Exploring Compatibility of Information Services

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***Abstract*—This study develops a stylized model of a duopoly market with two players, the incumbent firm and the entrant firm. Recently, a coopetition mechanism through a compatibility strategy has become widely used in the information industry as one of the promising strategies to increase demand and mitigate competition. Moreover, the firms have massively explored the two-way compatible strategy where consumers can flexibly utilize and freely choose which information services the firms provide. Therefore, deriving from the common phenomenon, we derive a game-theoretic model when the two firms are competing horizontally and the incumbent has the software competitive advantage. We then numerically discover the firms' equilibrium strategy and find that a two-way compatibility strategy is optimally adopted under the following conditions: (i) when competition between two firms is horizontal, (ii) when consumer loyalty is high, and (iii) when the price difference between the platforms is substantial. Conversely, the entrant will withdraw from the market due to a not-beneficial situation.**

***Index Terms*—compatibility, coopetition, competitive advantage, information service**

I. Introduction

The advancement of network technology has made the satisfaction of market demand no longer monopolized by a single firm, leading the information service industry grow significantly. For example, when it comes to office software in the past, Microsoft Office as the incumbent is undoubtedly the industry leader with a high market share of 87.6% [1]. However, with the increasing demand for enterprise software for cloud computing, more and more users adopt cloud-based productivity software. According to Consumer News and Financial Channels (Consumer News and Business Channel, CNBC) reported in April 2020 [2]: the G suite as the entrant has exceeded 6 million paid enterprise users, which posed a major threat to incumbents. Moreover, in the face of the new market competition, some incumbent firms choose to optimize their original information goods to compete with competitors. However, some firms decide to cooperate with competitors. They complement and strengthen the advantages of both parties by improving the value of information goods and services to increase profits and create a win-win strategy. In 2015, A world-renowned Enterprise Resource Planning (ERP) system company, SAP, originally committed to providing consumers with the on-site deployment of software construction services. However, with the rising demand for cloud computing from enterprises, SAP decided to cooperate with the leading public cloud brand-Amazon Web Service (AWS). The firm provides users with SAP system services that are compatible with the AWS cloud platform and builds a higher-value one-stop service by leveraging AWS's infrastructure integrity. Therefore, this research utilizes the stylized model to know the interaction between the incumbent (e.g., Microsoft Office, SAP), which have software advantage, when facing the entrant (e.g., Google Workspace, AWS). How will they interact with others, and how the two-way compatible strategy is being adopted for both the firms? For this research, we will mainly concentrate on a scenario under the rivalry between two players where two platforms are in horizontal competition, and the incumbent observes the software service advantage. Moreover, we currently only focus on the numerical analysis of the two firms' equilibrium outcomes.

II. Literature Review

Our study ties directly to the following three research streams: (i) product compatibility, (ii) platform coopetition, and (iii) pricing strategy. The growing number of studies in this area have shown the significance of these topics; hence, we emphasize our literature review on game-theoretical models and pertinent informational products.

A. Product Compatibility

The study from [6] examined the compatibility decisions of two competing platform owners and considered

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the correlation between consumers' preferences for hardware and software and analyzed the optimal compatible strategies when the two platform owners were horizontally differentiated. Meanwhile, the study from [7] also investigated the impact of network externality according to the product compatibility in two types of market structures of the wearable device under a two-dimensional product differentiation model with various quality levels. Our study differs from the prior research, where we focus on the pricing decision of two competing firms, i.e., the incumbent and the entrant, on information services (i.e., software and platform services) with the incumbent has the software service advantage as the vertical difference.

B. Platform Coopetition

Coopetition strategy has been questioned and discussed in supply chain management research and practice. Based on [8], the research discussed the classic case of Apple Inc. and Microsoft Inc. to explain the importance of "competitive sense-making" in coopetition relationships. Moreover, the research from [9] explored the strategic decision of an incumbent firm to open a proprietary technology platform to allow same-side coopetition in a market characterized by network effects and uncovered some results that the intense network effects would make new players shun the market, so intellectual property (IP) sharing was not possible in equilibrium.

Unfortunately, prior studies only discussed the platform firms' strategies to attract competitive complementary firms to enter the market and create an ecosystem. However, few studies explored the cooperation strategy between the two competing platforms which linking to compatibility strategy in a direct approach, i.e., building the two-way compatibility strategy in a horizontal competition model. Therefore, this research will fill the gap by constructing a stylized model for this practical phenomenon.

C. Platform Pricing Strategy

Based on [10], they examined intertemporal price discrimination (IPD) with complementary products in the context of e-readers software. They developed a dynamic demand model for e-reader adoption and added IPD to heterogeneous consumers into different periods and reduced the need to balance across consumer types. Moreover, Lin (2020) illustrated that price discrimination on one side can strengthen the incentive to discriminate on the other.

While prior research mostly focus on the pricing behavior, our study completes the discussion on the strategic decision under the coopetition environment by utilizing prices as a decision variable.

III. The Model

This study employs a two-dimensional model using a vertically-differentiated Hotelling model [3,4,5] with two players, an incumbent firm and a new entrant firm. Moreover, we follow the consumer utility function constructed by [6], assuming that consumers are uniformly distributed on a two-dimensional graph of area size 1. The incumbent and the entrant strive to maximize their profits in the information service market. This research establishes that the incumbent's software service has vertical difference for all market consumers, affecting consumers' utility when purchasing information services. We propose a scenario based on the rivalry between two players, with the two platforms competing horizontally. In order to avoid the blurring focus of this research and simplify the market factors with less influence, we assume that the total consumer's demand from the two firms is equal to 1. Moreover, this study focuses on the setting that the two firms provides the platform services (P_k) and software services (S_k) of their own products, where the incumbent and the entrant are denoted with $k \in \{1, 2\}$, respectively. In addition, both the software and platform services provided by the firms are perceived as the alternative services, with similar product functions and service content, either firm can satisfy the consumer demand.

Furthermore, we assume that when the two firms adopt the two-way compatibility strategy, they only consider the launch cost of their software compatible to the competitors' platforms, and do not consider other external costs incurred by transferring their software to different platforms. In this study, we focus on the sub-game perfection Nash equilibrium with complete information.

We use the Hotelling linear city to formulate the consumer utilities to the firms' software. The incumbent and the entrant are located at the two ends of the market line $[0, 1]$. The consumers in our model are heterogeneous in their preference of the platform/software services because both firms offer different features and functionalities of the software, and thus a consumer location is denoted by x, y, respectively, that is uniformly distributed along the Hotelling line, i.e., $x, y \sim$Uniform$[0, 1]$. Meanwhile, ϕ is the differences in consumer preferences for software's services with vertical difference between two firms (i.e., this study assumes that all consumers have preferences for the incumbent's software services; hence, the incumbent obtains the competitive advantage). For example, when all consumers in the market have preferences for the software service provided by the incumbent, the positions of firms 1 and 2 to consumers are located on the coordinates $(1, 1+\phi)$ for different dimension. At this time, the distance between the software of the incumbent and the consumer is $(1-x)$, and the distance between the software of the entrant to the consumer is $(1 + \phi - x)$. However, due to the lower distance cost of the incumbent, the incumbent perceives the software advantages and stimulates it to be more attractive to consumers. Similarly, the distance between the platform of the incumbent and the consumer is $(1 - y)$,

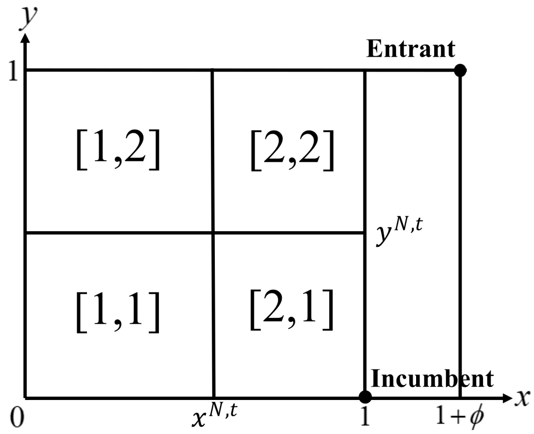

Fig. 1. The consumer's purchasing decisions under the two-way compatibility strategy

and the distance between the platform of the entrant to the consumer is $(1 + \phi - y)$. The entrant with platform advantages has lower distance cost for the consumer. Moreover, when the values of ϕ is greater, implying that there is a higher difference in the preferences between the two firms for the consumer. Therefore, the model settings will have a significant impact on the distribution of market demand. Furthermore, we denote $j \in \{P, S\}$ to represent the platform and software services, respectively. If there is a mismatch between the real product and the ideal product desired by a consumer, the consumer will incur a loss of utility. This loss of utility is formulated as a misfit cost associated with a disutility cost t_j (i.e., also assumed as the consumers' loyalty) and the distance between the product and the consumer's location [11]. Furthermore, v_j is the value generated by the consumer to the service j; such that, v_P and v_S represent the initial utility of the consumer to the platform and software service, respectively.

Under the condition where there is no competitive advantage for both firms, the coordinate position of two firms (x, y) are as follows, the incumbent is located between $[1, 0]$, meanwhile, the entrant is located between $[1, 1 + \phi]$. We first formulate a consumer utility with regard to the two-way compatible strategy. When the firms execute the compatibility strategy, it is necessary for the two firms to pay the platform fee γ_k and Δ indicates the difference of two platforms, i.e., $\Delta = \gamma_1 - \gamma_2$. Therefore, the consumer's purchasing decisions under the two-way compatibility strategy is depicted in Figure 1.

Therefore, the consumer utilities are formulated as follows:

1) When the consumer chooses both software and platform services of the incumbent or the entrant, i.e., $U_{11}^t = (v_P + v_S) - t_S(1-x)^2 - t_P(y)^2 - p_1^t - \gamma_1$, or $U_{22}^t = (v_P + v_S) - t_S(1+\phi-x)^2 - t_P(1-y)^2 - p_2^t - \gamma_2$, respectively.
2) When the consumer chooses either the software services of the incumbent or the platform service of the entrant, and the software service of the entrant or the platform service of the incumbent, $U_{12}^t = (v_P + v_S) - t_S(1-x)^2 - t_P(1-y)^2 - p_1^t - \gamma_2$ or $U_{21}^t = (v_P + v_S) - t_S(1+\phi-x)^2 - t_P(y)^2 - p_2^t - \gamma_1$, respectively.

From the utility functions of the two firms, the demand functions of their respective platform and software services can be derived, i.e., $U_{11}^t = U_{21}^t (U_{12}^t = U_{22}^t)$ with respect to x and y. Moreover, the demand of the software service of the incumbent can be calculated by means of integration. The x-axis integration range is 0 to x^t or y^t; meanwhile, the y-axis integration ranges from x^t or y^t to 1. The demand formulations when both firms have no competitive advantage, under the different consumer's types are presented as below:

1) The demand of the software service of the incumbent under the two-way compatible strategy, the x-axis, y-axis of the integral ranges from 0 to x^t and y^t, i.e., $D_{1S}^t = \int_0^{x^t} f(x)dx$, and $D_{1P}^t = \int_0^{y^t} g(x)dx$, respectively.
2) The demand of the platform service of the entrant under the the two-way compatible strategy, the x-axis and y-axis of the integral ranges from x^t to 1 and y^t to 1, $D_{2P}^t = \int_{x^t}^1 f(x)dx$, and $D_{2P}^t = \int_{y^t}^1 g(x)dx$, respectively.

The demand, i.e., $D_{12}^t = \int_{y^t}^1 \int_0^{x^t} 1dxdy$ represents the software demand of the incumbent on the platform 2, and $D_{21}^t = \int_0^{y^t} \int_{x^t}^1 1dxdy$ represents the entrant's software demand on platform 1. Therefore, the profit formulas of the two firms are shown below, where λ represents the unit cost of the software on the competitor's platform. The profit functions of the both incumbent and entrant under the two-way compatible strategy are, i.e., $\Pi_1^t(p_1^t) = p_1^t(D_{1S}^t) + \gamma_1(D_{1P}^t) + \lambda(D_{21}^t - D_{12}^t)$, and $\Pi_2^t(p_2^t) = p_2^t(D_{2S}^t) + \gamma_2(D_{2P}^t) + \lambda(D_{12}^t - D_{21}^t)$, respectively. We obtain the first-order differential results of the decision variables p_1^t and p_2^t by solving the game simultaneously of the two firms' profit formulas equal to zero. Therefore, the equilibrium decisions under market non-retention strategy can be derived, as shown in Proposition 1.

Proposition 1: When the incumbent has the software service advantage, and thus the equilibrium decisions falls as the following results:

$$\begin{aligned} p_1^t &= \lambda + \frac{1}{3}\phi(4+\phi)t_S; \\ p_2^t &= \lambda + \frac{1}{3}\phi(2-\phi)t_S. \end{aligned}$$

Proof. When the two firms are bidirectionally compatible, the Hessian matrix is also used to prove that the the respective equilibrium prices, i.e., p_1^t, p_2^t, are the maximum value. Therefore, if Hessian matrix, i.e., $\mathbb{H}^t$, is a negative definite matrix, indicating that there is a unique maximum value, and such that the equilibrium solution is the optimal solution. There exist a unique equilibrium of the firms' best-response functions based on the following property: Since $t_S > 0, \phi > 0$, then $\frac{\partial^2 \Pi_1^t}{\partial {p_1^t}^2} = -\frac{1}{\phi t_S} < 0$

$$det \begin{pmatrix} \frac{\partial^2 \Pi_1^t}{\partial {p_1^t}^2} & \frac{\partial^2 \Pi_1^t}{\partial p_1^t, \partial p_2^t} \\ \frac{\partial^2 \Pi_2^t}{\partial p_2^t, \partial p_2^t} & \frac{\partial^2 \Pi_2^t}{\partial {p_2^t}^2} \end{pmatrix} = \frac{3}{4\phi^2 t_S^2} \geq 0.$$

Hence, it is proved that H^t is a negative definite matrix due to the sign of the second-order derivatives and $det(\mathbb{H}^t)$ is negative; moreover, $\frac{\partial \Pi_1^t}{\partial p_1^t} = 0, \frac{\partial \Pi_2^t}{\partial p_2^t} = 0$. Therefore, the uniqueness of the incumbent's equilibrium decisions is confirmed.

From the Proposition 1, we can acquire the firms' optimal demands and profits by substituting the equilibrium decisions into the firms' demands and profits functions in Corollary 1 and Corollary 2, respectively.

Corollary 1: The firms' optimal demands in both service and platform:

1) the incumbent's and entrant's software services optimal demands are, i,e., $D_{1S}^t(p_1^t, p_2^t) = \frac{4+\phi}{6}$ and $D_{2S}^t(p_1^t, p_2^t) = \frac{2-\phi}{6}$, respectively.
2) The incumbent's and entrant's platform services optimal demands, i,e., $D_{1P}^t(p_1^t, p_2^t) = \frac{t_P - \gamma_1 + \gamma_2}{2t_P}$ and $D_{2P}^t(p_1^t, p_2^t) = \frac{t_P + \gamma_1 - \gamma_2}{2t_P}$, respectively.

And

Corollary 2: The firms' optimal profits are: the incumbent's and entrant's software services optimal profits, i.e., $\Pi_1^t(p_1^t, p_2^t) = \frac{1}{18}[\phi(4+\phi)^2 t_S + \frac{9(\lambda+\gamma_1)(t_P - \gamma_1 + \gamma_2)}{t_P}]$ and $\Pi_2^t(p_1^t, p_2^t) = \frac{1}{18}[\phi(\phi-2)^2 t_S + \frac{9(\lambda+\gamma_2)(t_P + \gamma_1 - \gamma_2)}{t_P}]$, respectively.

IV. Findings

In this scenario, the two firms are competing horizontally where the incumbent has the software service advantage. According to the equilibrium results derived in Section III. In this chapter, we will utilize the numerical analysis to verify and analyze the influence of consumer loyalty and the platform fee on decision variable under the two-way compatibility strategy. The parameter values used in this research are designed with reference to relevant literatures and the rationality of parameter definitions. Therefore the analysis is shown in Figure 2.

When the fee difference between the two firms' platforms approaches zero, the market demand for the entrant will be negative, implying that the entrant will exit the market under this condition. Furthermore, when the entrant does not have the software advantages to compete with the incumbent in terms of platforms, there is no benefit for the

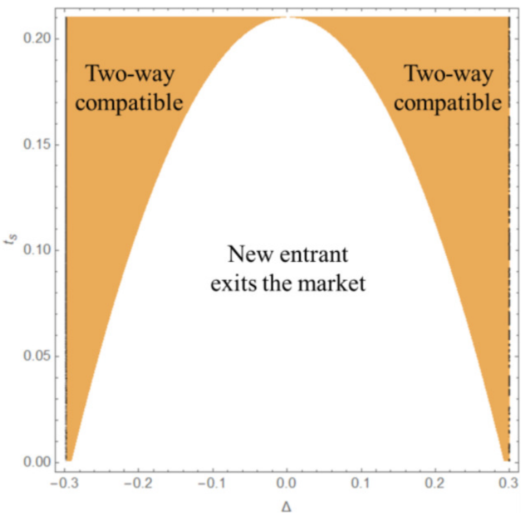

Fig. 2. Equilibrium strategies of two firms under the two-way compatibility strategy ($\phi = 0.2, t_P = 0.3, \lambda = 0.1$)

entrant. Therefore, the entrant should not join the market competition because the lack of capability in competing with the incumbent will eliminate the entrant from the market.

Moreover, when the fee difference between the two platforms widens, and consumers are highly loyal to the software, it is beneficial for the two firms to adopt a two-way compatibility strategy. This is because the two firms will give up the price competition on the platform, and one of them is willing to compromise. In addition, the other party potentially charges a higher platform fee; in practice, many different platforms may differentiate the market by lowering/increasing the platform fees. Suppose consumers do not easily switch software services to different firms; in that case, the two firms can utilize the two-way compatibility strategy, the competition intensity of software services is reduced, and the software service prices of the two firms are increased, creating a win-win strategy.

V. Conclusion

This study explores two-way compatible strategy with the competition between the incumbent and the entrant where two platforms are in horizontal competition, and the incumbent observes the software service advantage. The two firms will choose the most beneficial strategy in the face of different competitor conditions. When the two firms have a consensus, they promote cooperation and create a win-win situation. Our study provides the following contributions: (i) building the stylized model to examine the effects of two-way compatibility strategy on the firms' equilibrium profits. (ii) addressing the two-way compatibility strategy as "state-of-the-art" under the different information services, i.e., software and platform services.

Since this study aims to understand better the impact of different vertical difference on firms' coopetition strategy, some assumptions are used to simplify the model. Future-related research can consider the following situations to make the results closer to the actual market conditions, as follows:

1) In this study, platform fees and cross-platform licensing costs are exogenous variables. Hence, the two variables can be included in firms' decision-making considerations, i.e., as in [10], and in [12], they consider the impact of licensing costs on profitability.
2) This research explores the two-way compatibility study; hence, the different compatibility strategies such as incompatibility and one-way compatibility strategies can be examined.

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