Master's Thesis

Title

On the Effectiveness of Growth and Profit Strategies for Platform Providers in API Economy Based on Multi-Sided Model

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Abstract

Network technology has developing and application services on the network have become widespread among many people. An API economy that information processing and data provision by APIs and these services collaboration thorough APIs creates new value is attracting attention in recent years. Such the economy is often modeled as two-sided market model where the platform provider provides some services via API to consumers as for the one-side and receives some services from developers as for the another-side. Then, the effect of interactions between consumes and developers on economic activities has been analyzed intensively. However, there exists other customer groups to interact with consumers and/or developers. One of typical examples is API evaluators that increase motivation to consume/develop APIs by their evaluations.

In this thesis, we introduce API evaluators to the API economy as one of the business strategies of platform provider, and we analyze the behavior of the API economy using our multi-sided market model. Numerical results with API evaluators show that the profit of the platform providers increases, however, the number of market participants decreases because of the increase of payments from consumer/developers to the platform providers. For the platform providers, the profit is always important in general, but the number of market participants is also important especially when the API economy is at early stages of its economic development. Therefore, we introduce the utility function of platform provider, which is the weighted sum of the profit and number of market participants, into our multi-sided market model. Then, we analyze the behavior of the API economy in detail and reveal the parameter region where the API economy would receive the benefit from participation of API evaluators while the number of participants in the market increases.

At the market with API evaluators, when the consumers and developers are positively affected each other, the number of participants in the market increases by 5.46 % and the profit of the platform increases by 4.5 times larger than that without the API evaluators.

Keywords

API economy

Platform

API evaluator

Multi-sided market

Two-sided market

Market Economy

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1 Introduction

Recently, network technology has developing and application services on the network have become widespread among many people. API economy that information processing and data provision by APIs and these services collaboration thorough APIs creates new value is attracting attention [1]. In API economy, developers and consumers connect to an platform, and services are supplied and consumed through APIs as Fig. 1. When these services are regarded as a "goods", API economy is regarded as a market economy, and a platform can be regarded as a market.

A two-sided market model is a model for analyzing the market economy. Two-sided market model can analyze a market of the most basic structure, where two customer groups interact with each other through a platform [2]. The two customer groups supply/consume services and interact to increase the market value. Among the studies using the two-sided market model, there are studies dealing with the digital market. Zhang et al. [3] describe a relationship between a quality of service provided by a developer and a network technology provided by a network provider. Nagurney et al. [4] find an equilibrium between price and supply when the developer can change the quality and quantity of service. Sen et al. [5] describes how best platform provider set number of features on a platform to maximize their utility in a scenario where developers develop an application using features on the platform and the application is used by consumers. Platform providers are paying attention to business strategies that change the number of features, and it thought that an optimal number of features can lead to increase market value. All the above is analyzed using a two-sided market model, but in real world there are customer groups other than developers and consumers [6]. For example, Trenz et al. [7] reveals that product reviews from consumers increase product offerings and increase purchase motivation on EC sites. The existence of evaluating services (APIs) is important for increasing the activity of the market.

A multi-sided market model is a model as a model for analyzing markets with more customer groups than the two-sided market. Recently, a multi-market has been attracting attention same as two-sided market [8, 9]. A multi-sided market model is defined as a market that is expected to multiple customer groups such as developers and consumers

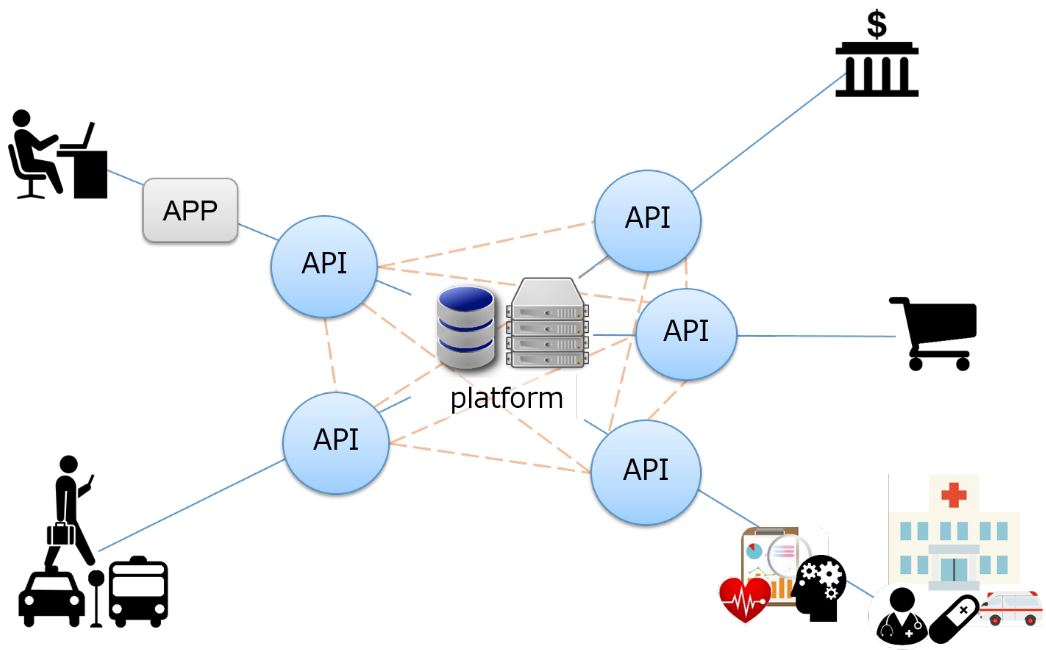

Figure 1: An example of API economy composition

and advertiser and so on interact each other and it increase a market value [10]. Using a multi-sided market model, there are studies analyzing a market where various customer groups interact. Stanoevska-Slabeva et al. [11] take Apple as an example and deals with a market where mobile phones and Internet is platforms. It analyzes the market where mobile operators, telecommunications carriers, application developers, advertisers, and consumers exist in a multi-sided market model, and describes roles and profits of each. Bisco Comandini et al. [12] analyze how Google increase their profit on their search engine platform. Platform provider provides better advertisements to consumers, and advertisers and consumers are attracted to this market, thereby the profit of the platform provider increases. However, these studies are only analysis in which the interaction between multiple customer groups is important for the platform provider, but do not describe the business strategy in which the platform provider increase the market value.

In Ref [13], we show a multi-sided market model including API evaluators based on a two-sided market model consisting of platform provider, developers, and consumers [5]. Our results show that, up to a certain amount of reward for API evaluators, the platform utility increases due to a positive API evaluators' impact on developers and consumers.

When too much reward for API evaluators is paid, the platform utility decreases. However, our results also show that, comparing the equilibriums of the markets with and without API evaluators, the number of market participants decreases because of the increase of the platform usage fee, although the platform utility increases in total. This model only analyze the platform provider strategies that increase the profit of platform provider. For the platform providers, the profit is always important in general, but the number of market participants is also important [14–17]. Because, the number of participants is small specially when the API economy is at early stages of its economic development. By introducing a parameter to increase the number of market participants, the model can analyze the platform strategies that increases other than the profit of platform provider.

Therefore, in this thesis, we show the multi-sided market model of the platform to increase the number of market participants based on the multi-sided market model in Ref. [13]. Specifically, we introduced a weighted sum of the number of market participants and profit of the platform provider in utility of platform provider. When platform provider increases the number of market participants, it is expected that platform usage fees decrease, and the platform utility decreases. However, it can be considered that there is a parameter area where the platform utility increases compared to without API evaluators due to participation of API evaluators. Therefore, we use our model to clarify the parameter area which increase both the number of market participants and the profits of the platform provider. In addition, we clarify parameters that maximize the number of market participants. By clarifying the requirements of these parameters, we consider a strategy to increase the utility of the platform provider while increasing the number of market participants that is important in the platform business.

This thesis is organized as follows. Section 2 explains our models with/without API evaluators. Section 3 explain how to find equilibriums with/without API evaluators using our model which is explained in Secion 2. Section 4 explains numerical examples and discuss the optimal strategies of platform provider. Finally, Section 5 explains the conclusions and future works.

2 Market Model of API Economy

2.1 Overview

In this section, we explain our model. First, we explain a two-sided market model based on [5]. In the two-sided market, there are platform provider, developers and consumers. Next, we add API evaluators to the market model to make a multi-sided model with API evaluators. Table 1 and Table 2 show variables in our model. Finally, we explain strategies of the platform provider that can be inferred from the utility function.

In this paper, there are some restrictions. In this thesis, we consider the case that consumers and developers pay platform fee to platform provider. Platform usage fees for a consumer p_c and platform usage fees for a developer b_d is considered the positive case, that is, $p_c > 0$ and $b_d > 0$. With this case, consumers and developers pay the platform usage fees to use the platform. Without the loss of generality, the maximum number of consumers, x_c, and the number of developers, n_d, is set to 1. When we treat the actual number of persons, we just re-scale n_d and x_c to the maximum possible numbers of developers and consumers [5].

2.2 Two-Sided Market Model without API Evaluators

Firstly, we explain a two-sided market where there are platform provider, developers and consumers. Figure 2 shows the profit relationships and interactions between platform provider, developers and consumers. Table 1 shows variables in the model. The platform provider receives the platform usage fees $b_d \times n_d$ [price/period] from the developers and the platform usage fees $p_c \times x_c$ [price/period] from consumers. b_d [price/person/period] is the platform usage fees per a consumer and p_c [price/person/period] is the platform usage fees per a developer. Platform usage fees are same for each consumer and for each developer as same as [5,18,19]. n_d [person] is the number of developers and x_c [person] is the number of consumers. The platform provider implements features on the platform, it costs $C(F)$ [price/period]. F is the number of features, and cost of implementing features on the platform changes depending on the number of features F. A developer pays the platform provider for a platform usage fees b_d and provides consumers with benefit $\theta \times \beta \times n_d$ [price/person/period]. In this thesis, the β is identical for each consumer and

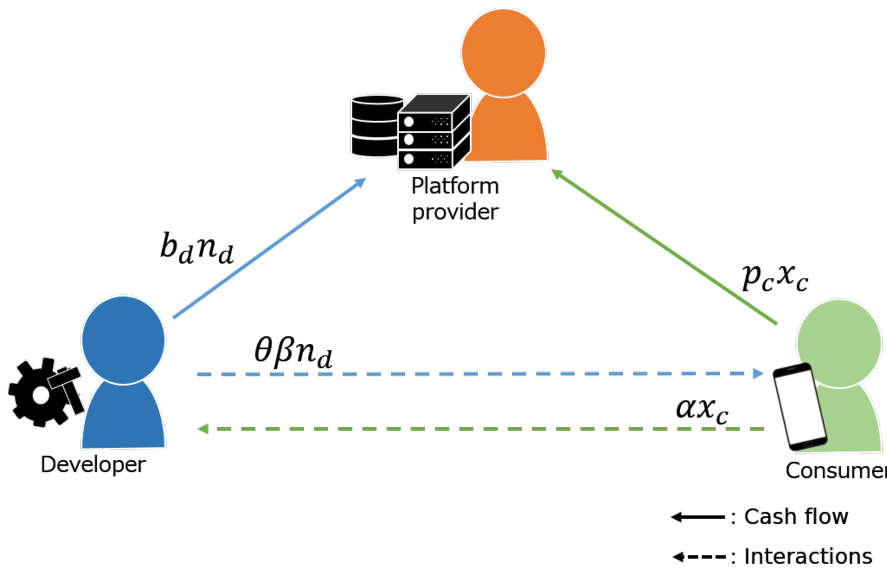

Figure 2: Illustration of two-sided market model: Platform provider, developers, and consumers

each developer. A developer development APIs, it cost $K(F)$ [price/person/period] + ϕ [price/person/period]. $K(F)$ is a common development cost for all developers, and ϕ is a development costs due to differences in developer skill levels of each developer. Ease of development APIs changes depending on the number of features F. A consumer pays the platform provider for the platform usage fees p_c and provides developers with benefit $\alpha \times x_c$ [price/person/period]. Note that α [price/person/person/period] is the parameter that represents the benefit of each developer from each consumer at a period. In this thesis, the α is identical for each developer and each consumer.

Utility functions of platform provider, developer and consumer are follows. The variables used are shown in the Table 1. The platform utility U_p is the utility function of platform provider and defined as,

$$U_p = p_c \times x_c + b_d \times n_d - C(F). \tag{1}$$

U_p represents the profit of the platform provider and is consists of revenues and expenses. In the equation, the revenue is the sum of the income from consumers $p_c \times x_c$ and the income from developers $b_d \times n_d$. The expense is $C(F)$ which is the cost to implementing F features on the platform. Note that $C(F)$ is defined in Sec. 4.1. The developer utility

Table 1: Notations used in our market model

p_c	Platform usage fees for a consumer per period ($0 < p_c$) [price/person/period]
b_d	Platform usage fees for a developer per period ($0 < b_d$) [price/person/period]
x_c	The number of consumers ($0 \le x_c \le 1$) [person]
n_d	The number of developers ($0 \le n_d \le 1$) [person]
F	The number of features
$C(F)$	The cost of implementing F features on the platform [price/period]
$K(F)$	Common development costs for all developers [price/person/period]
ϕ	Development costs due to differences in developer skill levels [price/person/period]
α	Benefit of a developer from a consumer [price/person/person/period]
β	Benefit of a consumer from a developer [price/person/person/period]
θ	Heterogeneity of quality of API services

U_d is the utility function of one developer and defined as,

$$U_d = \alpha \times x_c - b_d - (K(F) + \phi). \tag{2}$$

U_d consists of benefit, platform usage fees and cost. $\alpha \times x_c$ is benefit from consumer, and it increases linearly for x_c. b_d is platform usage fees for a developer. $K(F) + \phi$ is development cost to develop APIs. Note that $K(F)$ is defined in Sec. 4.1. The consumer utility U_c is the utility function of one consumer and defined as,

$$U_c = \theta \times \beta \times n_d - p_c. \tag{3}$$

U_c is consists of benefit and platform usage fees. θ is the non-uniformity of benefit that consumers feel, and it distribute [0,1]. $\beta \times n_d$ is benefit of interaction that can be enjoyed by using platform services and increases linearly with the number of developers n_d. p_c is platform usage fees.

2.3 Multi-Sided Market Model with API Evaluators

We describe a multi-sided market model with API evaluators. Figure 3 shows the profit relationships and interactions between a platform provider, developers, consumers and API

Table 2: Explanation of API evaluators variables in market model

y_e	Reward for an API evaluator per period [price/person/period]
$E(y_e)$	The number of API evaluators [person]
γ	Benefit of developer from an API evaluator [price/person/person/period]
ω	Benefit of consumer from an API evaluator [price/person/person/period]
λ	Benefit of API evaluator from a consumer/developer [price/person/person/period]
ξ	Rate of profit a platform provider can make from the size of the market [price/person/person/period]

evaluators. Table 1 show variables regards to the platform provider, developers and consumers. Table 2, which is variables regards to API evaluators. We explain the profit and interactions between API evaluators and developers/consumers. The platform provider pays rewards y_e [price/person/period] to one API evaluator. Developers impact one API evaluator $\lambda \times n_d$ [price/person/period]. Similarly, consumers impact one API evaluator $\lambda \times x_c$ [price/person/period]. In this thesis, the λ is identical for each API evaluator and each developer/consumer. Entire of API evaluators receive rewards from the platform provider $y_e \times E(y_e)$ [price/period]. API evaluators give benefit to one developer $\gamma \times E(y_e)$ [price/person/period] and give benefit to one consumers $\omega \times E(y_e)$ [price/person/period]. In this thesis, the γ and the ω is identical for each developer/consumer and each API evaluator. We assume that $\gamma \times E(y_e)$ is a motivation to development APIs will increase by being evaluated their APIs. We assume that $\omega \times E(y_e)$ is a motivation to use APIs will increase by looking at API evaluations.

Utility functions of platform provider, developer, consumer and API evaluator are follows. The variables used are shown in the Table 1 and Table 2. Utility functions of platform provider, developer and consumer are follows. The variables used are shown in the Table 1. The platform utility U_p is the utility function of platform provider and defined as,

$$U_p = p_c \times x_c + b_d \times n_d - y_e \times E(y_e) - C(F). \tag{4}$$

U_p represents the profit of the platform provider and is consists of revenues and expenses.

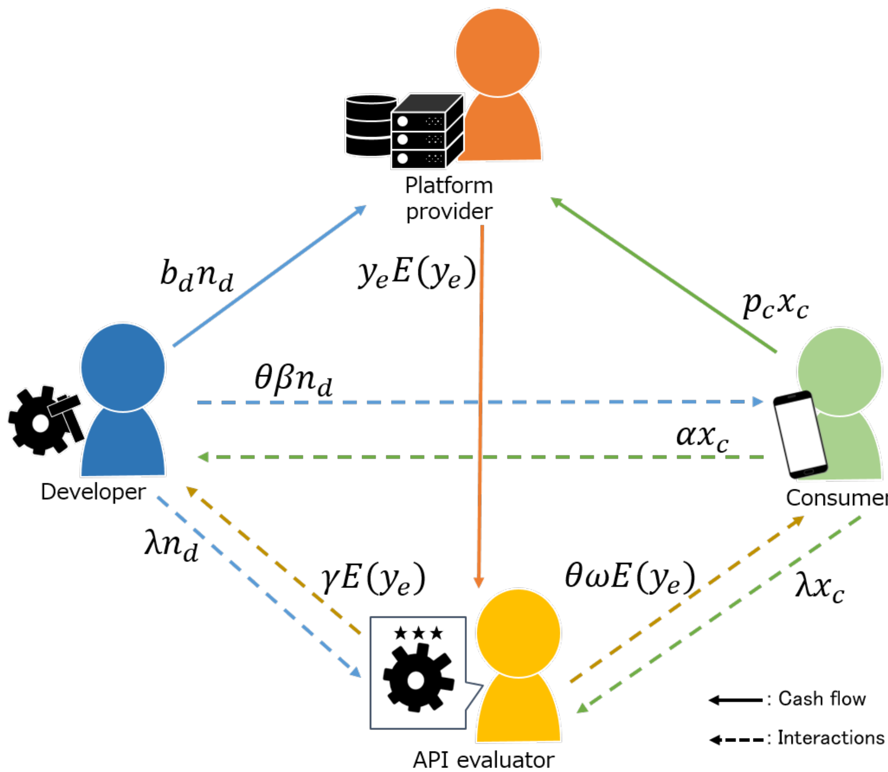

Figure 3: Illustration of multi-sided market model: Platform provider, developers, consumers, and API evaluators

In the equation, the revenue is the sum of the income from consumers $p_c \times x_c$ and the income from developers $b_d \times n_d$. $y_e \times E(y_e)$ is rewards for entire of API evaluators. The expense is $C(F)$ which is the cost to implementing F features on the platform. Note that $C(F)$ is defined in Sec. 4.1. With this utility, the platform usage fees increase largely, and the number of market participants decrease. Therefore, we will introduce a parameter to increase the number of market participants. B_p is added the parameter ξ to Eq. (4),

$$B_p = \xi \times (x_c + n_d) + U_p. \tag{5}$$

$\xi \times (x_c + n_d)$ is benefit of the number of market participants, and it is a linear function of consumer x_c and developers n_d, which is a main participant in the market. The developer utility U_d is the utility function of one developer and defined as,

$$U_d = \alpha \times x_c + \gamma \times E(y_e) - b_d - (K(F) + \phi). \tag{6}$$

U_d is consists of benefit, platform usage fees and cost. $\alpha \times x_c$ is benefit from consumer, and it increases linearly for x_c. $\gamma \times E(y_e)$ is benefit of API evaluators, and it increase linearly for $E(y_e)$. b_d is platform usage fees for a developer. $K(F) + \phi$ is development cost to develop APIs. Note that $K(F)$ is defined in Sec. 4.1. The consumer utility U_c is the utility function of one consumer and defined as,

$$U_c = \theta \times (\beta \times n_d + \omega \times E(y_e)) - p_c. \tag{7}$$

U_c is consists of benefit and platform usage fees. θ is the non-uniformity of benefits that consumers feel, and it distribute [0,1]. $\beta \times n_d$ is benefit of interaction that can be enjoyed by using platform services and increases linearly with the number of developers n_d. $\omega \times E(y_e)$ is benefit of API evaluators and it increase linearly for $E(y_e)$. p_c is platform usage fees.

The API evaluator utility U_e is the utility function of one API evaluator and defined as,

$$U_e = y_e + \lambda \times (n_d + x_c). \tag{8}$$

U_c is consists of an incentive and benefit. y_e is rewards from platform provider, and it is an incentive for participation of API evaluators from platform provider. $\lambda \times (n_d + x_c)$ is benefit of consumers and developers.

2.4 Strategies of Platform Providers to Maximize Their Utility Function

We describe strategies that the platform provider can take. The platform provider utility is the sum of the profit of a product of the platform usage fees and the number of market participants and negative costs. So, we can consider the following three strategies to increase the utility.

- Profit priority strategy
  A strategy to increase profits by raising platform usage fees. Increasing platform usage fees increase the profit per a person but reduce the number of market participants. When the number of market participants decreases, it considers that platform service development stagnates, and it is difficult to attract more platform users when the market conditions change.

- Market participation number priority strategy

  A strategy to increase profits by increasing the number of market participants . Although the profit per person is small, the interaction of customer groups is important in the platform business. The more customers there are in the market, the more interaction between customer groups. So, the market value increases. In addition, by increasing a feedback obtained from market participants , it is possible that platform service quality will improve, and the value of the market will increase.

- Cost reduction strategy

  A strategy to reduce the number of features on the platform. It reduces a platform cost. But if the number of features is reduced too much, it is difficult for developers to develop APIs. As a result, platform utility isn't increase. Even if the number of features is increased too much, some features isn't used and it is wasted. In this thesis, an optimal number of functions is derived from the platform usage fees and the number of market participants.

3 Methodology to Obtain Market Equilibrium

In this section, we explain a methodology to obtain an equilibrium in the multi-sided market where there are the platform provider, developers, consumers and API evaluators. There is a two-stage game as a way to find the equilibrium of a market [5, 20, 21]. In the first stage, the platform provider to set the price. In the second stage, the customer groups decide whether to join the platform. A two-stage game is a method to find the equilibrium by solving this in the order of the second step and the first step. In this time, we consider platform. So, a stage that platform provider determines the number of features is added. We solve these stage in reverse to find the equilibrium [5]. Note that the notations of variables with asterisk, such as x_c^* and n_d^*, represent the values of the variables at the equilibrium in the market without API evaluators. The notations of variables with "hat", such as $\hat{x_c}$ and $\hat{n_d}$, represent the values of variables at the equilibrium in the market with API evaluators.

We find an equilibrium without/without API evaluators based on [5]. Figure 4 shows overview of methodology of finding the equilibrium, and get platform utility U_p, the number of consumers x_c, the number of developers n_d, platform usage fees for a consumer p_c and platform usage fees for a developer b_d. How we find the equilibrium without API evaluators is as follows. In I. Adoption stage, we derive a relational expression between x_c, n_d and p_c, b_d. In II. Pricing stage, platform usage fees p_c, b_d is decided. In III. Design stage, the number of features F is decided. How we find the equilibrium with API evaluators is as follows. In I'. Adoption stage, we derive a relational expression between x_c and p_c and derive a relational expression between n_d and b_d. In II'. Pricing stage, platform usage fees p_c, b_d and rewards for API evaluator y_e is decided. In III'. Design stage, the number of features F is decided.

3.1 Equilibrium without API Evaluators

First, we find an equilibrium without API evaluators based on [5]. It corresponds to I. Adoption stage - III. Design stage in Fig. 4. Note that $F^*, x_c^*, n_d^*, p_c^*, b_d^*$ show variables in the equilibrium in the market without API evaluators.

At the Adoption stage, we derive a relational expression between x_c and p_c, and derive

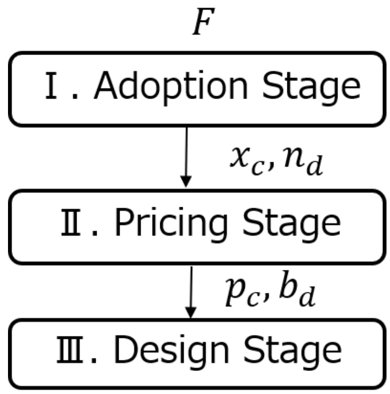

Figure 4: Solution methodology to find an equilibrium in the market without API evaluators

a relational expression between n_d and b_d. When $U_c = 0$, by solving Eq. (3) for θ,

$$\theta = \frac{p_c}{\beta n_d^*}. \tag{9}$$

θ represents the number of consumers that will not join the platform at the equilibrium [22]. That is, $\theta + x_c^* = 1$. Based on these equations, we have,

$$1 - x_c^* = \frac{p_c}{\beta n_d^*}. \tag{10}$$

When $U_d = 0$ Eq. (2) is solved for ϕ,

$$\phi = \alpha x_c^* - b_d - K(F). \tag{11}$$

ϕ represents the number of developers that will not join the platform at the equilibrium [19]. That is, $\phi = n_d^*$. Based on these equations, we have,

$$n_d^* = \alpha x_c^* - b_d - K(F). \tag{12}$$

Using Eqs. (10) and (12), p_c^*, b_d^* is

$$\begin{aligned} p_c^* &= \beta(1 - x_c^*) n_d^*, && (13) \\ b_d^* &= \alpha x_c^* - n_d^* - K(F). && (14) \end{aligned}$$

At the Pricing stage, We derive platform usage fees p_c, b_d. First, by using $\frac{\partial U_p}{\partial x_c^*} = 0$ and $\frac{\partial U_p}{\partial n_d^*} = 0$, the number of consumers x_c/developers n_d which maximizes the utility is obtained. And we derive platform usage fee p_c, b_d by using a relational expression between x_c and p_c and derive the number of developers n_d by using a relational expression between n_d and b_d. Given F, when x_c, n_d is decided, platform utility is

$$\max_{x_c^* n_d^*} U_p = p_c x_c^* + b_d n_d^* - C(F), \qquad (15)$$
$$s.t.\ 0 \leq x_c^* \leq 1,\ 0 \leq n_d^* \leq 1.$$

The number of consumers to maximize profits can be derived from $\frac{\partial U_p}{\partial x_c^*} = 0$,

$$\frac{\partial U_p}{\partial x_c^*} = (1 - 2x_c^*)\beta n_d^* + \alpha n_d^* = 0. \qquad (16)$$

From this, the following is derived;

$$x_c^* = \frac{\alpha + \beta}{2\beta}. \qquad (17)$$

Similarly, the number of developers to maximize profits can be derived from $\frac{\partial U_p}{\partial n_d^*} = 0$,

$$\frac{\partial U_p}{\partial n_d^*} = (1 - x_c^*)\beta x_c^* + \alpha x_c^* - 2n_d^* - K(F) = 0. \qquad (18)$$

From this, the following is derived;

$$n_d^* = \frac{(\alpha + \beta)^2 - 4\beta K(F)}{8\beta}. \qquad (19)$$

Substituting Eq. (17) and Eq. (19) for (13), platform usage fees for consumer is,

$$p_c^* = \frac{(\beta - \alpha)((\alpha + \beta)^2 - 4\beta K(F))}{16\beta}. \qquad (20)$$

Substituting Eq. (17) and Eq. (19) for (14), platform usage fees for developer is,

$$b_d^* = \frac{(3\alpha - \beta)(\alpha + \beta) - 4\beta K(F))}{8\beta}. \qquad (21)$$

Note that $p_c > 0$, $b_d > 0$, $x_c > 0$, $n_d > 0$ because p_c, b_d, x_c, n_d is positive value. So, α, β, $K(F)$ satisfy $\alpha < \beta$ and $4\ \beta\ K(F) < (\alpha + \beta)^2 < 4\ \beta\ (2 - K(F))$.

At the Design stage, we derive the number of features F. When equilibrium, we solve Eq. (15) using Eq. (17) and Eqs. (19) - (21). The following relational expression is obtained by $\frac{\partial U_p}{\partial F} = 0$,

$$C'(F^*) - [-\frac{\beta^2 - \alpha^2}{8\beta} - \frac{(\alpha + \beta)^2}{16\beta} - \frac{(3\alpha - \beta)(\alpha + \beta)}{16\beta}]K'(F^*) + \frac{K(F^*)K'(F^*)}{2} = 0, \qquad (22)$$

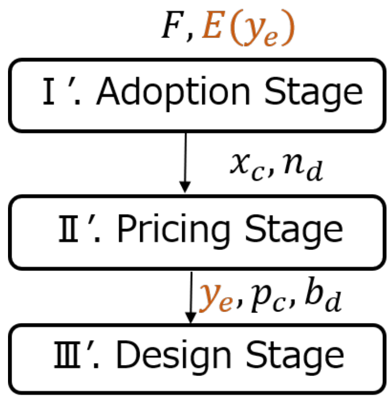

Figure 5: Solution methodology to find an equilibrium in the market with API evaluators

$$\frac{C'(F^*)}{K'(F^*)} = \frac{K(F^*)}{2} - \frac{(\alpha + \beta)^2}{8\beta}. \tag{23}$$

From these F, x_c, n_d, p_c, b_d, the platform utility U_p in the market without the API evaluators is calculated. In this methodology, the platform cost $C(F)$ and the development cost $K(F)$ are given in advance. We explain these settings in Section 4.1.

3.2 Equilibrium with API Evaluators

First, we find an equilibrium without API evaluators based on [5]. It corresponds to I'. Adoption stage - III'. Design stage in Fig. 5. Difference from Fig. 4, values for API evaluators is added. The number of API evaluators $E(y_e)$ is given in advance, and the rewards for API evaluator y_e is derived at the Pricing stage. Note that the number of consumers is $\hat{x_c}$, the number of developers is $\hat{n_d}$, platform usage fees for consumer is $\hat{p_c}$, platform usage fees for developer is $\hat{b_d}$ show variables in the equilibrium in the market with API evaluators.

At the Adoption stage, we derive a relational expression between x_c and p_c, and derive a relational expression between n_d and b_d. When $U_c = 0$, Eq. (7) is solved for θ,

$$\theta = \frac{\hat{p_c}}{\beta \hat{n_d} + \omega E(y_e)}. \tag{24}$$

θ represents the number of consumers that will not join the platform at the equilibrium [22].

That is, $\theta + \hat{x_c} = 1$. Based on these equations, we have,

$$1 - \hat{x_c} = \frac{\hat{p_c}}{\beta \hat{n_d} + \omega E(y_e)}. \tag{25}$$

When $U_d = 0$ Eq. (6) is solved for ϕ,

$$\phi = \alpha \hat{x_c} - \hat{b_d} + \gamma E(y_e) - K(F). \tag{26}$$

ϕ represents the number of developers that will not join the platform at the equilibrium [19]. That is, $\phi = \hat{n_d}$. Based on these equations, we have,

$$\hat{n_d} = \alpha \hat{x_c} - \hat{b_d} + \gamma E(y_e) - K(F). \tag{27}$$

Using Eqs. (25) and (27), $\hat{p_c}, \hat{b_d}$ is

$$\hat{p_c} = (1 - \hat{x_c})(\beta \hat{n_d} + \omega E(\hat{y_e})), \tag{28}$$

$$\hat{b_d} = \alpha \hat{x_c} - \hat{n_d} + \gamma E(\hat{y_e}) - K(F). \tag{29}$$

At the Pricing stage, We derive platform usage fees p_c, b_d and reward for API evaluator y_e. First, by using $\frac{\partial U_p}{\partial \hat{x_c}} = 0$ and $\frac{\partial U_p}{\partial \hat{n_d}} = 0$, the numbers of consumers, x_c, and developers, n_d, that maximize the utility is obtained. And we derive platform usage fees, p_c and b_d, by using a relational expression between x_c and p_c and derive the number of developers n_d by using a relational expression between n_d and b_d. The optimal reward for API evaluator y_e led from $\frac{\partial U_p}{\partial y_e} = 0$. Function of $E(y_e)$ is explained in Section 4.1.2. When API evaluators exist, given F, when x_c, n_d is decided, platform utility B_p is

$$B_p = \xi(\hat{x_c} + \hat{n_d}) + \hat{p_c}\hat{x_c} + \hat{b_d}\hat{n_d} - \hat{y_e}E(\hat{y_e}) - C(F). \tag{30}$$

Substituting Eqs. (28) and (29) for Eq. (30),

$$\begin{aligned} B_p = \xi(x_c + n_d) &+ (1 - \hat{x_c})(\beta \hat{n_d} + \omega E(\hat{y_e}))\hat{x_c} + \\ &(\alpha \hat{x_c} - \hat{n_d} + \gamma E(\hat{y_e}) - K(F))\hat{n_d} - \hat{y_e}E(\hat{y_e}) - C(F). \end{aligned} \tag{31}$$

Using Eq. (31), the numbers of consumers and developers to maximize profits can be derived from $\frac{\partial B_p}{\partial \hat{x_c}} = 0$ and $\frac{\partial B_p}{\partial \hat{n_d}} = 0$.

At the Design stage, we derive the number of features F as same as in Section 3.1 because it has nothing to do with API evaluators.

From these F, x_c, n_d, p_c, b_d, y_e, the platform utility B_p in the market where API evaluators exists is calculated. In this methodology, the platform cost $C(F)$, the development cost $K(F)$ and the number of API evaluators $E(y_e)$ are given in advance.

4 Numerical Examples

In this section, we explain the results and considerations obtained by changing parameters and functions. First, in Section 4.1, we explain parameters and functions settings. Using this settings, we get numerical examples and discuss the optimal strategy of platform provider in Sections 4.2 and 4.3.

4.1 Parameters and Functions Settings

In this section we explain parameters and functions. Platform cost, development cost and API evaluators follow a function shape. The benefit of developer from an API evaluator γ and the benefit of consumer from an API evaluator ω setting as follows. $\gamma = 0.08$, $\omega = 0.08$.

4.1.1 Platform cost $C(F)$ and development cost $K(F)$

We can assume a combination of platform cost $C(F)$ and development cost $K(F)$ as follows [5]. Respect to the number of features, the platform cost $C(F)$ increases convexly and the development cost $K(F)$ decreases concavely. Basic feature is low cost, but advanced feature is high cost. The more useful the features for developers, the higher the cost is. The functions set as follows.

$$C(F) = pF^w, K(F) = re^{sF} \tag{32}$$

In this thesis, parameters are $p = 0.008$, $w = 1.15$, $r = 0.4$, $s = -0.194$.

4.1.2 The number of API evaluators for rewards $E(y_e)$

The number of API evaluators depends on a reward paid by the platform provider. $E(y_e)$ is as follows, and we change shape of the function by changing parameter C, P.

$$E(y_e) = Cy_e^P \tag{33}$$

C, P are constant numbers. When $C = 1$, $E(y_e)$ is linear increase. The number of API evaluators increase by a certain number as rewards increase. In this thesis, parameters are $C = 0.8$, $P = 1$. When $C > 1$, $E(y_e)$ is concave increase. The number of API evaluators

Table 3: Difference of market characteristics with/without API evaluators: $\alpha = 0.65$, $\beta = 0.8$

$E(y_e)$	$\hat{y_e}$	U_p	x_c	n_d	p_c	b_d
Without API evaluators	0.0	0.0194	0.906	0.193	0.0145	0.125
0.8 y_e	0.0638	0.0225	0.896	0.208	0.0177	0.133
0.8 y_e^2	0.0793	0.0196	0.905	0.194	0.0148	0.126

increases slightly when the reward is small, but the number of API evaluators increases significantly when the reward is large. In this thesis, parameters are $C = 0.8$, $P = 2$.

4.2 Profit Strategies with API evaluators

We explain when maximize only the platform utility without considering the number of market participants. Basically, participation of API evaluators increases the platform utility and decreases the number of market participants. Note that the notations of variables with asterisk, such as x_c^* and n_d^*, represent the values of the variables at the equilibrium in the market without API evaluators. The notations of variables with "hat", such as $\hat{x_c}$ and $\hat{n_d}$, represent the values of variables at the equilibrium in the market with API evaluators. In this section, the parameter ξ is set to 0. We consider case that platform provider increases platform usage fees while the number of market participants decreases.

Fundamentally, platform usage fees, p_c and b_d increase and the number of consumers x_c decreases (Table 3). The platform utility U_p is increasing due to platform usage fees p_c and b_d increase and the increase in the number of developers n_d due to the influence of API evaluators.

Figure 6 shows the platform utility U_p against the reward for API evaluator y_e when the number of API evaluators $E(y_e) = 0.8\ y_e$. In these figures, the optimal reward for API evaluator $\hat{y_e}$ means the value of y_e that maximizes U_p (Eq. (4)). Non-optimal reward for API evaluator y_e reduces the platform utility U_p [13]. Non-optimal reward for API evaluator y_e is smaller or larger than the optimal value. By increasing the reward for API evaluator y_e up to the optimal value, the platform utility U_p increases due to the interaction between API evaluators and consumers/developers. However, when the reward for API

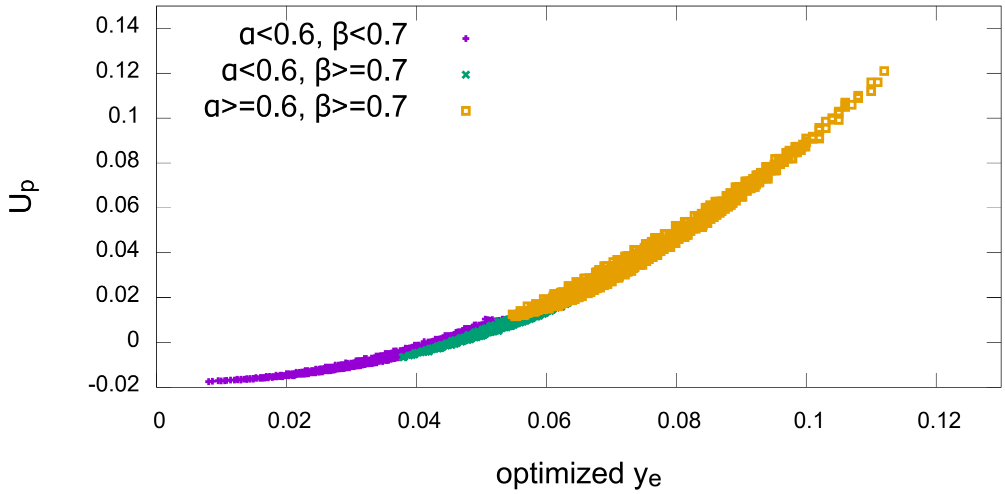

Figure 6: Platform utility U_p against the reward for API evaluator y_e: $E(y_e) = 0.8\ y_e$

evaluator y_e larger than the optimal value, the platform utility U_p decreases due to over payment of the reward to the API evaluator. The platform utility U_p and the optimal reward for API evaluator y_e are getting larger when α, β are large than when α is small and β is large. And they are getting larger when α is small and β is large than when α and β are small. The larger α, β, the larger the reward for API evaluator y_e. However, when α, β are small, the good effect of participation of API evaluators is not large, and the platform utility is negative. Figure. 7 shows the platform utility U_p against the reward for API evaluator y_e when the number of API evaluators $E(y_e) = 0.8\ y_e^2$. As with $E(y_e)$ $= 0.8\ y_e$, the larger the α, β, the larger the reward for API evaluator y_e.

Table 4 shows the market state U_p, x_c, n_d, p_c, b_d, y_e comparison with API evaluators and without API evaluators. Taking $\hat{y_e} = 0$ means that API evaluators do not exist in the market. Our results show that the platform utility U_p with API evaluators is about 16.4 times larger than that without API evaluators. Platform utility is $U_p = 0.0001$ when API evaluator does not exist, the platform utility is $U_p = 0.00184$ when API evaluators exist. The smallest increase in the platform utility U_p increase by 62.3 % when $\alpha = 0.71$, $\beta =$ 0.87. Platform utility is $U_p = 0.03211$ when API evaluator does not exist, the platform utility is $U_p = 0.0341$ when API evaluators exist. In both cases, it seems that the platform

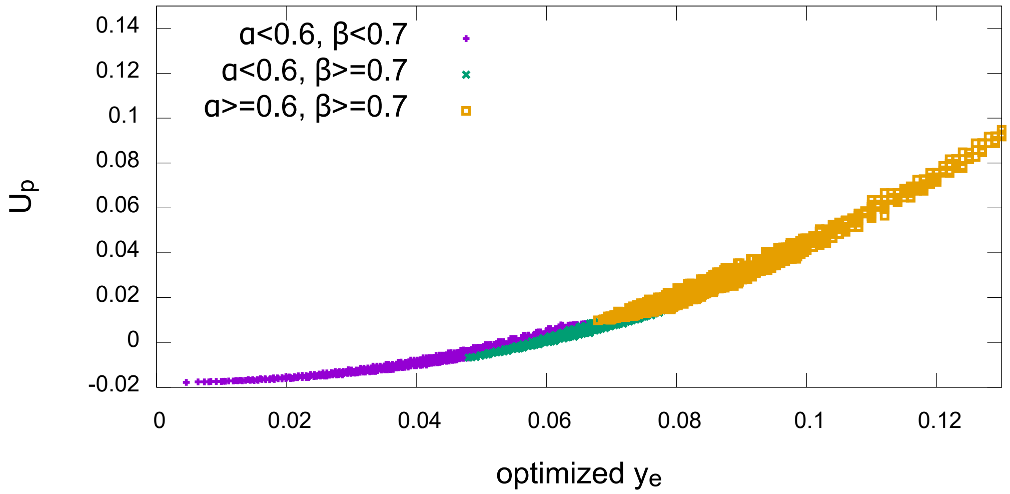

Figure 7: Platform utility U_p against the reward for API evaluator y_e: $E(y_e) = 0.8\ y_e^2$

Table 4: Market characteristics with/without API evaluator: U_p largest/smallest increase

case	α, β	$\hat{y_e}$	U_p	x_c	n_d	p_c	b_d
Largest increase	0.52, 0.76	0.0474	0.00164	0.833	0.145	0.0189	0.038
		0.0	0.0001	0.842	0.134	0.0161	0.033
Smallest increase	0.71, 0.87	0.0733	0.0341	0.899	0.241	0.0216	0.159
		0.0	0.0321	0.908	0.223	0.0178	0.151

utility increase mainly due to the increase in profits from the developers. When α and β are small, the platform utility is negative. So, participation of API evaluators has no merit. The larger the α and the smaller β, the greater the impact of participation of API evaluator. The larger the α and β, the smaller the impact of participation of API evaluators.

4.3 Growth and Profit Strategies with API evaluators

We explain how the parameter ξ impact on the platform profit U_p, platform usage fees p_c and b_d, the profit from consumers $p_c \times x_c$, and the profit from developers, $b_d \times n_d$, and the number of market participants $x_c + n_d$, in this section. The larger parameter ξ, the larger the number of market participants. The larger parameter ξ, the smaller the platform profit. Note that the equilibrium is derived for maximizing the platform utility B_p, but we select U_p and $x_c + n_d$ for further investigations.

Figure 8 shows the change in the optimal reward for API evaluator y_e against the parameter ξ. From this figure, we consider the reward for API evaluator y_e while change the parameter ξ. Figure 9 shows the change in the platform profit U_p against the parameter ξ. In these figures, the optimal reward for API evaluator $\hat{y_e}$ means the value of y_e that maximizes B_p (Eq. (5) to which we introduce ξ). Hereafter, a market where α, β is large is regard as mutually beneficial market, a market where α is small β is large is beneficial market, a market where α, β is small is independent market. In Figs. 8 and 9, depending on the values of α and β, the market is categorized into three types;

- mutually beneficial market where α and β are high values: $\alpha = 0.75$, $\beta =$0.8,
- beneficial market where β is high value but α is low value: $\alpha = 0.5$, $\beta = 0.8$,
- independent market where α and β are low values: $\alpha =$0.5, $\beta =$0.6.

In mutually beneficial market, $y_e = 0.0762$ at $\xi = 0.0$, $y_e = 0.0767$ at $\xi = 0.01$. The optimal reward for API evaluator y_e has increase tendency as ξ increases. Platform provider increase ξ when trying to increase the number of market participants while the profit of the platform decreases. In mutually beneficial market, the participation of API evaluators cause interaction between consumers and developers and increase platform profits. So, the optimal strategy is to increase the reward for API evaluators y_e. In beneficial market, y_e $= 0.0469$ at $\xi = 0.0$, $y_e = 0.0468$ at $\xi = 0.01$. The optimal reward for API evaluator y_e is almost unchanged as ξ increases. Platform provider increase ξ when trying to increase the number of market participants while the profit of the platform decreases slightly. In beneficial market, the good effect of participation of API evaluators diminishes. So, the optimal strategy is not to change the reward for API evaluators y_e. In independent market, $y_e = 0.0399$ at $\xi = 0.0$, $y_e = 0.0389$ at $\xi = 0.01$. The optimal reward for API evaluator y_e has decrease tendency as ξ increases. Platform provider increase ξ when trying to increase the number of market participants while the profit of the platform decreases. In independent market, the good effect of participation of API evaluators diminishes. So, the optimal strategy is to decrease the reward for API evaluators y_e.

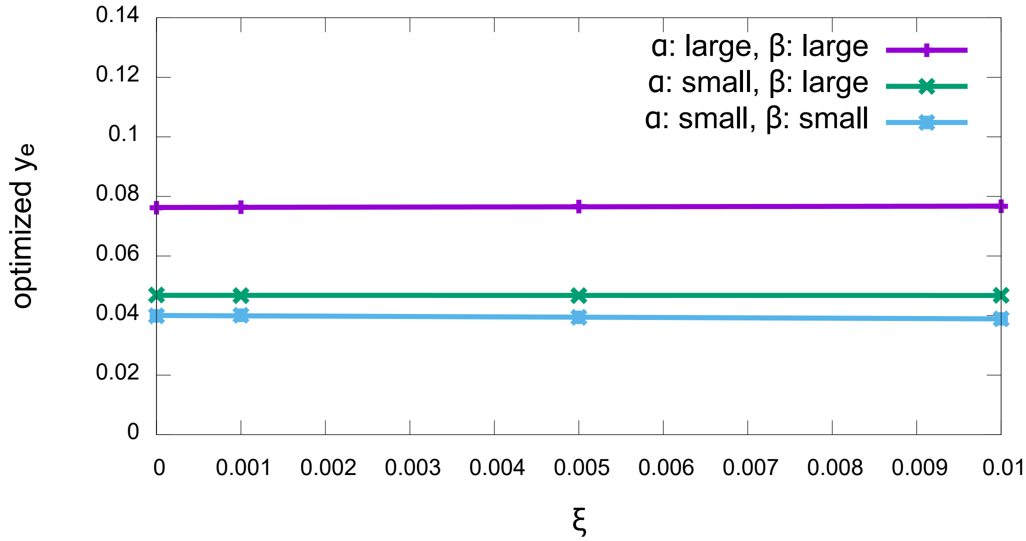

Figure 8: Impact of parameter ξ to the optimal reward for API evaluator y_e

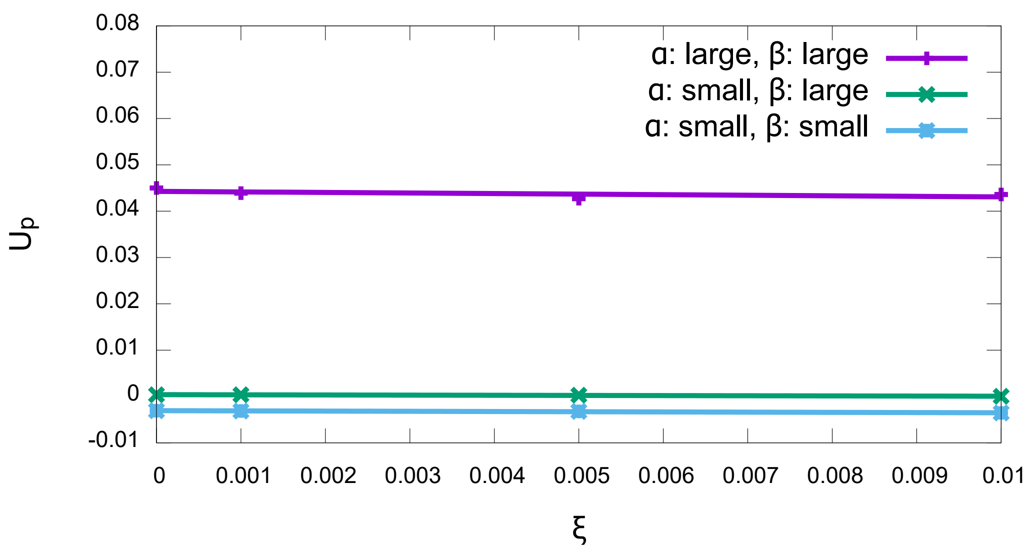

Figure 9: Impact of parameter ξ to the platform profit

Figure 10 shows changes in the platform profit from consumers $p_c \times x_c$ and from developers $b_d \times n_d$ against the parameter ξ. The platform profit U_p is subtracted the cost y_e $E(y_e)$ and $C(F)$ against sum of $p_c \times x_c$ and $b_d \times n_d$.Figure 11 shows changes in platform usage fees for consumers p_c and platform usage fees for developers b_d against the parameter ξ. From Fig. 10, as ξ increases, the platform profit from developers $b_d \times n_d$ increases and the platform profit from consumers $p_c \times x_c$ decreases. In order to expand the market in a single-sided market, it is natural to reduce platform usage fees, p_c and/or b_d, to increase the number of market participants, x_c and/or n_d, in the market. In the multi-sided market, when platform provider increases the number of market participants by increasing ξ, reducing the platform usage fees p_c, b_d is not always the only means of making profit. From Figs. 10 and 11, it can be observed that the platform profit from consumers $p_c \times x_c$ decreases as a result of lowering platform usage fees for consumers p_c, while the platform profit from developers $b_d \times n_d$ increases. This is because participation of API evaluators and expansion of the number of market participants by ξ. While The platform usage fees for developers b_d increases, the number of developers n_d increases due to mutual interaction with API evaluators and consumers. Although a certain increase in the number of developers n_d can be obtained just by participation of API evaluators, the effect is improved by both of expansion of the number of market participants strategy and participation of API evaluators.

Table 5 shows the market state U_p, x_c, n_d, p_c, b_d, y_e comparison with API evaluators and without API evaluators when $E(y_e) = 0.8\, y_e$. Taking $\hat{y_e} = 0$ means that API evaluators do not exist in the market. The larger parameter ξ, the lower platform profit and platform usage fees to consumers, and the larger the number of consumers and the number of developers and platform usage fees to developers. The increase in the number of developers despite the increase in platform usage fees to developers is due to the increase in the number of consumers due to the participation and interaction of API evaluators. So, by paying attention to the number of market participants, the interactions between customer groups is promoted. The number of market participants x_c + n_d increases the largest when α is small and β is large (beneficial market). The number of market participants x_c + n_d increases by 5.16 % from 0.968 to 1.12. The number of market participants x_c + n_d increases the smallest when α, β is small (independent market). The number of market

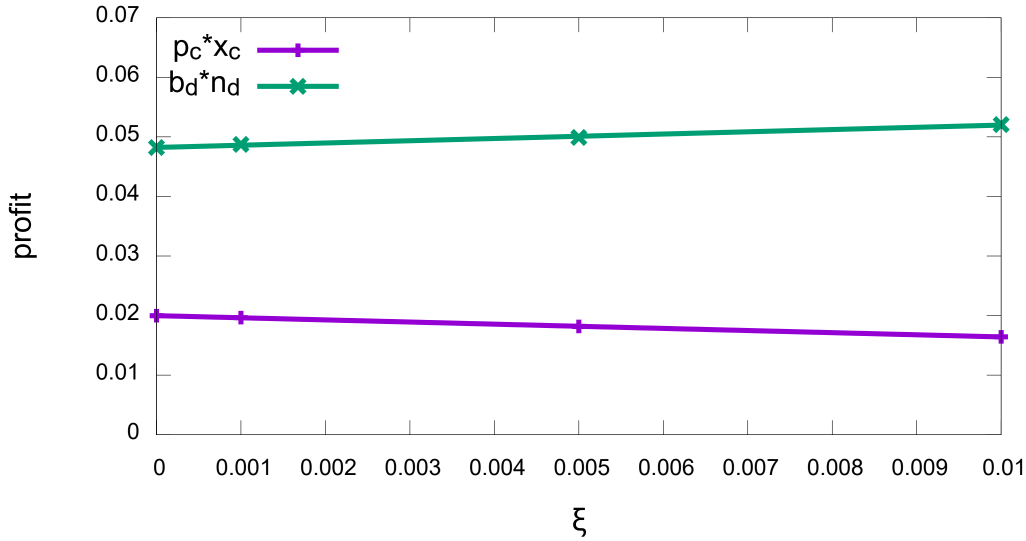

Figure 10: Impact of parameter ξ to the profits from consumers/developers

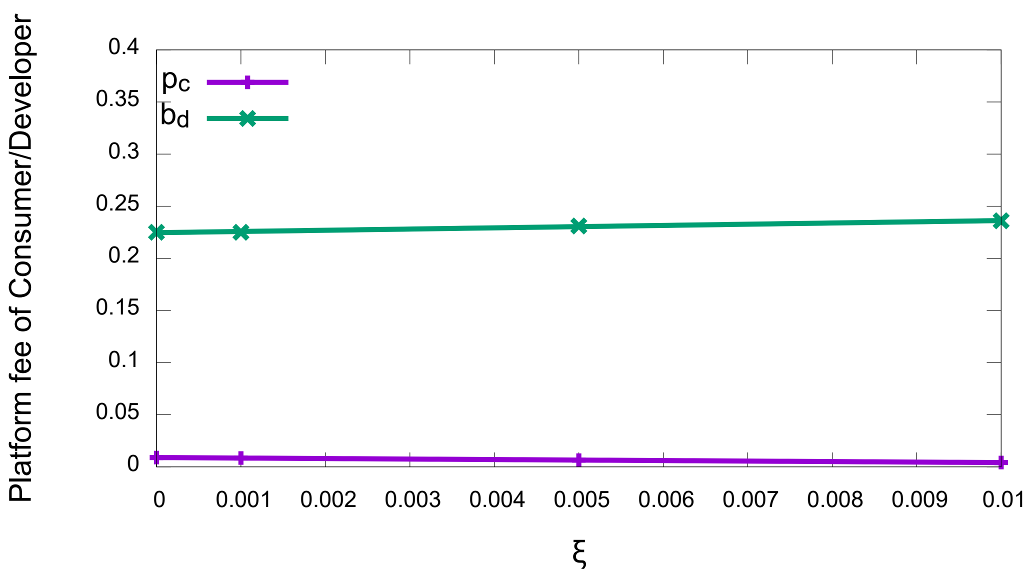

Figure 11: Platform usage fees against the parameter ξ

Table 5: Market characteristics with/without API evaluators: $E(y_e) = 0.8\ y_e$

case	α, β	$\hat{y_e}$	U_p	x_c	n_d	p_c	b_d
Largest increase	0.52, 0.78	0.0485	0.00181	0.866	0.152	0.0163	0.049
		0.0	0.0004	0.833	0.135	0.0176	0.027
Smallest increase	0.65, 0.66	0.0599	0.0205	0.979	0.204	0.0029	0.188
		0.0	0.0181	0.992	0.19	0.000948	0.184

participants $x_c + n_d$ increases by 0.338 % from 1.182 to 1.186. In both cases, the platform profit U_p increases compared to without API evaluators. In beneficial market is large, the number of market participants increase larger. In independent market, the number of market participants increase smaller. Table 6 shows the market state U_p, x_c, n_d, p_c, b_d, y_e comparison with API evaluators and without API evaluators when $E(y_e) = 0.8\ y_e^2$. Taking $\hat{y_e} = 0$ means that API evaluators do not exist in the market. As with $E(y_e) = 0.8\ y_e^2$, the larger parameter ξ, the lower platform profit and platform usage fees to consumers, and the larger the number of consumers and the number of developers and platform usage fees to developers. The number of market participants $x_c + n_d$ increases the largest when α is 0.53 and β is 0.71, i.e., beneficial markets. The number of market participants x_c + n_d increases by 5.46 % from 1.008 to 1.063. U_p increases compared to without API evaluators. The number of market participants $x_c + n_d$ increases the smallest when α is 0.86, β is 0.96, i.e., mutually beneficial markets. The number of market participants x_c + n_d increases by 0.0803 % from 1.246 to 1.247. In smallest increase case, the platform profit U_p decreases compared to without API evaluators. In beneficial market is large, the number of market participants increase larger. In mutually beneficial market, the number of market participants increase smaller. Table 7 shows compare when $E(y_e) = 0.8\ y_e$ and when $E(y_e) = 0.8\ y_e^2$ in the largest increase case. $\hat{y_e} = 0$ means that API evaluators do not exist in the market. When $E(y_e) = 0.8\ y_e$, the number of market participants $x_c + n_d$ increases by 5.16 %, the platform profit U_p increases by 4.5 times higher than without API evaluators. When $E(y_e) = 0.8\ y_e^2$, the number of market participants x_c + n_d increases by 5.46 %, but the platform profit U_p decreases. When $E(y_e) = 0.8\ y_e$ and beneficial market, platform can increase the number of market participants and the

Table 6: Market characteristics with/without API evaluators: $E(y_e) = 0.8\ y_e^2$

case	α, β	$\hat{y_e}$	U_p	x_c	n_d	p_c	b_d
Largest increase	0.53, 0.71	0.0577	0.000361	0.923	0.14	0.00766	0.08
		0.0	0.0005	0.873	0.135	0.0122	0.057
Smallest increase	0.86, 0.96	0.0118	0.0706	0.948	0.299	0.015	0.251
		0.0	0.0696	0.948	0.298	0.0148	0.246

Table 7: Compare of largest increase of the number of market participants when $E(y_e) = 0.8\ y_e$ and when $E(y_e) = 0.8\ y_e^2$

$E(y_e)$	$\alpha,\ \beta$	Rate of increase in U_p	Rate of increase in $x_c + n_d$
$0.8\ y_e$	0.52, 0.78	77.9 %	5.17 %
$0.8\ y_e^2$	0.53, 0.71	-27.8 %	5.46 %

platform profit. It should be noted that the platform profit decreases by 17.4 % from 0.00219 when maximizing profit.

When $\xi = 0$, the profit of the platform providers increases, however, the number of market participants decreases because of the increase of payments from consumer/developers to the platform providers. For the platform providers, the profit is always important in general, but the number of market participants is also important especially when the API economy is at early stages of its economic development. In this section, by increasing ξ, we increase the number of market participants. At early stages of its economic development, the platform provider is desirable to take a strategy of increasing the ξ and introducing API evaluators slightly to increase the the number of market participants because the number of market participants is small. At after stages of its economic development, the platform provider is desirable to take a strategy of maximizing the platform utility because the number of market participants is large.

5 Conclusion

Recently, network technology has developing and application services on the network have become widespread among many people. API economy that information processing and data provision by APIs and these services collaboration thorough APIs creates new value is attracting attention. We focus on bring API evaluators to market as one of the business strategies of platform provider, and we analyze the market using a multi-sided market model that weights the number of market participants and the profit of platform provider.

When maximize only platform profit without considering the number of participants in the market, platform usage fees increase, and the number of consumers decreases. The platform utility is increasing due to platform usage fees increase. Even if platform usage fees for developers increases, the number of developers increase. The reason is participation of API evaluator and interaction between developers and API evaluators. For the platform providers, the profit is always important in general, but the number of market participants is also important especially when the API economy is at early stages of its economic development. When we analyze use a multi-sided market model that weights the number of market participants and the profit of platform provider, the larger parameter of the number of participants in the market, the smaller the platform profit and the larger the number of participants in the market. The profit of platform provider is smaller than when maximize only the profit of platform provider, but larger than when without API evaluators. Our model can analyze the platform strategies that increases other than the profit of platform provider by introducing a parameter to increase the number of market participants.

The following future works can be considered to relax some limitations on our multi-sided market model. One of our future works is to consider a model in which some of the consumers are API evaluators. We assume that the platform provider introduce API evaluators by paying rewards them. But we can consider that consumers evaluate API voluntary in the real world. Besides, we focus mainly platform utility, but it is necessary to consider social benefits. We need to consider not only platform utility but also consumer utility and developer utility. For this purpose, we may need to obtain the Nash Equilibrium, which focuses on how players of a game react to their opponent's strategy.

Another possible work is to develop a model considering the economical development in time. It is well known that there are several stages, such as early stage and matured stage, of the economical development in the actual ecosystem. We believe that the behavior of participants to the API economy will change dependents on the stages of the economical development. Capturing such the market characteristics and developing its model is left for our future research topics.

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