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Utility Analysis of API Economy Based on Multi-Sided Platform Markets Model

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***Abstract*—API (Application Programming Interface) economy, where many participants join/interact and form the economy, is expected to increase collaboration between information services through API, and thereby, it is expected to increase market value from the service collaborations. In this paper, we introduce API evaluators, which are the activator of API economy by reviewing and/or evaluating APIs, and develop a multi-sided API economy model that formulates interactions among platform provider, API developers, consumers, and API evaluators. By obtaining the equilibrium that maximizes utility of all participants, the impact of API evaluators on the utility of participants in the API economy is revealed. Numerical results show that, with the existence of API evaluators, the number of developers and consumers increase by 1.5% and the utility of platformer increases by 2.3%. We also discuss the strategies of platform provider to maximize its utility under the existence of API evaluators.**

***Keywords*—API economy, multi-sided markets, API evaluator, platform, platform provider.**

I. Introduction

RECENTLY, various applications and services through networks are increasing against the background of the speeding up of networks and the progress of cloud technology. API economy, where many participants form the economy (Fig. 1) and interact through API, is expected to increase collaborations of information services, and thereby, is expected to increase market value [1]. In API economy, developers and consumers are connected to the platform; developers supply services to consumers through API, and consumers consume services through API. When we consider services as "goods," API economy is a market economy, and the platform is a market itself.

A two-sided market is a typical model to understand the fundamental behavior of the market economy. The model consists of a platform and two customer groups. Two customer groups interact with each other through the platform, and there is a network effect between the customer groups. In [2], Zhang *et al.* introduce a competitive model of developer and network providers, who supply services, and illustrate the benefit of improving service quality and network performance through capital investment. In [3], Nagurney *et al.* derive the equilibrium between price and supply when developers can determine both the quality and quantity of services.

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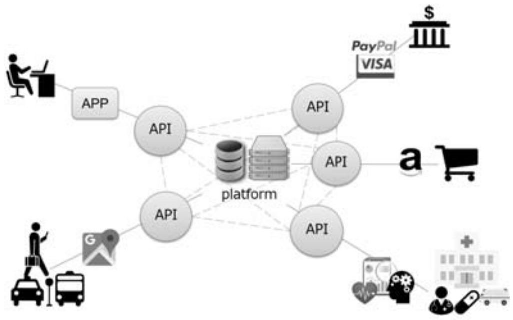

Fig. 1 API Economy

In [4], Fanti *et al.* introduce a model to understand the interaction between an OS provider and two application providers. The authors reveal differences of the social welfare for four competition models between application providers. Ref. [5] applies the two-sided market model to the economy of cellular networks and discusses how the two-sided market model applies to open APIs. The authors suggest that a telecommunication company, which is the platform provider, should support at least nation-wide to maximize the network effects and should decide the optimal price on both sides. In [6], Sen *et al.* introduces a number of functions on the platform as one of the business strategies of the platform provider. The functions, prepared by the platform provider, are useful for application development. As the number of functions increase, the development cost of developers decreases, but the implementation cost is incurred for the platform providers. The authors derive the optimal number of functions to maximize platform providers' benefits. All these works deal with a two-sided market although the number of customer groups is not limited to two in the actual market economy.

A multi-sided market, which considers more than two customer groups, is recently investigated in these researches on market economy. In [7], Evans *et al.* defined the multi-sided market as a market in which multiple customer groups, such as developers and consumers who enjoy the services and advertisers who provide advertisements, participate in a platform, and the interaction of multiple customer groups is expected to activate the market and increase market value. Ref. [8] discusses the role that the platform should play in the mobile service business. The model consists of platform provider, such as the Apple Inc., telecommunication carriers, application developers, advertisers, and consumers. Stanoevska-Slabeva *et al.* discuss how the telecommunication carriers contributed to the development of mobile platform service and conclude that most of the profits are taken over by the platform provider and the role of the telecommunication carriers is “dumb pipes”. The authors also reveal that such the conclusion cannot be captured by the two-sided market. In [9], Visco *et al.* analyze the business model of advertising revenue and reveal that consumer advertising leads to higher income in the search engine business. The search engine’s platform provides organic results to consumers and content providers and provides ad slots to advertisers. Consumers enjoy the contents from content providers and have ad information from advertisers. Using this model, it reveals that a strong network effect between consumers and advertisers occurs and make a profit for platform providers. These literatures show that customer groups other than developers and consumers is not negligible because the network effect among customer groups is important for platform provider. However, they only reveal the importance of multi-sided market model, not reveal a business strategy for platform providers [9]. We need investigate API economy by using multi-sided market model and reveal conditions for market to exist and the business strategy for platform provider.

In this paper, we focus on API evaluators as a business strategy for the platform provider and make a multi-sided market model that consists of the platform provider, developers, consumers, and evaluators. And we discuss the optimal strategy of the platform provider to maximize the utility of platform provider in the market where API evaluators exist. Note that the evaluation at the current EC site is often based on volunteers, but we assume platform provider pays for evaluation effort in this paper. Although the profit of the platform provider decreases as the payment to API evaluators increase, the market is activated by incorporating API evaluators, which in turn leads to the increase of the number of developers and the number of consumers due to the network effect: that is, the profit of platform provider is expected to increase indirectly. It is necessary for the platform provider that the increase of profit indirectly should be greater than the decrease of the profit directly. Based on our multi-sided model, we reveal the conditions for market to exist.

The rest of this paper is organized as follows. We provide a multi-sided market model that describes interactions among platform providers, developers, consumers, and evaluators in Section II. In Section III, we describe solution methodology. We analyze simulation results in Section IV, and conclude in Section V.

II. Multi-Sided Market Model

A. Market Model

In this section, we explain our multi-sided market model that describes interactions among platform provider, developers, consumers, and evaluators. Fig. 2 shows a multi-sided market model that we analyze in this paper. Table I shows parameter that used in our model. Different from Ref. [6], API evaluators are newly joined the market and interact with developers and consumers.

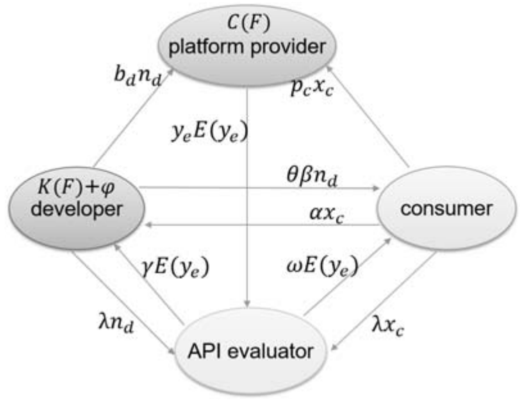

Fig. 2 Interactions among platformer, developers, consumers, and evaluators

First, we explain the interaction among platform provider, developers and consumers about Fig. 2. Platform provider gains platform fees, $b_d\ n_d$ from developers and $p_c\ x_c$ from consumers, and the cost to develop platform functions is $C(F)$. Here, the platform functions are not the service itself, but will be used for developing services. F is the number of platform functions. Developers pay platform fee b_d to platform provider, and give benefit $\theta\ \beta\ n_d$ to consumers. β is a marginal externality benefit that associated with a developer for a consumer. The cost of developing API by developers is $K(F)$. ϕ shows difference cost because of skill level difference across developers. Consumers pay platform fee p_c to platform provider, and give benefit $\alpha\ x_c$ to developers. α is a marginal value that consumers generate for a developer. In the figure, $\alpha\ x_c$, $\theta\ \beta\ n_d$, and $\lambda\ x_c$ are the network effect generated by the interactions among customer groups.

Then, we add API evaluators to this model. Platform provider pay rewards $y_e\ E(y_e)$ to evaluators as incentives. Developers give benefit $\lambda\ n_d$ to evaluators, and Consumer give benefit $\lambda\ x_c$ to evaluators. Evaluators give benefits $\gamma\ E(y_e)$ to developer and $\omega\ E(y_e)$ to consumers. At two-sided market, the only network effect that the number of developers increases, and the number of consumers increase exists. At multi-sided market, as the number of evaluators increases, the number of consumers increases, and moreover, the number of developers increases. Similarly, as the number of evaluators increases, the number of developers increases and moreover the number of consumers increases.

In our model, the primal concern is how to decide y_e to maximize the profit of the platform provider. As y_e increases, more evaluators join the market activate the market greatly. Note that we assume that evaluators give a positive review. However, increase of y_e mean that the payment from the platform provider to evaluators increases. The optimal value of y_e is not a trivial, and it is discussed in the later.

TABLE I
NOTATIONS USED IN OUR MARKET MODEL

notation	description
p_c	platform fee for consumers
b_d	platform fee for developers
y_e	reward to evaluator
x_c	number of consumers
n_d	number of developers
$E(y_e)$	number of evaluators
F	number of platform functions
$C(F)$	cost to develop platform functions
$K(F)$	cost to develop services
α	marginal value that associated with a consumer
β	marginal value that associated with a developer
γ, ω	marginal value that is associated with an evaluator
λ	marginal value that is associated with a developer and a consumer

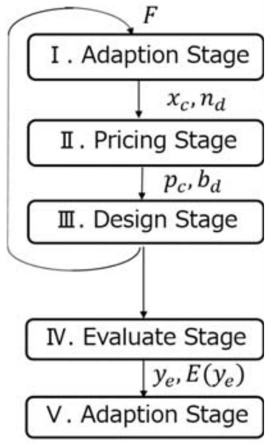

Fig. 3 Solution methodology

B. Utility Function

Utility functions of platform provider, developer, consumer and evaluator are as follows.

1) Platform Utility: The platform utility, U_p is formulated as,

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

p_c x_c is a benefit from consumer, b_d n_d is a benefit from developers. y_e $E(y_e)$ is the payment to evaluators and thus incurs as a cost. $C(F)$ is the cost to develop platform functions.

2) Developer Utility: The developer utility is formulated as,

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

α x_c is a benefit from consumers. α represents marginal value. b_d is a platform fee for developers. γ $E(y_e)$ is a beneficial effect from evaluators. $K(F)$ + ϕ is development cost.

3) Consumer Utility: The consumer utility is formulated as,

$$U_c = \theta\beta n_d + \ E(y_e) - p_c. \tag{3}$$

θ β n_d is a benefit from developers. ω $E(y_e)$ is a beneficial effect from evaluators. p_c is a platform fee for consumers.

4) Evaluator Utility: The evaluator utility is formulated as,

$$U_e = y_e E(y_e) + \lambda(n_d + x_c). \tag{4}$$

y_e $E(y_e)$ is a reward from platform providers. λ $(n_d + x_c)$ is an effect from developer and consumers.

III. SOLUTION METHODOLOGY

In this section, based on methodology in literature [6], we explain how to obtain the equilibrium of multi-sided market that platform provider, developers, consumers, and evaluators exist. Hereafter, values of variables at the equilibrium are represented by adding '$*$' to the notion of variables, such as F^*, p_c^*, and b_d^*.

Our method first obtains an equilibrium when the evaluators does not exist based on [6]. Then, we derive the benefit when the evaluators exist based on the equilibrium. Fig. 3 shows a method to decide the reward for evaluator y_e. We decide optimal function number F through adoption stage, pricing stage, and design stage based on [6]. In the adoption stage, developer and consumer whether join platform or not, so n_d and x_c are decided. In the pricing stage, platform provider decides platform fees b_d and x_c. Given F, p_c, b_d, x_c, and n_d, the optimal reward to evaluator y_e and number of evaluator $E(y_e)$ are calculated. Given y_e, through the post-adoption stage, we obtain x_c and n_d that maximize U_p.

First, we decide the number of consumers x_c and the number of developers n_d in the adoption stage. Note that we set $y_e = E(y_e) = 0$ when evaluators do not exist. The marginal consumer $\hat{\theta}$ is $1 - x_c$, and by setting $U_c = 0$,

$$\hat{\theta} = 1 - x_c = \frac{p_c}{\beta n_d^*}. \tag{5}$$

Similarly, the marginal developer is $\hat{\phi} = n_d$, and by setting $U_d = 0$,

$$\hat{\phi} = n_d = \alpha x_c^* - b_d - K(F). \tag{6}$$

Using Eqs. (5) and (6), we obtain Eqs. (7) and (8).

$$p_c = (1 - x_c^*)\beta n_d^*, \tag{7}$$
$$b_d = \alpha x_c^* - n_d^* - K(F). \tag{8}$$

Next, we determine the platform fee b_d and x_c by the pricing stage. Given F, x_c, n_d, the platform utility is written as,

$$\max_{x_c^* n_d^*} U_p = p_c x_c^* + b_d n_d^* - C(F), \tag{9}$$
$$s.t.\ 0 \le x_c^* \le 1, 0 \le n_d^* \le 1. \tag{10}$$

Using $\frac{\partial U_p}{\partial x_c^*} = 0$, the number of consumers which maximizes the platform profit is

$$\frac{\partial U_p}{\partial x_c^*} = (1 - 2x_c^*)\beta n_d^* + \alpha n_d^* = 0, \tag{11}$$
$$x_c^* = \frac{\alpha + \beta}{2\beta}. \tag{12}$$

Similarly, using $\frac{\partial U_p}{\partial n_d^*} = 0$,

$$\frac{\partial U_p}{\partial n_d^*} = (1 - x_c^*)\beta x_c^* + \alpha x_c^* - 2n_d^* - K(F) = 0, \quad (13)$$

$$n_d^* = \frac{(\alpha+\beta)^2 - 4\beta K(F)}{8\beta}. \quad (14)$$

Substituting Eqs. (12) and (14) in Eqs. (7), the platform fee of consumer is,

$$p_c^* = \frac{(\beta-\alpha)((\alpha+\beta)^2 - 4\beta K(F))}{16\beta}. \quad (15)$$

Substituting Eqs. (12) and (14) in Eqs. (8), the platform fee of developers is,

$$b_d^* = \frac{(3\alpha-\beta)(\alpha+\beta) - 4\beta K(F))}{8\beta}. \quad (16)$$

For the conditions $x_c > 0$, $n_d > 0$, $p_c > 0$, and $b_d > 0$, parameters α, β, and $K(F)$ should satisfy the conditions $\alpha < \beta$ and $4\beta K(F) < (\alpha+\beta)^2 < 4\beta(2 - K(F))$.

Next, we obtain the optimal number of platform functions F to maximize the platform profit in the design stage. In the equilibrium, $\frac{\partial U_p}{\partial F} = 0$. Let us substitute Eqs. (12), (14)-(16) in Eqs. (9) and calculate $\frac{\partial U_p}{\partial F}$, then we obtain,

$$C'(F^*) - [-\frac{\beta^2-\alpha^2}{8\beta} - \frac{(\alpha+\beta)^2}{16\beta} - \frac{(3\alpha-\beta)(\alpha+\beta)}{16\beta}]K'(F^*) + \frac{K(F^*)K'(F^*)}{2} = 0, \quad (17)$$

which is rewrite as,

$$\frac{C'(F^*)}{K'(F^*)} = \frac{K(F^*)}{2} - \frac{(\alpha+\beta)^2}{8\beta}. \quad (18)$$

Finally, we decide the optimal reward to evaluators y_e and the number of evaluators $E(y_e)$ in the evaluation stage, and the number of consumers x_c and the number of developers n_d when evaluators exist in the post-adoption stage. When evaluators exist, the marginal consumer $\hat{\theta}$ is $1 - x_c$, and by setting $U_c = 0$,

$$\hat{\theta} = 1 - x_c = \frac{p_c - \omega E(y_e)}{\beta n_d^*}. \quad (19)$$

Using Eqs. (5) and Eqs. (19), the increase of the number of consumers, Δx_c, is,

$$\Delta x_c = \frac{\omega E(y_e)}{\beta n_d^*}. \quad (20)$$

Similarly, when evaluators exist, the marginal developer $\hat{\phi}(= n_d)$ is determined by setting $U_d = 0$,

$$\hat{\phi} = n_d = \alpha x_c^* - b_d + \gamma E(y_e) - K(F). \quad (21)$$

Using Eqs. (6) and Eqs. (21), the increase of number of developers, Δn_d, is,

$$\Delta n_d = \gamma E(y_e). \quad (22)$$

IV. Numerical Examples

A. Evaluation Method

In Section III, the cost to develop platform functions $C(F)$, the development cost $K(F)$, and the number of evaluator $E(y_e)$ are not decided in advance. For our evaluations, we defined these functions as follows.

1) $C(F)$ and $K(F)$: Platform function is important for platform provider and developers. For developers, the additional platform function can significantly reduce the development cost, but it is a high cost for platform provider to implement too many platform functions. We consider two type, Amazon Web Service (AWS) type and IP Multimedia Subsystem (IMS) types, by combination of cost of developing platform function $C(F)$ and development cost $K(F)$ [6].

For AWS type, the cost to develop platform functions $C(F)$ is a convex increasing function, and the development cost $K(F)$ is a concave decreasing function. For IMS type, the cost $C(F)$ is a convex increasing function, and the development cost $K(F)$ is a convex decreasing function. For both types, $C(F)$ increases as the number of function increases, while the development cost $K(F)$ decreases as the number of function increases. For AWS type, when few platform functions are developed, basic functions exist on the platform and the development cost $K(F)$ decrease greatly. When many platform functions are developed, additional functions are niche and the development cost $K(F)$ decrease slightly. For IMS type, because it is assumed that APIs are developed by reusing the platform functions, development cost $K(F)$ decrease greatly as the number of functions increases. In this paper, we present only the results for AWS type given $C(F) = 0.008F^{1.15}$, $K(F) = 0.4e^{0.194F}$, $\alpha = 0.65$, $\beta = 0.8$, but confirmed that a similar tendency can be obtained in the IMS type with $C(F) = 0.001F^{0.5}$, $K(F) = 0.18 - 0.016e^{1.3F}$, $\alpha = 0.6$, $\beta = 0.8$.

2) $E(y_e)$: The number of evaluators increases by rewards from the platform provider. In this paper, we suppose two types of $E(y_e)$: linear type and concave type. For the linear type, $E(y_e)$ increases linearly as y_e increases and is represented as $C \cdot y_e$, where C is constant number. For the concave type, $E(y_e)$ increases concavely as y_e increases and is represented $C \cdot y_e^P$, where C and P are constant numbers.

B. Sensitivity Analysis

In this section, we analyze the changes of platform utility when we change parameters γ, ω, which determine the impact on evaluators to other customer groups, and the parameters C and P of $E(y_e)$ $(= C\ y_e^P)$. We calculate the platform utility when the rewards for evaluator y_e is changed from 0.0 to 0.09, and then, obtain the optimal rewards that gives the maximum platform utility.

First, we analyze the change of platform utility against the change of parameter γ, ω of impact on other customer groups of evaluators. Fig. 4 shows the platform utility when the cost to develop platform functions $C(F)$ and the development cost $K(F)$ is AWS type and the number of evaluators $E(y_e)$ is

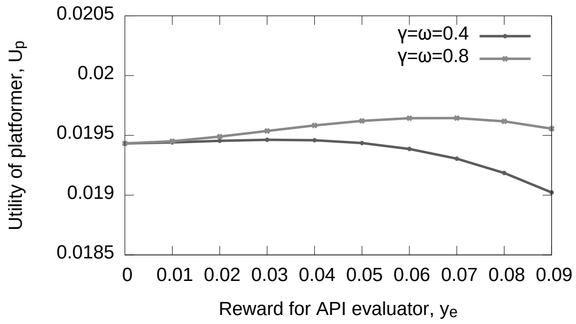

Fig. 4 Platform utility U_p: AWS type, ω, $\gamma = 0.4, 0.8$

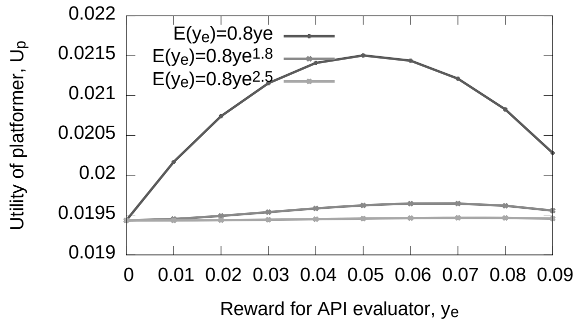

Fig. 5 Platform utility U_p against the number of evaluator $E(y_e)$: AWS type, $\gamma = \omega = 0.8$

$0.8y_e^{1.8}$. When γ, $\omega = 0.8$, the maximum platform utility is 0.0196 at $y_e = 0.07$ and increase about 1.0% from the platform utility is 0.0194 at $y_e = 0$. When γ, $\omega = 0.4$, the platform utility is 0.0195 at $y_e = 0.04$ and increase about 1.0%. As the parameter γ, ω are larger, the maximum value of the platform utility U_p is larger, and the rewards for evaluator y_e which gives the maximum platform utility is also larger. In other words, as the marginal value that is associated with an evaluator γ, ω is larger, the platform provider obtains high platform utility by increasing the rewards for evaluator.

Next, we analyze the platform utility by changing types and parameters of the number of evaluators $E(y_e)$. Fig. 5 shows the platform utility when the cost to develop platform functions $C(F)$ and the development cost $K(F)$ is AWS type and γ, ω is 0.8. The platform utility becomes larger when the number of evaluators $E(y_e)$ is the linear type comparing with when $E(y_e)$ is the concave type. However, the platform utility decrease greatly when y_e is slightly different from the optimal value and when $E(y_e)$ is the linear type. When $E(y_e)$ is the linear type, the maximum platform utility is 0.0215 at $y_e = 0.05$ and increase about 1.1% compared to the platform utility at $y_e = 0.0$. When $E(y_e) = 0.8y_e^{1.8}$, the maximum platform utility is 0.0196 at $y_e = 0.07$, when $E(y_e) = 0.8y_e^{2.5}$, the maximum platform utility is 0.0195 at $y_e = 0.07$. That is, for the concave type, differences in the exponent of the concave increase type has little effect on the platform utility.

Fig. 6 summarizes the number of consumers x_c, the number of developers n_d, the number of evaluators $E(y_e)$ and the platform utility U_p when $C = 10$. For AWS type, the maximum platform utility is 0.0453 at $y_e = 0.05$ and increase about 2.3% compared to the platform utility 0.0194 at $y_e = 0$. When y_e is 0.05, the number of consumers x_c is 1.0021 and the number of developers n_d is 0.5917. The number of developers and consumers increase about 1.5% compared to the number of developers and consumers 1.0980 at $y_e = 0$.

C. Optimal Strategy of Platform Provider

By the sensitivity analysis, platform provider should decrease the rewards for evaluators y_e when the marginal value that is associated with evaluators γ, ω is small, should increase the rewards for evaluators y_e when the marginal value

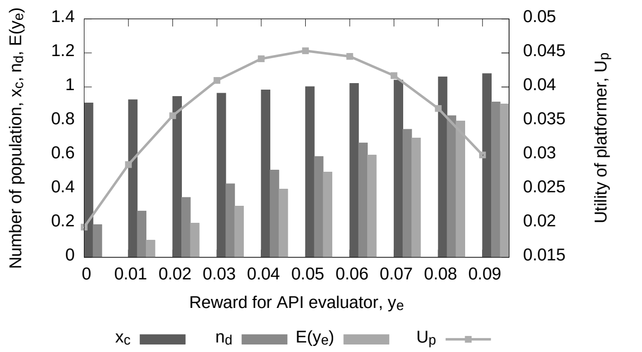

Fig. 6 The number of market participants and the platform utility U_p: AWS type, $\gamma = \omega = 0.8$, $E(y_e) = 10y_e$

that is associated with evaluators γ, ω is large. Results of changes of the number of evaluators suggest that the platform provider needs to be careful not to make its reward too high when the number of evaluators increase by a fixed number for the rewards. We conclude that platform provider can increase the platform utility by setting a small number of rewards for evaluator when the parameters are unclear because the platform utility increase up to a certain amount under all parameter settings.

Using our multi-sided model, we can consider an optimal setting of the number of functions F or an optimal setting of the rewards for evaluators y_e as a business strategy of the platform provider. Our question is which of these business strategies has a greater benefit on platform utility. Fig. 7 shows the platform utility U_p for the number of platform functions F from 0 to 4 at AWS type. The maximum platform utility is 0.0194 at $F = 1.985$ and increase about 1.2% compared to the platform utility 0.0165 at $F = 0$. Note that, by the Fig. 5 in Section IV-B, the platform utility is expected to increase 1.1% by optimizing the rewards for evaluators. This result shows that optimizing the number of platform functions is more effecting than the optimizing the reward. However, optimization of the number of functions needs software development and takes a high cost for platform provider in general. Thus, optimizing the rewards is good

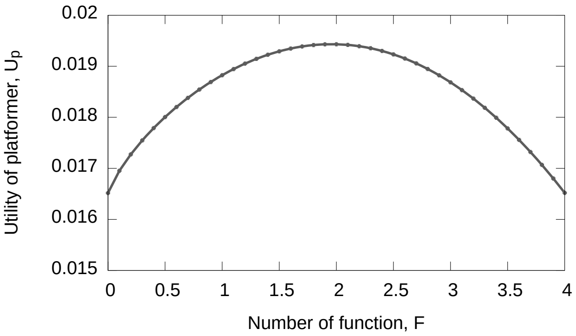

Fig. 7 Platform utility U_p against the number of funtion F: AWS type

alternative for platform provider to activate the market.

V. Conclusion

API economy, where many participants join/interact and form the economy, is expected to increase collaboration between information services through API, and thereby, is expected to increase market value from the service collaborations. We added API evaluators as the activator of API economy and develop a multi-sided market model that describes interactions among platform provider, developers, consumers, and evaluators. We discuss the effect of parameter to platform utility by using this model. Numerical results suggest that when API evaluators join the platform, then number of developers and consumers increases by 1.0-1.5% and the utility of platform provider increases by 1.0%-2.3%.

We can further consider the effect to market from another customer group other than API evaluator. Examples of another customer group are advertising agency, mobile operator and so on.

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