform attempts to advertise that the risk is not that high and considers investing more in security, since the cost of effort is not very high. This finding is interesting because the number of consumers is affected by the expected loss of joint sites. The result shows that even if there is no direct influence on consumers from the expected loss of joint sites, consumers seem to be affected implicitly as platform ecosystem circulates.

On the contrary, when the cost of the main platform's effort level is high, the number of consumers and joint sites changes, regardless of the degree of the consumers' perceived risk. As the expected loss of joint sites increases, whether consumers have a high or low risk, the number of consumers increases, whereas the number of joint sites tends to decrease. This is surprising in that consumers tend to perceive the high cost of the main platform's effort level as implying a more protected platform ecosystem. When the main platform's effort level is relatively high, consumers can rely more on the main platform owing to its increased interest in the joint sites' loss. As the expected loss of joint sites increases, they tend to hesitate to join the main platform. However, consumers perceive this environment as an opportunity for a more protected and secure platform ecosystem.

〈Table 2〉 Weak Network Externality $(0 < \theta_c < 1)$

| Range of the cost parameter | $0 < c < \frac{A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)}{2(1+\beta)(1+\beta\theta_c+\theta_j)}$ | $\frac{A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)}{2(1+\beta)(1+\beta\theta_c+\theta_j)} < c < \frac{A\alpha^2\beta(1+\theta_j-\theta_c(2+\beta+2\theta_j))}{2(1+\beta)\theta_c(1+\beta\theta_c+\theta_j)}$ | $\frac{A\alpha^2\beta(1+\theta_j-\theta_c(2+\beta+2\theta_j))}{2(1+\beta)\theta_c(1+\beta\theta_c+\theta_j)} < c$ |
|---|---|---|---|
| $\frac{dn_c}{d\theta_j}$ | $n_c$ will decrease | $n_c$ will decrease | $n_c$ will increase |
| $\frac{dn_j}{d\theta_j}$ | $n_j$ will increase | $n_j$ will decrease | $n_j$ will decrease |

〈Table 3〉 Strong Network Externality $(\theta_c > 1)$

| Range of the cost parameter | $0 < c < \frac{A\alpha^2\beta(1+\theta_j-\theta_c(2+\beta+2\theta_j))}{2(1+\beta)\theta_c(1+\beta\theta_c+\theta_j)}$ | $\frac{A\alpha^2\beta(1+\theta_j-\theta_c(2+\beta+2\theta_j))}{2(1+\beta)\theta_c(1+\beta\theta_c+\theta_j)} < c < \frac{A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)}{2(1+\beta)(1+\beta\theta_c+\theta_j)}$ | $\frac{A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)}{2(1+\beta)(1+\beta\theta_c+\theta_j)} < c$ |
|---|---|---|---|
| $\frac{dn_c}{d\theta_j}$ | $n_c$ will decrease | $n_c$ will increase | $n_c$ will increase |
| $\frac{dn_j}{d\theta_j}$ | $n_j$ will increase | $n_j$ will increase | $n_j$ will decrease |

To make changes in the main platform's effort level, we differentiate the effort level into the expected loss of consumers and joint sites, depending on the expected loss of participants.

***Proposition 3***

*When the expected loss of consumers is relatively large* $(\theta_c > 1)$, *the effort level of a monopoly platform increases as the expected loss of the joint site increases. However, when the expected loss of consumers is relatively small* $(0 < \theta_c < 1)$, *the monopoly platform lowers its effort level as the expected loss of the joint site increases.*

**Proof.** See the Appendix.

Proposition 3 demonstrates that lowering the expected loss of consumers leads to an increase in the effort level of the main platform. This is an interesting finding, because it is typically considered that when the perceived risk is high, the main platform would or should increase its effort level to attract more members. Surprisingly, our finding shows the opposite outcome of Campbell *et al.* (2007), in which the main platform appears to be lowering its effort level as the expected loss of consumers increases. This can be explained by preventing the excessive effort that the main platform may have to exert to protect the consumers' presumed loss. As the expected loss of consumers increases, the main platform may consider the increase as the overly perceived risk of consumers. Therefore, the main platform itself can determine that it would be better off concentrating its investment on areas other than investing effort in the authing service, such as making the interface convenient.

However, when the loss of consumers is already high, the main platform expands its effort level as the expected loss of joint sites increases. The reason the main platform changes its effort level according to consumers' expected loss is that it does not want to lose both sides of participants. If the expected loss of consumers is already high, there would be less possibility of consumers joining the authing service. Moreover, as the loss of joint sites increases, they do not have an incentive to be involved in the authing service. To overcome this dilemma, the main platform increases its effort level to attract both sides of participants. On the contrary, when the expected loss of consumers is already low, the main platform tends to lower its effort level as the expected loss of joint sites increases. This outcome indicates that joint sites obtain larger benefit from more consumers being involved in an authing service; more consumers improve the main platform and eventually attract more joint sites, without effort level by the platform. Hence, the main platform has no incentive to care about the loss of joint sites when the loss of consumers is already low.

## 4.3 Socially Efficient Outcome

We now solve for the effort level that maximizes the total surplus. The total surplus (TS) is defined as the sum of the surplus of all the players in the market, consumer surplus (CS) and joint site surplus, as well as the main platform's profits. $\mathrm{TS} = \mathrm{CS} + \pi_j + \pi$.

$$CS = \int_{\theta_c n_j - \alpha e}^{1} (v_c + \alpha e - \theta_c n_j)\, dv_c \qquad (12)$$

is the consumer surplus, and

$$\pi_j = \int_{\theta_j n_j - \beta n_c}^{1} (v_j - \theta_j n_j + \beta n_c)\, dv_j \qquad (13)$$

is the joint site surplus. Maximizing the total surplus, the main platform should choose

$$e^{S^*} = \frac{\begin{gathered}\alpha(1+A+\beta+A\beta+\beta^2+\theta_j(2+A(2+\beta)\\ +(1+A)\theta_j)+\theta_c(-1+A\beta(1+\beta)\\ +(-1+A\beta)\theta_j))\end{gathered}}{\begin{gathered}2c-\alpha^2(1+\beta^2)+2c\beta^2\theta_c^2+\\ 4c\beta\theta_c(1+\theta_j)+(2c-\alpha^2)\theta_j(2+\theta_j)\end{gathered}} \quad (14)$$

$$n_c^S = \frac{\begin{gathered}2c+\alpha^2(A+\beta+A\beta)-2c\beta\theta_c^2\\ +2c(-1+\beta)\theta_c(1+\theta_j)\\ +\theta_j(4c+A\alpha^2(2+\beta)\\ +(2c+A\alpha^2)\theta_j)\end{gathered}}{\begin{gathered}2c-\alpha^2(1+\beta^2)\\ +2c\beta^2\theta_c^2+4c\beta\theta_c(1+\theta_j)\\ +(2c-\alpha^2)\theta_j(2+\theta_j))\end{gathered}} \quad (15)$$

$$n_j^S = \frac{\begin{gathered}2c(1+\beta)+\alpha^2(-1+A\beta(1+\beta))\\ +2c\beta(1+\beta)\theta_c\\ +(2c(1+\beta)+\alpha^2(-1+A\beta))\theta_j\end{gathered}}{\begin{gathered}2c-\alpha^2(1+\beta^2)+2c\beta^2\theta_c^2\\ +4c\beta\theta_c(1+\theta_j)+(2c-\alpha^2)\theta_j(2+\theta_j)\end{gathered}} \quad (16)$$

### 4.4 Comparison between Social Optimum and Monopoly

To examine the welfare implications, we compare equilibrium participation levels by the changes moving from the social optimum to the monopoly platform. Comparison of $n_c^M$ and $n_c^S$ leads to the following proposition.

***Proposition 4***

*When the expected loss of consumers is relatively low* $\theta_c < 1+\theta_j+\frac{\beta(1+\beta)}{1+\theta_j}$, *the numbers of consumers and joint sites in the monopoly market do not reach the socially optimal level. However, when the expected loss of consumers is relatively high* $\theta_c > 1+\theta_j+\frac{\beta(1+\beta)}{1+\theta_j}$, *the numbers of consumers and joint sites in the monopoly market exceed the socially optimal level.*

**Proof.** See the Appendix.

It appears that in Proposition 4, when the expected loss of consumers is low, more participants join the authing service at the socially optimal level than in the monopoly platform. A likely consequence of fewer participants joining the authing service in the monopoly platform is related to Proposition 1. As indicated, when the expected loss of consumers decreases, there is an increases in the number of consumers and joint sites in the monopoly platform. In other words, the main platform does not have to reach the socially optimal number of participants in order to maximize profits. Conversely, in terms of relatively high expected loss of consumers, the numbers of consumers as well as joint sites exceed the social optimum. Even if the number of both parties decreases while the loss of consumers increases, the participation level of the monopoly platform surpasses the socially optimal level. This result means that in order to make greater profits, the platform attracts more participants to apply for the authing service rather than considering both parties' surplus.

By comparing the optimal levels of efforts under the monopoly and the social welfare conditions, we derive the following proposition.

***Proposition 5***

*When the expected loss of consumers is relatively low* $\theta_c < 1+\theta_j+\frac{\beta(1+\beta)}{1+\theta_j}$, *the effort level of the main platform in the monopoly market does not reach the socially optimal level. However, when the expected loss of consumers is relatively high* $\theta_c < 1+\theta_j+\frac{\beta(1+\beta)}{1+\theta_j}$, *the effort level of the main platform in the monopoly market exceeds the socially optimal level.*

**Proof.** See the Appendix.

Proposition 5 illustrates that in the case of relatively low expected loss of consumers, the monopoly platform has a smaller effort level compared to that of the social optimum. From Proposition 3, the monopoly platform tends to increase its effort level as consumers' perceived loss decreases. Nonetheless, the effort level of the monopoly platform does not reach the socially optimal level. This result indicates that the monopoly platform does not need to increase its effort level in order to maximize its profit, but rather that the optimal effort level to maximize the benefits to all parties in the platform ecosystem is much higher. When the expected loss of consumers is relatively high, the effort level of the monopoly platform exceeds the social optimum. This finding means that from the socially optimal perspective, the effort level need not match that of the platform.

From policymakers' perspective, encouraging the main platform to invest more effort implies increasing the security of the joint sites. Increasing the effort level of the main platform is important because it directly relates to the main platform's security level, which affects the security of the joint sites. To make the market more secure, it would be better for the main platform to increase its effort level. When consumers' expected loss is relatively high, the main platform would spontaneously increase its effort level in the absence of regulation. Government regulation of the main platform's effort level is adequate only when the expected loss of consumers is reasonably low given the value of the main platform. Therefore, policymakers should encourage the main platform when consumers perceive the loss as being low.

## Ⅴ. Conclusion

In this study, we developed a two-sided market model to analyze the phenomenon of authing services in the platform ecosystem. We explicitly showed that there are both positive and negative network externalities in using authing services. The main findings include the following: 1) When consumers perceive low expected loss, more consumers and linked platforms tend to join the platform's authing service. 2) The changes in players' participation levels differ according to the cost of effort and the risk condition that consumers perceive. 3) The main platform's effort level depends predominantly on the expected loss of consumers. 4) When the consumers' loss is low, the monopoly platform has no incentive to increase the number of participants to the social optimum. 5) Policymakers should encourage main platforms to increase their effort levels for social welfare when the expected loss of consumers is low.

The findings of this study have several managerial implications. First, platform owners can increase the number of members using the authing service when they try to lower the perceived loss of members. To encourage more players joining the authing service within the platform, platform owners should show consumers that the loss on being hacked is relatively low. To do so, platform managers can advertise to consumers that a platform is sufficiently secured from linked platforms. Second, our findings highlight that platform managers focus more on consumers' loss than joint sites' loss when their budgets are limited. Platform managers should place more interest in the consumer side, since joint sites are linked with the virtuous cycle of consumer participation. Third, policymakers can encourage platform owners to comply with the policy, which improves the total surplus in the platform ecosystem. According to the results, platform owners have no incentive to change the effort level and the number of participants when the expected loss of consumers is relatively low. However, to increase the total surplus of every participant, policymakers should provide an incentive to make platform owners change their effort levels for others.

The results of this study make the following contributions to the literature. First, our research contributes to the platform integration literature by investigating both positive and negative network externalities in the platform ecosystem (Gowrisankaran and Stavins, 2002; Li and Agarwal, 2016). In contrast to most prior studies, which have focused more on the positive aspect of network externalities, our study showed that a negative aspect also exists. Second, the authing service is a relatively new service in the platform ecosystem and it influences not only the perceived behavior of consumers in the main platform but also that of linked platforms. This study complements the two-sided platform literature that has applied platforms' authing service. Lastly, the current findings add to a growing body of literature on the relationship between technology convenience and security risk (August and Tunca, 2006; McKinnon and Tallam, 2003; Tam *et al.*, 2010). Consistent with the findings in previous studies, our study contributes to the convenience-security literature by showing the existence of a user incentive-security tradeoff and by providing the proper level of participations and security effort level for the platform market. Although this study showed a two-sided platform authing strategy and demonstrated how an authing service could be applied to it, it has a few limitations. First, this study did not use any field data, as it employed a game-theoretic model. More comprehensive research using empirical validation could be undertaken in the future. Second, the model considers the cost of security only before the platform is hacked. In the real world, certain security costs are realized only after the platform is hacked.

This research has raised many questions in need of further investigation. Further work needs to be undertaken to establish who will bear liability in this model. When a platform is hacked, it is difficult to determine who the responsible party is, that is, who will cover the costs of being hacked. More broadly, future studies should also consider those who choose to use authing services, meaning which platform has the power to decide on the authing service. This study assumed that the power to decide whether to authenticate depends on the main platform only. However, in the real world, there exists a power struggle between main platforms and joint sites.

## References

[1] 김종기, 오다운, "전자상거래의 프라이버시 정책 인식이 개인정보제공의도에 미치는영향", *Information Systems Review*, 제18권, 제3호, 2016, pp. 185-207.

[2] 안호주, 장재영, 김범수, "금융기관 종사자들을 정보보안 위험관리로 이끄는 요인", *Information Systems Review*, 제17권, 제3호, 2015, pp. 39-64.

[3] 유소은, 김태하, 차훈상, "스마트폰 이용자의 모바일 광고 수용의사에 영향을 주는 요인: 개인화된 서비스, 개인정보보호, 광고 피로도 사이에서의 딜레마", *Information Systems Review*, 제17권, 제2호, 2015, pp. 77-100.

[4] 최보미, 박민정, 채상미, "개인정보보호 기술 수용행동에 영향을미치는 요인에 대한 연구", *Information Systems Review*, 제17권, 제3호, 2015, pp. 77-94.

[5] Armstrong, M., "Competition in two-sided markets", *The RAND Journal of Economics*, Vol.37, No.3, 2006, pp. 668-691.

[6] August, T. and T. I. Tunca, "Network software security and user incentives", *Management Science*, Vol.52, No.11, 2006, pp 1703-1720.

[7] August, T. and T. I. Tunca, "Who should be responsible for software security? A comparative analysis of liability policies in network environ-

ments", *Management Science*, Vol.57, No.5, 2011, pp 934-959.

[8] Bonneau, J., C. Herley, P. C. Van Oorschot, and F. Stajano, "The quest to replace passwords: A framework for comparative evaluation of web authentication schemes", *IEEE Symposium on Security and Privacy*, July 2012, pp. 553-567.

[9] Campbell, J., N. Greenauer, K. Macaluso, and C. End, "Unrealistic optimism in internet events", *Computers in Human Behavior*, Vol.23, No.3, 2007, pp. 1273-1284.

[10] Cantafio, B., "Security vs. convenience. Is RSA secur ID the answer", *Global Information Assurance Certification Paper*, Vol.1, 2004, p. 4.

[11] Cavusoglu, H., H. Cavusoglu, and J. Zhang, "Security patch management: Share the burden or share the damage?", *Management Science*, Vol.54, No.4, 2008, pp. 657-670.

[12] Economides, N. and J. Tag, "Network neutrality on the Internet: A two-sided market analysis", *Information Economics and Policy*, Vol.24, No.2, 2012, pp. 91-104.

[13] Feng, T., Z. Liu, K. A. Kwon, W. Shi, B. Carbunar, Y. Jiang, and N. Nguyen, "Continuous mobile authentication using touchscreen gestures", *IEEE Conference on Technologies*, 2012, pp. 451-456.

[14] Freedman, L. P., M. C. Gibson, S. P. Ethier, H. R. Soule, R. M. Neve, and Y. A. Reid, "Reproducibility: Changing the policies and culture of cell line authentication", *Nature Methods*, Vol.12, No.6, 2015, pp. 493-497.

[15] Glass, S., T. Hiller, S. Jacobs, and C. Perkins, "Mobile IP Authentication, Authorization, and Accounting Requirements", No. RFC 2977, 2000.

[16] Grosse, E. and M. Upadhyay, "Authentication at scale", *IEEE Security & Privacy*, Vol.11, No.1, 2013, pp. 15-22.

[17] Grossklags, J., N. Christin, and J. Chuang, "Secure or insure?: A game-theoretic analysis of information security games", In *Proceedings of the 17th International Conference on World Wide Web*, 2008, pp. 209-218.

[18] Hagiu, A., "Pricing and commitment by two sided platforms", *The RAND Journal of Economics*, Vol.37, No.3, 2006, pp. 720-737.

[19] Huang, P., M. Ceccagnoli, C. Forman, and D. J. Wu, "Appropriability mechanisms and the platform partnership decision: Evidence from enterprise software", *Management Science*, Vol.59, No.1, 2013, pp. 102-121.

[20] Jeun, I., M. Kim, and D. Won, "Enhanced password-based user authentication using smart phone", *International Conference on Grid and Pervasive Computing*, 2012, pp 350-360.

[21] Katz, M. L. and C. Shapiro, "Network externalities, competition, and compatibility", *The American Economic Review*, Vol.75, No.3, 1985, pp. 424-440.

[22] Katz, M. L. and C. Shapiro, "Technology adoption in the presence of network externalities", *The Journal of Political Economy*, Vol.94, No.4, 1986, pp. 822-841.

[23] Kim, B. C. and Y. W. Park, "Security versus convenience? An experimental study of user misperceptions of wireless internet service quality", *Decision Support Systems*, Vol.53, No.1, 2012, pp. 1-11.

[24] Kim, B. C., P. Y. Chen, and T. Mukhopadhyay, "The effect of liability and patch release on software security: The monopoly case", *Production and Operations Management*, Vol.20, No.4, 2011, pp. 603-617.

[25] Lamport, L., "Password authentication with insecure communication", *Communications of the ACM*, Vol.24, No.11, 1981, pp. 770-772.

[26] Li, Z. and A. Agarwal, "Platform integration and

demand spillovers in complementary markets: Evidence from Facebook's integration of Instagram", *Management Science*, 2016, pp. 1-22.

[27] Neuman, B. C. and T. Ts'o, "Kerberos: An authentication service for computer networks", *IEEE Communications Magazine*, Vol.32, No.9, 1994, pp. 33-38.

[28] Rabkin, A., "Personal knowledge questions for fallback authentication: Security questions in the era of Facebook", In *Proceedings of the 4th Symposium on Usable Privacy and Security*, 2008, pp. 13-23.

[29] Rochet, J. C. and J. Tirole, "Platform competition in two-sided markets", *Journal of the European Economic Association*, Vol.1, No.4, 2003, pp. 990-1029.

[30] Ryan Holmes, "Hootsuite's CEO on what he learned from getting hacked on social media", *Harvard Business Review*, 2016, Available at https://hbr.org/2016/10/hootsuites-ceo-on-what-he-learned-from-getting-hacked-on-social-media/.

[31] Tam, L., M. Glassman, and M. Vandenwauver, "The psychology of password management: A tradeoff between security and convenience", *Behaviour & Information Technology*, Vol.29, No.3, 2010, pp. 233-244.

[32] Wang, R., L. Xing, X. Wang, and S. Chen, "Unauthorized origin crossing on mobile platforms: Threats and mitigation", In *Proceedings of the 2013 ACM SIGSAC Conference on Computer & Communications Security*, 2013, pp. 635-646.

[33] Yenisey, M. M., A. A. Ozok, and G. Salvendy, "Perceived security determinants in e-commerce among Turkish university students", *Behaviour & Information Technology*, Vol.24, No.4, 2005, pp. 259-274.

# 〈Appendix〉

**Proof of Proposition 1**

A.1. Number of participants in a monopoly platform with respect to consumers' expected loss.

Consider the monopolistic case. Taking the derivative of $n_c^{M^*}$ with respect to $\theta_c$, we obtain equation (A1).

$$\frac{dn_c^{M^*}}{d\theta_c}=-\frac{(1+\theta_j)((1+\beta)(c+A\alpha^2\beta+c\beta\theta_c)+(c+c\beta+A\alpha^2\beta)\theta_j)}{c(1+\beta\theta_c+\theta_j)^3} \tag{A1}$$

Since $\frac{(1+\theta_j)((1+\beta)(c+A\alpha^2\beta+c\beta\theta_c)+(c+c\beta+A\alpha^2\beta)\theta_j)}{c(1+\beta\theta_c+\theta_j)^3}$ is positive, $\frac{dn_c^{M^*}}{d\theta_c}$ is always negative, which means that as the expected loss of consumers increases, the number of consumers decreases.

Taking the derivative of $n_j^{M^*}$ with respect to $\theta_c$, we obtain equation (A2).

$$\frac{dn_j^{M^*}}{d\theta_c}=-\frac{\beta((1+\beta)(c+A\alpha^2\beta+c\beta\theta_c)+(c+c\beta+A\alpha^2\beta)\theta_j)}{c(1+\beta\theta_c+\theta_j)^3} \tag{A2}$$

Similar to $\frac{dn_c^{M^*}}{d\theta_c}$, since $\frac{\beta((1+\beta)(c+A\alpha^2\beta+c\beta\theta_c)+(c+c\beta+A\alpha^2\beta)\theta_j)}{c(1+\beta\theta_c+\theta_j)^3}$ is positive, $\frac{dn_j^{M^*}}{d\theta_c}$ is always negative, which means that as the expected loss of consumers increases, the number of joint sites decreases.

**Proof of Proposition 2**

A.2. Number of participants in a monopoly platform with respect to joint sites' expected loss.

When the expected loss of consumers is relatively low $(0<\theta_c<1)$, $\frac{A\alpha^2\beta(1+\theta_j-\theta_c(2+\beta+2\theta_j))}{2(1+\beta)\theta_c(1+\beta\theta_c+\theta_j)}$ is bigger than $\frac{A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)}{2(1+\beta)(1+\beta\theta_c+\theta_j)}$, because when we subtract $\frac{A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)}{2(1+\beta)(1+\beta\theta_c+\theta_j)}$ from $\frac{A\alpha^2\beta(1+\theta_j-\theta_c(2+\beta+2\theta_j))}{2(1+\beta)\theta_c(1+\beta\theta_c+\theta_j)}$, we obtain $-\frac{A\alpha^2\beta(-1+\theta_c)}{2(1+\beta)\theta_c}$. Since the denominator of $-\frac{A\alpha^2\beta(-1+\theta_c)}{2(1+\beta)\theta_c}$ is always positive, the numerator determines the sign. Arranging the numerator by the expected loss of consumers yields:

$$-(A\alpha^2\beta(-1+\theta_c))>0\Leftrightarrow -A\alpha^2\beta+A\alpha^2\beta\theta_c<0\Leftrightarrow 0<\theta_c<\frac{A\alpha^2\beta}{A\alpha^2\beta}\Leftrightarrow 0<\theta_c<1$$

Therefore, $\frac{A\alpha^2\beta(1+\theta_j-\theta_c(2+\beta+2\theta_j))}{2(1+\beta)\theta_c(1+\beta\theta_c+\theta_j)}$ is bigger than $\frac{A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)}{2(1+\beta)(1+\beta\theta_c+\theta_j)}$, when $0<\theta_c<1$. Moreover, $\frac{A\alpha^2\beta(1+\theta_j-\theta_c(2+\beta+2\theta_j))}{2(1+\beta)\theta_c(1+\beta\theta_c+\theta_j)}$ is smaller than $\frac{A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)}{2(1+\beta)(1+\beta\theta_c+\theta_j)}$, when $\theta_c>1$.

Consider the monopolistic case. Taking the derivative of $n_c^{M^*}$ with respect to $\theta_j$, we obtain equation (A3).

$$\frac{dn_c^{M^*}}{d\theta_j}=\frac{(2c\beta(1+\beta)\theta_c^2-A\alpha^2\beta(1+\theta_j)+\theta_c(2c(1+\beta)+A\alpha^2\beta(2+\beta)+2(c+c\beta+A\alpha^2\beta)\theta_j))}{2c(1+\beta\theta_c+\theta_j)^3} \tag{A3}$$

Since the denominator of $\frac{dn_c^{M^*}}{d\theta_j}$ is always positive, $\frac{dn_c^{M^*}}{d\theta_j}$ is positive if the numerator is positive. Given that $-A\alpha^2\beta(1+\theta_j)$ is negative, $\frac{dn_c^{M^*}}{d\theta_j}$ is positive if $2c\beta(1+\beta)\theta_c^2+\theta_c(2c(1+\beta)+A\alpha^2\beta(2+\beta)+2(c+c\beta+A\alpha^2\beta)\theta_j)$ is bigger than $A\alpha^2\beta(1+\theta_j)$. Note that

$2c\beta(1+\beta)\theta_c^2+\theta_c(2c(1+\beta)+A\alpha^2\beta(2+\beta)+2(c+c\beta+A\alpha^2\beta)\theta_j)-A\alpha^2\beta(1+\theta_j)>0$

$\Leftrightarrow A\alpha^2\beta(-1-\theta_j+\theta_c(2+\beta+2\theta_j))+2(1+\beta)\theta_c(1+\beta\theta_c+\theta_j)c>0.$

Then, we rearrange the above formulas as the following equation (A4).

$$c>\frac{A\alpha^2\beta(1+\theta_j-\theta_c(2+\beta+2\theta_j))}{2(1+\beta)\theta_c(1+\beta\theta_c+\theta_j)} \tag{A4}$$

Therefore, when $c>\frac{A\alpha^2\beta(1+\theta_j-\theta_c(2+\beta+2\theta_j))}{2(1+\beta)\theta_c(1+\beta\theta_c+\theta_j)}$, the numerator is positive and this leads to positive $\frac{dn_c^{M^*}}{d\theta_j}$. This result means that in the range of $c>\frac{A\alpha^2\beta(1+\theta_j-\theta_c(2+\beta+2\theta_j))}{2(1+\beta)\theta_c(1+\beta\theta_c+\theta_j)}$, $n_c$ increases as the expected loss of joint sites increases. However, when $0<c<\frac{A\alpha^2\beta(1+\theta_j-\theta_c(2+\beta+2\theta_j))}{2(1+\beta)\theta_c(1+\beta\theta_c+\theta_j)}$, the numerator is negative, which leads to negative $\frac{dn_c^{M^*}}{d\theta_j}$. In this condition, as the expected loss of joint sites increases, the number of consumers tends to decrease.

As for the changes in the number of joint sites with respect to the expected loss of joint sites, we differentiate $n_j^{M^*}$ with respect to $\theta_j$.

$$\frac{dn_j^{M^*}}{d\theta_j}=-\frac{2c(1+\beta)+A\alpha^2\beta(1+2\beta)+\beta(-A\alpha^2\beta+2c(1+\beta))\theta_c+(A\alpha^2\beta+2c(1+\beta))\theta_j}{2c(1+\beta\theta_c+\theta_j)^3} \tag{A5}$$

From equation (A5), we find that the denominator of $\frac{dn_j^{M^*}}{d\theta_j}$ is always positive. To figure out whether $\frac{dn_j^{M^*}}{d\theta_j}$ is positive or not, we should determine the sign of the numerator. We rearrange the numerator as follows:

$$-\{2c(1+\beta)+A\alpha^2\beta(1+2\beta)+\beta(-A\alpha^2\beta+2c(1+\beta))\theta_c+(A\alpha^2\beta+2c(1+\beta))\theta_j\} \tag{A6}$$
$$\Leftrightarrow A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)-2c(1+\beta)(1+\beta\theta_c+\theta_j)$$

The numerator is positive if equation (A6) is positive. To find the condition of c, we set equation (A6) as positive and rearrange the equations.

$$\begin{aligned} & A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)-2c(1+\beta)(1+\beta\theta_c+\theta_j)>0 \\ \Leftrightarrow\ & -2c(1+\beta)(1+\beta\theta_c+\theta_j)>-(A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)) \\ \Leftrightarrow\ & 2c(1+\beta)(1+\beta\theta_c+\theta_j)<A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j) \\ \Leftrightarrow\ & c<\frac{A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)}{2(1+\beta)(1+\beta\theta_c+\theta_j)} \end{aligned} \tag{A7}$$

Therefore, from equation (A7), we find that in the condition of $0<c<\frac{A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)}{2(1+\beta)(1+\beta\theta_c+\theta_j)}$, the numerator is positive, which leads to positive $\frac{dn_j^{M^*}}{d\theta_j}$. Positive $\frac{dn_j^{M^*}}{d\theta_j}$ means that in this condition, as the expected loss of joint sites increases, the number of joint sites tends to increase. However, if the condition is $c>\frac{A\alpha^2\beta(-1-2\beta+\beta\theta_c-\theta_j)}{2(1+\beta)(1+\beta\theta_c+\theta_j)}$, the numerator is negative, which leads to negative $\frac{dn_j^{M^*}}{d\theta_j}$. This result means that in this condition, as the expected loss of joint sites increases, the number of joint sites decreases.

**Proof of Proposition 3**

A.3. Effort level in monopoly

Consider the monopolistic case. Taking the derivative of $e^{M^*}$ with respect to $\theta_c$ yields equation (A8).

$$\frac{de^{M^*}}{d\theta_c}=-\frac{A\alpha\beta(1+\beta+\theta_j)}{2c(1+\beta\theta_c+\theta_j)^2} \tag{A8}$$

Since the denominator of $\frac{de^{M^*}}{d\theta_c}$ is always positive, $\frac{de^{M^*}}{d\theta_c}$ is positive if the numerator is positive. However, given that $A\alpha\beta(1+\beta+\theta_j)$ is always positive, the numerator of $\frac{dn_c}{d\theta_c}$ is always negative. Therefore, $\frac{dn_c}{d\theta_c}$ is always negative.

Taking the derivative of $e^{M^*}$ with respect to $\theta_j$, we obtain equation (A9).

$$\frac{de^{M^*}}{d\theta_j}=\frac{A\alpha\beta(-1+\theta_c)}{2c(1+\beta\theta_c+\theta_j)^2} \tag{A9}$$

Since the denominator of $\frac{de^{M^*}}{d\theta_j}$ is always positive, $\frac{de^{M^*}}{d\theta_j}$ is positive if the numerator is positive. By rearranging the numerator of $\frac{de^{M^*}}{d\theta_j}$ and setting the numerator as positive, we obtain equation (A10).

$$-A\alpha\beta + A\alpha\beta\theta_c > 0 \Leftrightarrow A\alpha\beta\theta_c > A\alpha\beta \Leftrightarrow \theta_c > A\alpha\beta / A\alpha\beta \Leftrightarrow \theta_c > 1 \tag{A10}$$

Therefore, from equation (A10), we find that in the condition of $\theta_c > 1$, the numerator is positive, which leads to positive $\frac{de^{M^*}}{d\theta_j}$. Positive $\frac{de^{M^*}}{d\theta_j}$ means that in this condition, as the expected loss of joint sites increases, the effort level of the monopoly platform increases. However, if the condition is $0 < \theta_c < 1$, the numerator is negative, which leads to negative $\frac{de^{M^*}}{d\theta_j}$. This result means that in this condition, as the expected loss of joint sites increases, the effort level of the monopoly platform decreases.

**Proof of Proposition 4**

A.4. Difference of participation levels between monopolistic platform and social optimum. The difference in equilibrium consumers' participation levels as we move from the socially optimal platform to the monopolistic two-sided platform is

$$\begin{aligned}\triangle n_c &= n_c^{S^*} - n_c^{M^*} \\ &= \frac{\alpha^2(1+\theta_j)(A\alpha^2(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j)) + 2c(1+\beta\theta_c+\theta_j)(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j)))}{2c(1+\beta\theta_c+\theta_j)^2(2c(1+\beta\theta_c+\theta_j)^2-\alpha^2(1+\beta^2+\theta_j(2+\theta_j)))}\end{aligned} \tag{A11}$$

while the difference in the equilibrium participation levels of the joint sites is

$$\begin{aligned}\triangle n_j &= n_j^{S^*} - n_j^{M^*} \\ &= \frac{\alpha^2\beta(A\alpha^2(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j)) + 2c(1+\beta\theta_c+\theta_j)(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j)))}{2c(1+\beta\theta_c+\theta_j)^2(2c(1+\beta\theta_c+\theta_j)^2-\alpha^2(1+\beta^2+\theta_j(2+\theta_j)))}\end{aligned} \tag{A12}$$

The second-order conditions for the socially optimal maximization problem are $\frac{1}{2}(-4c+\frac{2\alpha^2\beta^2}{(1+\beta\theta_c+\theta_j)^2} + \frac{2\alpha^2(1+\theta_j)^2}{(1+\beta\theta_c+\theta_j)^2}) < 0$. As we rearrange by $c$, the second-order conditions become $c > \frac{\alpha^2(1+\beta^2+\theta_j(2+\theta_j))}{2(1+\beta\theta_c+\theta_j)^2}$. In order to focus on interior solutions, only we assume that the second-order conditions are fulfilled. The denominators of both $\triangle n_c$ and $\triangle n_j$ are always positive for $c > \frac{\alpha^2(1+\beta^2+\theta_j(2+\theta_j))}{2(1+\beta\theta_c+\theta_j)^2}$, which holds under second-order conditions.

Therefore, the signs of $\triangle n_c$ and $\triangle n_j$ are determined by the numerator, which is positive if $\theta_c < 1+\theta_j+\frac{\beta(1+\beta)}{1+\theta_j}$. Since $A\alpha^2(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j))$ and $\alpha^2\beta$ ($\beta$>0) are positive, $\triangle n_c$ is positive if $(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$ is positive. However, if $(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$ is negative, we need to compare whether $A\alpha^2(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j)$ or $2c(1+\beta\theta_c+\theta_j)(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$ is big. Given that $(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$ is negative, $A\alpha^2(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j))$ can never be bigger than $2c(1+\beta\theta_c+\theta_j)(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$.

$$(A\alpha^2(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j))-2c(1+\beta\theta_c+\theta_j)(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j)))$$

$$=\frac{\alpha^2(1+\beta^2+\theta_j(2+\theta_j))}{2(1+\beta\theta_c+\theta_j)}\times\frac{A(1+\beta+\theta_j)}{(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))}<c \qquad \text{(A13)}$$

The left-hand side of equation (A13) is negative, because $(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))<0$. Therefore, when $\theta_c<1+\theta_j+\frac{\beta(1+\beta)}{1+\theta_j}$, $\triangle n_c$ is positive, and $\theta_c>1+\theta_j+\frac{\beta(1+\beta)}{1+\theta_j}$, $\triangle n_c$ is negative.

Given that $A\alpha^2(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j))$ and $\alpha^2\beta$ ($\beta$>0) are positive, $\triangle n_j$ is positive if $(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$ is positive. However, if $(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$ is negative, we need to compare whether $A\alpha^2(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j))$ or $2c(1+\beta\theta_c+\theta_j)(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$ is big. Given that $(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$ is negative, $A\alpha^2(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j))$ can never be bigger than $2c(1+\beta\theta_c+\theta_j)(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$. Same as $\triangle n_c$, the left-hand side of equation (A13) is negative ($\because (1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))<0$). Therefore when $\theta_c<1+\theta_j+\frac{\beta(1+\beta)}{1+\theta_j}$, $\triangle n_j$ is positive, and when $\theta_c>1+\theta_j+\frac{\beta(1+\beta)}{1+\theta_j}$, $\triangle n_j$ is negative.

**Proof of Proposition 5**

A.5. Difference in effort level between monopolistic platform and socially optimal platform.

The difference in equilibrium effort level as we move from the socially optimal platform to the monopolistic two-sided platform is

$$\triangle e=e^{S^*}-e^{M^*}$$

$$=\frac{A\alpha^3(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j))+2c\alpha(1+\beta\theta_c+\theta_j)(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))}{2c(1+\beta\theta_c+\theta_j)\{2c(1+\beta\theta_c+\theta_j)^2-\alpha^2(1+\beta^2+\theta_j(2+\theta_j))\}} \qquad \text{(A14)}$$

Note that the second-order conditions for the planner's maximization problem are $\frac{\alpha^2(1+\beta^2+\theta_j(2+\theta_j))}{2(1+\beta\theta_c+\theta_j)}<c$,

and the denominator of $\triangle e$ is always positive. Therefore, the sign is determined by the numerator, which is positive if $\theta_c < 1+\theta_j+\frac{\beta(1+\beta)}{1+\theta_j}$. Since $A\alpha^3(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j))$ is positive, $\triangle e$ is positive if $(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$ is positive. However, if $(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$ is negative, we need to compare whether $2c\alpha(1+\beta\theta_c+\theta_j)(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$ or $A\alpha^3(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j))$ is large. Assuming that $(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$ is negative, $A\alpha^3(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j))$ could never be bigger than $2c\alpha(1+\beta\theta_c+\theta_j)(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))$

$$
\begin{aligned}
& A\alpha^3(1+\beta+\theta_j)(1+\beta^2+\theta_j(2+\theta_j))-2c\alpha(1+\beta\theta_c+\theta_j)(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j)) \\
& =\frac{\alpha^2(1+\beta^2+\theta_j(2+\theta_j))}{2(1+\beta\theta_c+\theta_j)}\times\frac{A(1+\beta+\theta_j)}{(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))}< c
\end{aligned}
\tag{A15}
$$

The left-hand side of equation (A15) is negative because of $(1+\beta+\beta^2-\theta_c(1+\theta_j)+\theta_j(2+\theta_j))<0$. Therefore, when $\theta_c < 1+\theta_j+\frac{\beta(1+\beta)}{1+\theta_j}$, $\triangle e$ is positive, and $\theta_c > 1+\theta_j+\frac{\beta(1+\beta)}{1+\theta_j}$, $\triangle e$ is negative.

Information Systems Review
Volume 20 Number 1
March 2018

# Authing Service of Platform: Tradeoff between Information Security and Convenience

Eun Sol Yoo* · Byung Cho Kim**

## Abstract

Online platforms recently expanded their connectivity through an authing service. The growth of authing services enabled consumers to enjoy easy log in access without exerting extra effort. However, multiple points of access increases the security vulnerability of platform ecosystems. Despite the importance of balancing authing service and security, only a few studies examined platform connectivity. This study examines the optimal level of authing service of a platform and how authing strategies impact participants in a platform ecosystem. We used a game-theoretic approach to analyze security problems associated with authing services provided by online platforms for consumers and other linked platforms. The main findings are as follows: 1) the decreased expected loss of consumers will increase the number of players who participate in the platform; 2) linked platforms offer strong benefits from consumers involved in an authing service; 3) the main platform will increase its effort level, which includes security cost and checking of linked platform's security if the expected loss of the consumers is low. Our study contributes to the literature on the relationship between technology convenience and security risk and provides guidelines on authing strategies to platform managers.

***Keywords: Platform, Network Externality, Authing Service, Game Theory***

---

* Department of Logistics, Service & Operations Management, College of Business, Korea University
** Corresponding Author, Department of Logistics, Service & Operations Management, College of Business, Korea University

## ◐ 저 자 소 개 ◑

**유 은 솔 (graceat@korea.ac.kr)**

중앙대학교에서 경영학 학사를 취득하였으며, 고려대학교 경영학과에서 석·박사 통합 과정 재학 중이다. 주요 연구 관심분야는 플랫폼 경쟁(platform competition), 네트워크 외부성(network externality) 등이다.

**김 병 조 (bkim@korea.ac.kr)**

서강대학교에서 수학 전공으로 이학사, University of Chicago 에서 통계학 석사, Carnegie Mellon University에서 경영학 석·박사 학위를 취득하였다. 미국 Virginia Tech 경영대학 조교수를 역임하였으며 현재 고려대학교 경영대학에서 부교수로 재직 중이다. MIS Quarterly, Production and Operations Management, Decision Science 등의 학술지에 논문을 게재하였으며 주요 연구 관심분야는 기술경영, 정보기술 등이다.

**논문접수일 : 2018년 02월 01일** **게재확정일 : 2018년 03월 27일**
**1차 수정일 : 2018년 03월 19일**