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Digitalization in Two-Sided Platform[1]

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Abstract:

In this paper we study the effects of the introduction of a new two sided platform endowed with artificial intelligence in a market where a firm provides a brick and mortar platform to buyers and sellers. In our theoretical model we show that the decision of whether to introduce the new platform depends on the reduction of the search cost for the consumers. We also show that the introduction of the platform enlarges the market with more consumers using both platforms. Finally we study the welfare effect of the introduction of the platform opening the discussion on whether certain artificial intelligence devices for shopping should be regulated.

JEL Classification: L1, L2, L8.

Keywords: e-Commerce; Intermediary; Two-sided markets.

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1. Introduction

In many industries, intermediaries provide platforms that enable transactions between buyers and sellers. This has been increasingly so as trade shifts from brick and mortar businesses to the digital world. In recent years, the development of Internet of Things (IoT) has allowed for simplified access to the e-commerce. For instance buyers and sellers can now use apps to trade, or transactions can occur via voice activated devices such as Echo dot from Amazon, Google Home from Google, or the Home Pod from Apple. Other examples of IoT facilitating transactions are the dash buttons sold by Amazon and that allowed for immediate purchase of a given product just by the pressing of a button. Also, some intermediaries have recently started to offer their buyers a personalised and smooth shopping experience. This is the case of Nordstrom offering fashion advice through its Trunk Club or Alibaba who opened its first fashion Artificial Intelligence concept store in 2018. All these examples have in common one feature: an existing intermediary introduces artificial intelligence to facilitate and in some cases even remove completely the shopping experience of the buyers.

Although the application of artificial intelligence to the daily life is experiencing an exponential development, its effect on the current e-commerce remains to be analysed. Namely, in this paper we determine the conditions under which it is profitable for intermediaries to introduce a new artificial intelligence platform in the market. We are able to determine for which type of products is it profitable to add the artificial intelligence. We also study the effects in terms of pricing of the platform for the buyers and sellers. We do so by analysing a specific market where an intermediary provides a conventional platform that brings together buyers and sellers. This platform has the characteristics of a two-sided market, namely, buyers utility is increasing in the number of sellers in the platform and the sellers surplus is increasing in the number of buyers in the platform. The intermediary faces the choice of introducing a new technology/artificial intelligence platform that reduces the search cost of the buyers, providing them additional surplus. This additional surplus can result from a recommendation system, lower transportation costs, and in general more shopping convenience. We abstract from the costs of developing the platform, focusing solely on the demand effects of its introduction. Buyers and sellers are also able to trade in the brick-and -mortar business which constitutes our outside option. Finally buyers and sellers have heterogeneous preferences regarding the traditional internet platform vs the brick-and-mortar business and vs the artificial intelligence platform. This way we capture the idea that some users will be more tech savy and able to use the new technologies while others still prefer traditional shopping methods.

For the sake of illustration we will take the example of Amazon who introduced in 2014 the Dash Button service. The Dash Button is a Wi-Fi connected device that allows users to instantly order household items that they are about to run out of. For example, if buyers have a Detergent K Dash Button installed at home, then they only need to push the button to automatically order their favorite detergent. With the Dash Button, buyers can enjoy not only the low search or transportation cost in the shopping process and but also the smaller risk of running out of household items. Due to its convenience, the Dash button became popular within some Amazon users. According to a survey in 2017[4], 63% of users are very likely to purchase additional buttons in the future. In addition, for some products, more than half of all orders were transacted through Dash Buttons. It is worth emphasising that Amazon offered the Dash button for free to the buyers ($5 rebatable on purchases) and charged the sellers $15 per button and a percentage

[4] https://blog.fieldagent.net/pushing-all-the-right-buttons-survey-of-amazon-dash-users-mobile-research-survey

over the sales. This pricing is different from the fees charged by Amazon in its conventional platform. Additionally, the dash button was not recommended by Amazon for all its products, but only for products with low search cost and with high repeated purchases such as household items. Currently Amazon is focusing on developing its intelligent system Alexa. Compared with the Dash Buttons, Alexa can give buyers more flexibility and convenience. For example, Alexa can provide information on when Packages arrive, it can scan your home products and automatically add them to your shopping carts, and it can place orders for just by voice activation. Since Amazon allows approved third-party users to develop Alexa, it rapidly becomes an independent platform that is capable of supporting its customers with 10,000 skills[5]. By analyzing our model, we obtain the intermediary's pricing strategy and the motivation for the intermediary to introduce a new tech platform that uses AI technology to the two-sided market. Specifically, we have the following findings. First, we find that an increase in the additional surplus of the AI technology attracts more users to the new platform while fewer users to the conventional platform. Together, the technology advancement brings more users to the intermediary overall. Although the additional surplus of the AI technology affects the demands (supplies) of the platforms in an intuitive way, its effect on the member fees of the platforms is uncertain. It turns out the effect of the additional surplus of the AI technology depends on the network externalities in the two sides of the two-sided market. In addition, we find that the introduction of the new platform may not necessarily lower the member fees of the conventional platform. Although the underlying competition may move down the member fee on the traditional platform, the intermediary may increase it to attract more users to the new platform and to generate more network effect there. Specifically, we find that when the buyers generate more network externality to the sellers, the intermediary will charge a higher buyer's fee after the introduction of the new tech platform, and vice-versa. Moreover, we point out that the introduction of the new tech platform may not always benefit the intermediary, in which case the intermediary would keep the traditional platform only. In detail, we find that it is always profitable for the intermediary to introduce the new tech platform to the two-sided market when products have smaller network externalities. This is true even when the additional surplus generated by the tech platform is small. However, for products that have large network externalities, it is profitable for the intermediary to introduce the new tech platform only when the additional surplus by the tech platform is large. Lastly, we also predict that the intermediary would find it optimal to replace the conventional platform with the new tech platform altogether when the additional surplus by the tech platform is sufficiently large.

The remainder of the paper is organized as follows. We first review related literature in section 2. Then we present the model before and after the introduction of the new tech platforms respectively in section 3. Based on that, in section 4 we focus on the symmetric market and explore the changes in market structure due to the introduction of new tech platform and conclude in section 5.

2. Literature Review

Our research contributes to investigating how the introduction of AI technology affects the economics of intermediary. As indicated by the previous studies, intermediaries play a critical role in the current e-commerce market (Rysman, 2009). It not only improves social welfare by minimizing inefficient searching between buyers and sellers (Biglaiser, 1993; Yavaş, 1994), but also alleviates the potential moral hazard problem and certificate high product quality for buyer (Kirmani and Akshay, 2000; Li, 1998; Biglaiser

[5] https://www.wired.com/2017/02/amazon-alexa-hits-10000-skills-plenty-room-grow/

and Friedman, 1994; Rubinstein and Wolinsky, 1987). The conventional wisdom in the intermediary economic literature suggests that intermediaries act as middlemen or experts in the market. More precisely, intermediaries buy products from producers first and then resell the products to buyers at a higher price. However, with the development of internet technology, the economics of intermediary changes. Current emerging intermediaries like Uber and Airbnb no longer claim the possession of the products on the website, they now function as a pure platform in the two-sided market(Rochet and Tirole, 2004a,b, 2006) or multi-sided market (Hagiu and Wright, 2015) - market in which two or more distinct groups interact with via a platform.

The two-sided market is complex. Although there was a growing literature in last two decades on the general role that intermediaries play in the two-sided market, the intermediaries' adoption of AI technology has surprisingly received scant attention, except a few empirical studies (Möhring, Michael et al.,2017; Oyedele and Simpson, 2007). Thus it is difficult for us to capture all specificities of all industries. In our study, we focus on the online intermediaries that introduce AI technology to the market and we are curious about how the introduction of AI technology can influence the two-sided market structure. Following Hagiu (2007), we take the matching process between two sides of the market as given. In addition, we take into consideration the cross-network effects or externalities in the two-sided market. Specifically, we assume that each member benefits more from the transactions in the two-sided market when more members from the other side are available (Tremblay, 2016). The simplifications help us to understand the critical aspect of the study: the change in the two-sided market due to the introduction of AI technology. As indicated by Farah and Ramadan (2017), technologies like AI could significantly change buyers' behavior, market structures and so on. Hence, it is crucial to explore the potential changes that AI technology bring to the market.

In contrast to the established models of two-sided markets where one intermediary(company) runs only one platform, in our model the intermediary owns two platforms. One represents the conventional platform, the other represents the new platform which uses AI technology. Although both platforms share the same owner, there still exist competitions between them. Consequently, our study extends the literature in two-sided platform in both the strand of competition (Caillaud and Jullien, 2003; Loginova and Mantovani, 2019) and the strand of platform pricing. First, we contribute to the literature on two-sided platform competition by allowing platforms to share the same owner and by introducing quality heterogeneity to the model in an innovative way. To investigate the potential competition between the conventional platform and the new platform, we follow Rochet and Tirole (2003) to adjust the Hotelling model. Instead of having the outside option on one end of the Hotelling line, we have it on both ends of the line. In other words, it is equivalent to a Salop circle model, which enables us to eliminate the technical issue of the "corner" difficulties (Salop, 1979) and make it simpler to analyze the qualitative equilibrium properties of the model. Moreover, it avoids the potential distortions that could be introduced by the relative positions of two platform on the Hotelling line. We also introduce vertical differentiation in a similar way as Lin et al. (2016) to distinguish two platforms. Particularly, we use the quality heterogeneity of platforms to model the convenience provided by AI technology.

Secondly, since the intermediary can determine the access or member fee of both the conventional platform and the new tech platform, our study also contributes to the literature on platform pricing. In Rochet and Tirole (2003), intermediary devote much attention to how it courts each side of the market. In most cases, the intermediary makes profit on one side of the market while it subsidizes the other side. As pointed out by Armstrong (2006), the equilibrium member fees of the intermediary depend on the relative magnitude of the cross-group externalities on both sides of the market. Specifically, the intermediary usually charges a high member fee on the side that generates a smaller network externality and charges a low, even negative, member fee on the side that generates a high network externality. Based on their research, our paper adds a new tech platform to the two-sided market. In our study, the intermediary not only can coordinate the member fees on both sides of the same platform, but it can also coordinate the member fees of different platforms. In addition to the previous finding, we observe that the intermediary may manipulate the member fees of different platforms to reduce competition. This implies that the intermediary may charge a high price on one side of one platform while charging a low price on the same side of the other platform.

3. Model

The players in our model are buyers, sellers, and a large intermediary. The intermediary owns a platform (platform A) that brings together buyers and sellers. The intermediary operates as a dominant firm and is considering the introduction of a new platform in the market (platform B) where buyers obtain additional surplus due to the reduction of search cost. Buyers and sellers are heterogeneous in their preference for the platform. This model can have different interpretations: i) The intermediary owns a large physical marketplace such as Macy's or El Corte Ingles and is considering offering an online platform ii) The intermediary owns an online platform such as Amazon and is considering introducing a new platform with some new characteristics, such as Amazon Alexa. iii) The intermediary owns a platform such as Nordstrom and is considering the introduction of another platform that adds fashion advices to buyers such as the Trunk Club. The buyers and sellers can also interact in the brick and mortar businesses, which we assume to operate as a competitive fringe in the competitive market and constitutes an outside option in the monopoly market.

In this market, buyers and sellers benefit from cross-network externalities, meaning that the higher the number of sellers in the platform, the higher the utility of the buyers and vice-versa. As such, we treat the platforms as two-sided markets. In what follows, we first analyze the optimal pricing strategy of the intermediary in the monopoly market when it offers only the conventional platform (A), and then we study the optimal pricing strategy when the intermediary offers also the tech platform (B). We compare the profits and find conditions under which introducing the new tech platform is optimal for the intermediary.

3.1. Scenario 1: Baseline

The intermediary owns platform A only. Since the firm operates in a two-sided market each member of the platform benefits more from the transaction when there are more members on the other side of the market. Consequently, the net surplus of buyers and sellers using platform A takes the form

$$U_1^b(x) = u^b + V(q^s) - p_1^b - t_b x \tag{1}$$

$$U_1^s(x) = u^s + V(q^b) - p_1^s - t_s x \tag{2}$$

Here, $U^g(x)$ is the gross utility of platform A for users on side $g \in \{b, s\}$, u^g is the standalone utility of platform A on side $g \in \{b, s\}$, p_1^g is the fixed membership fee charged by platform A on side $g \in \{b, s\}$ in scenario 1, x is the distance between the platform and the user's ideal location, and t_g is the transportation cost on side $g \in \{b, s\}$. We use functions $V(\ell)$ to denote the transaction gains of users when there are

ℓ members on the other side of the platform. In other words, $V(\ell)$ measures the positive cross-network network effect stemming from ℓ users on the other side of the platform. We assume $V(\ell)$ takes the linear form $e \times \ell$, where e measures the network externatility in the market.

Suppose that both buyers and sellers are heterogeneous in their preference for the platforms. The heterogeneity is represented by a variant of the Hotelling specification[6]: buyers and sellers are uniformly distributed in two Hotelling lines, one for the buyers and one for the sellers. Specifically, platform A is located within the Hotelling line, and the outside option is at the two ends with the net surplus of u^g on the side $g \in \{b, s\}$. The distances between platform A and two outside options are $d_b^{AO}(d_s^{AO})$ and $d_b^{AB} + d_b^{BO}$ $(d_s^{AB} + d_s^{BO})$ respectively on buyer's (seller's) Hotelling line.[7] The distance parameters between any two platforms measure the degree of substitutability between those two platforms as perceived by the buyers/sellers. When the distance between the two platforms is large, those two platforms are less substitutable.[8] [9] The timeline of moves in the model is as follows. First, the intermediary determines member fees on both sides of the market for platform A. Then, all sellers and buyers choose between platform A and the outside option O simultaneously. Given the timeline of the model, we start by determining the demand and supply of platform A. In this setup, we are able to observe the same implicit demand of platform A on the side $g \in \{b, s\}$, which takes the following form:

$$q_1^g = \frac{(d_g^{AO} + d_g^{AB} + d_g^{BO})t_g + 2eq_1^{-g} - 2p_1^g}{2t_g} \tag{3}$$

where q_1^g is the demand on the side $g \in \{b, s\}$ in scenario 1, and q_1^{-g} is the demand of the other side of $g \in \{b, s\}$. According to equation (3), the number of user on one side of the market is increasing in the number of users on the other side of the market. In addition, it is decreasing in the member fee charged by the platform. We assume for simplicity and without loss of generality that both the transportation costs of sellers t_b and of buyers t_s are equal to 1. Solving the simultaneous equation 3, we are able to get the explicit demand and supply of platform A as follows:

$$q_1^b = \frac{1}{2-2e^2}[(d_b^{AO} + d_b^{AB} + d_b^{BO}) + e(d_s^{AB} + d_s^{AO} + d_s^{BO}) - 2ep_1^s - 2p_1^b] \tag{4}$$

$$q_1^s = \frac{1}{2-2e^2}[(d_s^{AO} + d_s^{AB} + d_s^{BO}) + e(d_b^{AB} + d_b^{AO} + d_b^{BO}) - 2ep_1^b - 2p_1^s] \tag{5}$$

Consequently, the profit of the intermediary equals:

$$\pi_1 = p_1^b q_1^b + p_1^s q_1^s \tag{6}$$

[6]We use a similar model as Rochet & Tirole (2003) since adjusting the Hotelling model enables us to eliminate the technical issues that are induced by the locations of the platform after the introduction of the platform B.

[7]We define the distance between platform A and one end of the Hotelling line as the sum of two parts d^{AB} and d^{BO} for convenience. This will become clear upon the introduction of platform B

[8]Note that we allow the platform locations on the buyer's Hotelling line to be different from their locations on sellers' Hotelling line. This is because the substitutability between two platforms in buyers' regard could be different from that in sellers' regard. For example, Amazon Alexa might be quite different from the Amazon marketplace for buyers because of its unique and innovative shopping method, while sellers who care more about shipping, storage, and business mode Amazon Alexa and Amazon marketplace are similar. We later simplify this assumption by allowing all distances to be equal.

[9]Equivalently, we can also view the Hotelling line as a Salop Circle where the two endpoints of the Hotelling line overlap with each other.

Under Assumption 1, the optimal member fees for the buyer and the seller are unique and given respectively by:

$$p_1^b* = \frac{d_b^{AO} + d_b^{AB} + d_b^{BO}}{4} \tag{7}$$

$$p_1^s* = \frac{d_{bs}^{AO} + d_s^{AB} + d_s^{BO}}{4} \tag{8}$$

Corresponding, the number of users on platform A at equilibrium are:

$$q_1^b* = \frac{2[d_b^{AO} + d_b^{AB} + d_b^{BO}] + 2e[d_s^{AO} + d_s^{AB} + d_s^{BO}]}{8(1-e)(e+1)} \tag{9}$$

$$q_1^s* = \frac{2[d_s^{AO} + d_s^{AB} + d_s^{BO}] + 2e[d_b^{AO} + d_b^{AB} + d_b^{BO}]}{8(1-e)(e+1)} \tag{10}$$

Proof. See the Appendix A.1. ■

3.2. Scenario 2: conventional platform and Tech Platform

In this section, we analyse the changes when the intermediary introduces a new tech platform B into the market. It represents a new emerging platform in the current e-commerce market. On the one hand, the introduction of tech platform attracts more users to the intermediary, stealing business from the brick and mortar stores. On the other hand, it may diminish the number of users on the conventional platform through potential competition. Consequently, how the introduction of new tech platform may influence the market structure is unclear. Here, buyers' net surplus of using platform A and platform B take the forms

$$U_{A2}^b(x) = u^b + V_A(q_{A2}^s, q_{B2}^s) - p_{A2}^b - x \tag{11}$$

$$U_{B2}^b(x) = u^b + V_B(q_{A2}^s, q_{B2}^s) - p_{B2}^b - x + s \tag{12}$$

where $U_{A2}^b(x)$ is the buyer's net utility in scenario 2 if it chooses platform A and $U_{B2}^b(x)$ is the buyer's surplus if it chooses platform B, u^b denotes the buyer's standalone utility of using platforms; $q_{A(B)2}^s$ denotes the number of sellers on platform A (platform B), $p_{A(B)2}^b$ denotes buyer's member fee to join platform A (platform B), and $V_{A(B)}$ denotes the network externality on platform A (platform B). Specifically, the network benefits generated by two platforms are $V_A = e(q_{A2}^s + \gamma q_{B2}^s)$ and $V_B = e(q_{B2}^s + \gamma q_{A2}^s)$ repectively. In these formulations, the parameter $\gamma \in [0, 1]$ measures the compatibility between two platforms. When γ equals zero, there is no compatiblity between two platforms. However, when γ equals one, there is full compatiblity between two platforms. In addition, we use s to denote the additional surplus the buyers are able to enjoy on platform B, which you could either view as the reduction in transaction cost or search cost.

Assumption 1 *We assume throughout the paper that* $1 \geq \gamma > \frac{1}{3}$*. Otherwise, the network externality* $e < \frac{2}{3-3\gamma}$

Assumption 1 introduces an upper bound on the network effect which guarantees that all platforms are active in the market and that the profit of the intermediary is concave in both the monopolistic market and the competitive market. We assume that platform B is located in the interval between platform A and the outside option with a distance of $d_g^{AB} + d_g^{BO}$ on the side $g \in \{b, s\}$. Specifically, the distance between platform A and one end of the Hoteling line equals d_b^{AO} (d_s^{AO}), the distance between platform B and platform A equals d_b^{AB} (d_s^{AB}), and the distance between platform B and the other end of the Hotelling line equals d_b^{BO} (d_s^{BO}) on the buyer's (seller's) side. With the introduction of tech platform B, we are able to derive the implicit demands of platform A and platform B as follows:

$$q_{A2}^b = \frac{d_b^{AO} + d_b^{AB} - eq_{B2}^s + 2eq_{A2}^s + p_{B2}^b - 2p_{A2}^b - s + \gamma(-ep_{A2}^b + 2ep_{B2}^b)}{2} \tag{13}$$

$$q_{B2}^b = \frac{d_b^{AB} + d_b^{BO} + 2eq_{B2}^s - eq_{A2}^s - 2p_{B2}^b + p_{A2}^b + 2s + \gamma(-ep_{B2}^b + 2ep_{A2}^b)}{2} \tag{14}$$

Following the same method, we can derive implicit functions of supply q_{A2}^s of platform A and supply q_{B2}^s of platform B in scenario 2 as:

$$q_{A2}^s = \frac{d_s^{AO} + d_s^{AB} - fq_{B2}^b + 2fq_{A2}^b + p_{B2}^s - 2p_{A2}^s + \gamma(-fp_{A2}^b + 2fp_{B2}^b)}{2} \tag{15}$$

$$q_{B2}^s = \frac{d_s^{AB} + d_s^{BO} + 2fq_{B2}^b - fq_{A2}^b - 2p_{B2}^s + p_{A2}^s + \gamma(-fp_{B2}^b + 2fp_{A2}^b)}{2} \tag{16}$$

Combining the implicit demand and supply functions on both platforms, under fulfilled expectations, we can obtain the get the explicit functions of demands and supplies of platform A and platform B. This expression can be found in the Appendix A.2. Based on the model setup, the profit of the intermediary that owns both platform A and platform B equals:

$$\begin{aligned} \pi_2(p_{A2}^b, p_{B2}^b, p_{A2}^s, p_{B2}^s) &= p_{A2}^b q_{A2}^b(p_{A2}^b, p_{B2}^b, p_{A2}^s, p_{B2}^s) + p_{B2}^b q_{B2}^b(p_{A2}^b, p_{B2}^b, p_{A2}^s, p_{B2}^s) \\ &+ p_{A2}^s q_{A2}^s(p_{A2}^b, p_{B2}^b, p_{A2}^s, p_{B2}^s) + p_{B2}^s q_{B2}^s(p_{A2}^b, p_{B2}^b, p_{A2}^s, p_{B2}^s) \end{aligned}$$

The intermediary maximizes its profit by choosing a seller fee and a buyer fee for each platform. The following proposition gives us the optimal member fees.

Under Assumption 1, the buyer's optimal member fee p_{A2}^b on platform A, seller's optimal member fee p_{A2}^s on platform A, buyer's optimal member fee p_{B2}^b on platform B, seller's optimal member fee p_{B2}^s on platform B are respectively:

$$p_{A2}^b = \frac{3d_b^{AB} + 2d_b^{AO} + d_b^{BO}}{6} \tag{17}$$

$$p_{A2}^s = \frac{3d_s^{AB} + 2d_s^{AO} + d_s^{BO}}{6} \tag{18}$$

$$p_{B2}^b = \frac{3d_b^{AB} + d_b^{AO} + 2d_b^{BO} + 3s}{6} \tag{19}$$

$$p_{B2}^s = \frac{3d_s^{AB} + 2d_s^{BO} + d_s^{AO}}{6} \tag{20}$$

Proof. See Appendix A.3. ■

3.3. Scenario 3: Tech Platform

In this section we study the case if the intermediary decides removes the conventional platform A and keeps only platform B. Similar to section 3.1, the net surplus of buyers and sellers using platform B takes the form

$$U_3^b(x) = u^b + V(q^s) - p_3^b - x + s \tag{21}$$
$$U_3^s(x) = u^s + V(q^b) - p_3^s - x \tag{22}$$

Given the net surplus of both sides of the market and the symmetric assumption, we are able to get the explicit demand and supply of platform B as:

$$q_3^b = \frac{(d_b^{AO} + d_b^{AB} + d_b^{BO}) + 2eq_3^s - 2p_3^b + 2s}{2} \tag{23}$$
$$q_3^s = \frac{(d_s^{AO} + d_s^{AB} + d_s^{BO}) + 2eq_3^b - 2p_3^s}{2} \tag{24}$$

Solving the simultaneous Equation 24 and Equation 23, we are able to get the explicit demand and supply of platform B as follows:

$$q_3^b = \frac{1}{2-2e^2}[(d_b^{AO} + d_b^{AB} + d_b^{BO}) + e(d_s^{AO} + d_s^{AB} + d_s^{BO}) - 2ep_3^s - 2p_3^b - 2s] \tag{25}$$
$$q_3^s = \frac{1}{2-2e^2}[(d_s^{AO} + d_s^{AB} + d_s^{BO}) + e(d_b^{AO} + d_b^{AB} + d_b^{BO}) - 2ep_3^b - 2p_3^s - 2es] \tag{26}$$

In this context, the profit of the intermediary that operates only platform B equals:

$$\pi_3 = p_3^b q_3^b + p_3^s q_3^s$$

The optimization of the intermediary's profit gives us the optimal member fee on platform B as shown in the following proposition.

Under Assumption 1, buyer's optimal member fee p^b on platform B, seller's optimal member fee p^s on platform B are respectively:

$$p_3^b{*} = \frac{d_b^{AO} + d_b^{AB} + d_b^{BO} + 2s}{4} \tag{27}$$
$$p_3^s{*} = \frac{d_s^{AO} + d_s^{AB} + d_s^{BO}}{4} \tag{28}$$

Corresponding, the number of users on platform A at equilibrium are:

$$q_3^b{*} = \frac{2[(d_b^{AO} + d_b^{AB} + d_b^{BO}) + 2s] + 2e(d_s^{AO} + d_s^{AB} + d_s^{BO})}{8(1-e)(1+e)} \tag{29}$$
$$q_3^s{*} = \frac{2(d_s^{AO} + d_s^{AB} + d_s^{BO}) + 2e(d_s^{AO} + d_s^{AB} + d_s^{BO} + 2s)}{8(1-e)(1+e)} \tag{30}$$

4. Competitive Market

To investigate the influence of competition, we introduce a competitive fringe to our model in this section. The players in our competitive model are buyers, sellers, a large intermediary and a competitive fringe. The intermediary owns a platform (platform A) that brings together buyers and sellers. The intermediary operates as a dominant firm and is considering the introduction of a new platform in the market (platform B) where buyers obtain additional surplus due to the reduction of search cost. Different from the monopoly market, the introduction of new tech platform in the competitive market not only influences the intermediary's pricing strategy, but also affects the strategies of the competitive fringe. Similar to the analysis of monopoly market, we first analyse the optimal pricing strategy of the intermediary in the competitive market when it offers only the conventional platform (A) and then we study the optimal pricing strategy when the intermediary offers also the tech platform (B). We compare the profits and find conditions under which introducing the new tech platform is optimal for the intermediary.

4.1. Competitive Scenario 1: conventional platform

This section analyzes the scenario where the intermediary owns platform A only. In this scenario, there are two platforms in the market. One is platform A that is operated by the intermediary, the other is platform O operated by the competitive fringe. The players in our model are buyers, sellers, a large intermediary, and a competitive fringe of firms. In this market, buyers and sellers benefit from cross-network externalities, meaning that the higher number of sellers in the platform, the higher utility of the buyers and vice-versa. As such, we treat the platforms as two-sided markets. Consequently, the net surplus of buyers and sellers using platform $k \in \{O, A\}$ takes the form

$$U_k^b(x) = u^b + V(q_k^s) - p_k^b - t_b x \tag{31}$$

$$U_k^s(x) = u^s + V(q_k^b) - p_k^s - t_s x \tag{32}$$

Here, $U_k^g(x)$ is the gross utility of platform $k \in \{O, A\}$ for users on side $g \in \{b, s\}$, u^g is the standalone utility on side $g \in \{b, s\}$, p_k^g is the fixed membership fee charged by platform k on side $g \in \{b, s\}$, x is the distance between the platform and the user's ideal location, and t_g is the transportation cost on side $g \in \{b, s\}$. We use functions $V(\ell)$ to denote the transaction gains of buyers and sellers respectively when there are ℓ members on the other side of the platform. In other words, $V(\ell)$ measures the positive cross-network network effect stemming from ℓ users on the other side of the platform. We assume $V_b(\ell)$ takes the linear form $e \times \ell$, where e measures the network externatility on buyer's side and seller's side respectively.

Both buyers and sellers are heterogeneous in their preference for the platforms. The heterogeneity is represented by a variant of the Hotelling specification [10]: buyers and sellers are uniformly distributed in two Hotelling lines, one for the buyers and one for the sellers. Specifically, platform A is located within the Hotelling line, and the competitive fringe O is at the two ends [11]. The distances between platform A and two ends are $d_{AO}^b(d_{AO}^s)$ and $d_{AB}^b + d_{BO}^b$ ($d_{AB}^s + d_{BO}^s$) respectively on buyer's (seller's) Hotelling line[12] The distance parameters between any two platforms measure the degree of substitutability between those two platforms as perceived by buyers/sellers. When the distance between the two platforms is large, those two platforms are less substitutable.[13]. The timeline of moves in the model is as follows. First, both

[10]Our model uses a variation of the Hotelling line as Rochet and Tirole (2003). The adjustment of the Hotelling model enables us to eliminate the technical issues of platform location induced by the introduction of platform B.

[11]Equivalently, we can also view the Hotelling line as a Salop Circle where the two endpoints of the Hotelling line overlap with each other.

[12]We define the distance between platform A and one end of the Hotelling line as the sum of two parts d_{AB} and d_{BO} for notation simplification. This will become clear upon the introduction of platform B

[13]Note that we allow the platform locations on buyers' Hotelling line to be different from their locations on sellers' Hotelling line. This is because the substitutability between two platforms in buyers' regard could be different from that in sellers'

the intermediary and the competitive fringe determine the member fees on its own platform respectively. Then, all sellers and buyers choose between platform A and platform O. Given the timeline of the model, we start by determining the demand and supply of platform A and platform O. In this setup, we are able to observe the same implicit demand of platform $k \in \{O, A\}$ on the side $g \in \{b, s\}$, which takes the following form:

$$q_k^g = \frac{2(p_{-k}^g - p_k^g) + 2e(q_k^{-g} - q_{-k}^{-g}) + t_g(d_{AO}^g + d_{AB}^g + d_{BO}^g)}{2t_g} \tag{33}$$

where q_k^g is the demand of platform $k \in \{O, A\}$ on side $g \in \{b, s\}$, q_{-k}^g is the demand of the competitive platform of k on side $g \in \{b, s\}$, q_k^{-g} is the demand of platform k on the other side of side g, and q_{-k}^{-g} is the demand of the competitive platform of platform k on the other side of side g. According to equation (3), the number of users on one side of the market is increasing in the number of its users, who are using the same platform but are on the other side of the market. However, the number of users is decreasing in the number of its competitor's users on the other side of the market. In addition, it is decreasing in the member fee charged by the platform while increasing in the member fee charged by its competitor. Solving the simultaneous equation 33, we are able to get the explicit demand and supply of platform A as shown in the Appendix A.5. Consequently, the profit of the intermediary equals:

$$\pi_k = p_k^b q_k^b + p_k^s q_k^s \tag{34}$$

We assume for simplicity and without loss of generality that both the transportation costs of sellers t_b and of buyers t_s are equal to 1.

Under Assumption 1, there is a unique symmetric equilibrium in the market, and it is given by:

$$p^b* = \frac{d_{AO}^b + d_{AB}^b + d_{BO}^b - 2e(d_{AO}^s + d_{AB}^s + d_{BO}^s)}{2} \tag{35}$$

$$p^s* = \frac{d_{AO}^s + d_{AB}^s + d_{BO}^s - 2e(d_{AO}^b + d_{AB}^b + d_{BO}^b)}{2} \tag{36}$$

Proof. See the Appendix A.6. ■

4.2. Competitive Scenario 2: conventional platform and Tech Platform

This section analyzes the scenario where the intermediary owns platform A and platform B. In this scenario, there are three platforms in the market: platform A, platform B and platform O. Among them, platform A and platform B are operated by the intermediary, and platform O is operated by the competitive fringe. The intermediary operates as a dominant platform A and is considering the introduction of a new platform in the market (platform B) where buyers obtain additional surplus. This additional surplus could come from variable sources, including but not limited to, the improvement of the recommendation system, the reduction of search cost, and the great convenience provided by artificial intelligence. On the one hand, the introduction of a tech platform attracts more users to the intermediary, stealing business from

regard. For example, Amazon Alexa might be quite different from Amazon marketplace for buyers because of its unique and innovative shopping method. However, Amazon Alexa and Amazon marketplace are similar for sellers because they care more about shipping, storage, and profit than shopping experiences. We later simplify this assumption by allowing all distances to be the same.

the brick and mortar stores. On the other hand, it may diminish the number of users on the conventional platform A through potential competition. Consequently, how the introduction of a new tech platform may influence the market structure is unclear.

To investigate, we first check the surplus of users on each side of the market. In the second scenario, buyers' net surpluses of using platform O is the same as the previous section. However, the utilities of using platform A and of using platform B take the following form respectively:

$$U_A^b(x) = u^b + V_A(q_A^s, q_B^s) - p_A^b - x \tag{37}$$

$$U_B^b(x) = u^b + s + V_B(q_A^s, q_B^s) - p_B^b - x \tag{38}$$

where $U_A^b(x)$ is the buyer's net utility if it chooses platform A and $U_B^b(x)$ is the buyer's surplus if it chooses platform B, $q_{A(B)}^s$ denotes the number of sellers on platform A (platform B), $p_{A(B)}^b$ denotes buyer's member fee to join platform A (platform B), and $V_{A(B)}$ denotes the network externality on platform A (platform B). Specifically, the network benefits generated by two platforms are $V_A = e(q_A^s + \gamma q_B^s)$ and $V_B = e(q_B^s + \gamma q_A^s)$ respectively. In these formulations, the parameter $\gamma \in [0, 1]$ measures the compatibility between two platforms. When γ equals zero, there is no compatibility between two platforms. However, when γ equals one, there is full compatibility between the two platforms. In addition, we use s to denote the additional surplus the buyers are able to enjoy on platform B, which you could either view as the reduction in transaction cost or search cost. We assume that platform B is located in the interval between platform A and the outside option with a distance of $d_{AB}^g + d_{BO}^g$ on the side $g \in \{b, s\}$. Specifically, the distance between platform A and one end of the Hoteling line equals d_{AO}^b (d_{AO}^s), the distance between platform B and platform A equals d_{AB}^b (d_{AB}^s), and the distance between platform B and the other end of the Hotelling line equals d_{BO}^b (d_{BO}^s) on the buyers' (sellers') side. With the introduction of tech platform B, we are able to derive the implicit demands of platform A, platform B, and platform O as follows:

$$q_A^b = \frac{p_B^b + p_O^b - 2p_A^b + 2eq_A^s - e\gamma q_A^s - eq_B^s + 2e\gamma q_B^s - eq_O^s - s + d_{AB}^b + d_{AO}^b}{2} \tag{39}$$

$$q_B^b = \frac{p_A^b - 2p_B^b + p_O^b - eq_A^s + 2e\gamma q_A^s + 2eq_B^s - e\gamma q_B^s - eq_O^s + 2s + d_{AB}^b + d_{BO}^b}{2} \tag{40}$$

$$q_O^b = \frac{p_A^b + p_B^b - 2p_O^b - eq_A^s - e\gamma q_A^s - eq_B^s - e\gamma q_B^s + 2eq_O^s - s + d_{AO}^b + d_{BO}^b}{2} \tag{41}$$

Following the same method, we can derive implicit functions of supply q_A^s of platform A, supply q_B^s of platform B, and supply q_O^s of platform O as:

$$q_A^s = \frac{p_B^s + p_O^s - 2p_A^s + 2eq_A^b - e\gamma q_A^b - eq_B^b + 2e\gamma q_B^b - eq_O^b - s + d_{AB}^s + d_{AO}^s}{2} \tag{42}$$

$$q_B^s = \frac{p_A^s - 2p_B^s + p_O^s - eq_A^b + 2e\gamma q_A^b + 2eq_B^b - e\gamma q_B^b - eq_O^b + 2s + d_{AB}^s + d_{BO}^s}{2} \tag{43}$$

$$q_O^s = \frac{p_A^s + p_B^s - 2p_O^s - eq_A^b - e\gamma q_A^b - eq_B^b - e\gamma q_B^b + 2eq_O^b - s + d_{AO}^s + d_{BO}^s}{2} \tag{44}$$

According to the implicit demand and supply functions, the number of buyers (sellers) of one platform is always decreasing in the platform's buyer (seller) fee, while is increasing in the buyer (seller) fee on other platforms. Because of cross-network externality, the number of users on one side of a platform is always increasing in the number of users on the other side of the same platform. On platform O, the number of users decreases in the number of users on the other side of platform A and platform B. However, the relationship between platform A and platform B depends on the compatibility between two platforms. When the compatibility γ is larger than $\frac{1}{2}$, the number of users on one side of platform A (B) is increasing in the number of users of platform B (A) on the other side. Otherwise, it is the opposite.

Combining the implicit demand and supply functions on both platforms, under fulfilled expectations, we can obtain the explicit functions of demands and supplies of platform A, platform B and platform O. This expression can be found in the Appendix A.7.

In this scenario, the profit of the intermediary that owns both platform A and platform B equals:

$$\begin{aligned}\pi_p(p_A^b, p_B^b, p_A^s, p_B^s, p_O^b, p_O^s) &= p_A^b q_A^b(p_A^b, p_B^b, p_A^s, p_B^s, p_O^b, p_O^s) + p_B^b q_B^b(p_A^b, p_B^b, p_A^s, p_B^s, p_O^b, p_O^s) \\ &+ p_A^s q_A^s(p_A^b, p_B^b, p_A^s, p_B^s, p_O^b, p_O^s) + p_B^s q_B^s(p_A^b, p_B^b, p_A^s, p_B^s, p_O^b, p_O^s)\end{aligned}$$

and the profit of the competitive fringe that operate platform O equals

$$\pi_O(p_A^b, p_B^b, p_A^s, p_B^s, p_O^b, p_O^s) = p_O^b q_O^b(p_A^b, p_B^b, p_A^s, p_B^s, p_O^b, p_O^s) + p_O^s q_O^s(p_A^b, p_B^b, p_A^s, p_B^s, p_O^b, p_O^s)$$

The intermediary and the competitive fringe maximize each profit by choosing a seller fee and a buyer fee for its platform(s). The following proposition gives us optimal member fees.

Under Assumption 1, the buyer's optimal member fee p_A^b on platform A, seller's optimal member fee p_A^s on platform A, buyer's optimal member fee p_B^b on platform B, seller's optimal member fee p_B^s on platform B, buyer's optimal member fee p_O^b on platform O, seller's optimal member fee p_O^s on platform O are respectively:

$$p_A^b = \frac{2}{3}d_b^{AB} + \frac{7}{12}d_b^{AO} + \frac{5}{12}d_b^{BO} + \frac{-10e-2e\gamma}{12}(d_s^{AB} + d_s^{AO} + d_s^{BO}) - \frac{s}{12} \tag{45}$$

$$p_A^s = \frac{2}{3}d_s^{AB} + \frac{7}{12}d_s^{AO} + \frac{5}{12}d_s^{BO} + \frac{-10e-2e\gamma}{12}(d_b^{AB} + d_b^{AO} + d_b^{BO}) \tag{46}$$

$$p_B^b = \frac{2}{3}d_b^{AB} + \frac{7}{12}d_b^{BO} + \frac{5}{12}d_b^{AO} + \frac{-10e-2e\gamma}{12}(d_s^{AB} + d_s^{AO} + d_s^{BO}) + \frac{5s}{12} \tag{47}$$

$$p_B^s = \frac{2}{3}d_s^{AB} + \frac{5}{12}d_s^{AO} + \frac{7}{12}d_s^{BO} + \frac{-10e-2e\gamma}{12}(d_b^{AB} + d_b^{AO} + d_b^{BO}) \tag{48}$$

$$p_O^b = \frac{1}{3}d_b^{AB} + \frac{1}{2}d_b^{AO} + \frac{1}{2}d_b^{BO} + \frac{-4e-2e\gamma}{6}(d_s^{AB} + d_s^{AO} + d_s^{BO}) - \frac{s}{6} \tag{49}$$

$$p_O^s = \frac{1}{3}d_s^{AB} + \frac{1}{2}d_s^{AO} + \frac{1}{2}d_s^{BO} + \frac{-4e-2e\gamma}{6}(d_b^{AB} + d_b^{AO} + d_b^{BO}) \tag{50}$$

(51)

Proof. See Appendix A.8. ■

5. Past and Future of AI

5.1. Effect of AI on Two-Sided Market

From now on, we simplify our analysis by allowing for symmetry in the location of the platforms. Namely, we assume that the platforms and the outside option are located at a distance of d from each other. Consequently, we remove the distortions by factors other than the additional surplus introduced by tech platform B on both sides of the market. To investigate how the introduction of AI technology affects the two-sided platform, we compare scenario 1 with scenario 2 in several aspects, including the number of users, profit, and social welfare. We find that the introduction of AI technology changes both the number of users and welfare in the two-sided market. In addition, its effect depends heavily on both the network externality in the two-sided market and the compatibility between two platforms.

We first analyze the intermediary's number of users. We find that the introduction of the new tech platform does not necessarily move up the number of users for the intermediary. Only when network externality in the two-sided is sufficiently small, the introduction of the new tech platform always attracts more users to the intermediary. However, the introduction of the new tech platform may reduce the number of users when network externality in the two-sided market is large. Specifically, we have

Corollary 1 *Under Assumption 1,*

- *If $e \leq \frac{2}{5-3\gamma}$, there are always more users on the intermediary after the introduction of tech platform B.*
- *If $e > \frac{2}{5-3\gamma}$, there must exist some $\hat{s_q^g} > 0$ on side $g \in \{b, g\}$ such that when $s > \hat{s_q^g}$ on on side $g \in \{b, g\}$, there are more users of the intermediary on the side $g \in \{b, g\}$ after the introduction of tech platform B. Otherwise, it is the opposite.*

Proof.

See Appendix A.9

■

We also compare the intermediary's profit before and after the introduction of the tech platform to the market. We also find that the introduction of the new tech platform is always profitable for the intermediary only when the network externality in the two-sided market is sufficiently small. Otherwise, its influence on the intermediary's profit depends on the additional tech surplus on platform B. Specifically, we derive:

Corollary 2 *Under Assumption 1,*

- *When $e < \frac{14}{23-9\gamma}$,it is always profitable to introduce platform B in the two-sided market.*
- *When $e \geq \frac{14}{23-9\gamma}$, there exist some some $\hat{s_\pi^g} > 0$ on side $g \in \{b, g\}$ such that when $s > \hat{s_\pi^g}$ on on side $g \in \{b, g\}$, the introduction of the tech platform always moves up the intermediary's profit. Otherwise, it is the opposite.*

Proof. To investigate the profit change due to the introduction of the tech platform in the monopolistic market, we first calculate the change in the intermediary's profit $d\pi$, which equals $\pi_2 - \pi_1$. Specifically, we get

$$d\pi = \frac{d^2(14-23e+9e\gamma)}{8(-1+e)(-2+e+e\gamma)} - \frac{ds}{-2+e+e\gamma} - \frac{(-4+3e^2-3e^2\gamma+3e^2\gamma^2)s^2}{(-2+e+e\gamma)(2+e+e\gamma)(-2-3e+3e\gamma)(2-3e+3e\gamma)}$$

Under Assumption 1, we can easily find that $d^{AB}\pi$ is increasing in s. Then we proceed to check the value of $d^{AB}\pi$ when s equals zero. Specificallly, we find that when $e < \frac{14}{23-9\gamma}$, its value at $s = 0$ is always non-negative. Otherwise, its value becomes negative when s equals zero. Consequently, we could conclude that when $e < \frac{14}{23-9\gamma}$, the introduction of the tech platform always moves up the intermediary's profit in the two-sided market. Otherwise, there exist some some $\hat{s_\pi^g} > 0$ on side $g \in \{b, g\}$ such that when $s > \hat{s_\pi^g}$ on on side $g \in \{b, g\}$, the introduction of the tech platform always moves up the intermediary's profit. Otherwise, it is the opposite.

■

Besides the intermediary's profit and the number of users, we also investigate the effect of the tech platform on social welfare in the two-sided market. Specifically, we check the change of consumer surplus and the change of producer surplus due to the introduction of the new tech platform. We find that when the network externality in the two-sided market is sufficiently small or when compatibility between two platforms is sufficiently large, the introduction of the new tech platform always raises the consumer surplus. Otherwise, the influence of the new tech platform depends on the value of the tech surplus s introduced by the new platform. More precisely, our finding could be summarized as follows:

Corollary 3 *Under Assumption 1, there exists some $e_{cs} \in (0, \frac{2}{3})$ such that*

- *if $e < e_{cs}$, the introduction of the new tech platform always increases the consumer surplus in the market.*
- *If $e > e_{cs}$, there exists some $\gamma_{cs} \in (0, 1)$ such that the introduction of the new tech platform always increases the consumer surplus in the market when $\gamma > \gamma_{cs}$. Otherwise, there exists some $s_{cs} > 0$ such that the introduction of the new tech platform always increases the consumer surplus in the market when $s > s_{cs}$, while reduces the consumer surplus when $s < s_{cs}$*

Proof. See Appendix A.10 ■

We also investigate the change in producer surplus due to the introduction of the new tech platform. Different from consumer surplus, we find that only when both the network externality in the two-sided market and the compatibility between two platforms are sufficiently large, the introduction of the new tech platform always raises the consumer surplus. Otherwise, the influence of the new tech platform depends on the value of the tech surplus s introduced by the new platform. More precisely, our finding could be summarized as follows:

Corollary 4 *Under Assumption 1, There exists some $e_{ps} \in (0, 1)$ such that*

- *If $e > e_{ps}$, there must exist some $\gamma_{ps} \in (0, 1)$ such that the introduction of the new tech platform always increases the producer surplus in the market when $\gamma > \gamma_{ps}$.*

- *Otherwise, there exists some* $s_{ps} > 0$ *such that the introduction of the new tech platform always increases the producer surplus in the market when* $s > s_{ps}$*, while reduces the producer surplus when* $s < s_{ps}$*.*

Proof. See Appendix A.11 ■

5.2. The Next Step in Artificial Intelligence Development

In this section, we study the conditions under which the intermediary would find it optimal to replace the conventional platform with the new tech platform altogether. To see whether removing the conventional platform would benefit the intermediary, we check the profit change when conventional platform A is completely replaced. We compare scenario 2 where the intermediary operates both the conventional platform and new tech platform with scenario 3 where the intermediary only operates the new tech platform.

We first analyze the change in the intermediary's number of users after removing platform A. We find that removing the conventional platform does not necessarily move up the number of users for the intermediary. Only when network externality in the two-sided is sufficiently large, the introduction of the new tech platform always attracts more users to the intermediary. However, removing the conventional platform may reduce the number of users when network externality in the two-sided market is small. Specifically, we have

Corollary 5 *Under Assumption 1*

- *If* $e \geq \frac{2}{5-3\gamma}$*, there are always more users on the intermediary after removing platform A.*
- *If* $e < \frac{2}{5-3\gamma}$*, there always exist some* $0 < \tilde{\tilde{s}}_q^g \leq 1$ *such that when* $0 < s < \tilde{\tilde{s}}_q^g$*, keeping the traditional platform is more profitable on side* $g \in \{b, s\}$*. Otherwise, it is the opposite.*

Proof. See Appendix A.12 ■

We also compare the intermediary's profit before and after removing the conventional platform A. Specifically, we focus on two polar scenarios. One is that platform A and platform B have no compatibility; the other is that platform A and platform B fully compatibility. We find that the influence of removing the conventional platform depends heavily on the value of tech surplus on the new tech platform B. Specifically, we derive

Corollary 6 *Under Assumption 1*

- *If platform A and platform B are not compatible and network externality* $e > \frac{14}{23}$ *, then there must exist some* $s_{pi}^n > 0$ *such that the removing platform a is more profitable when* $s < s_{pi}^n$*. Otherwise, it is more profitable to keep both platform A and platform B.*
- *If platform A and platform B are not compatible and network externality* $e \leq \frac{14}{23}$*, there must exist some* $s_{pi}^{\tilde{\tilde{n}}} > s_{pi}^{\tilde{n}} > 0$ *such that the removing platform a is more profitable when* $s \in [s_{pi}^{\tilde{n}}, s_{pi}^{\tilde{\tilde{n}}}]$*. Otherwise, it is more profitable to keep both platform A and platform B.*

- *If platform A and platform B are fully compatible, there always exists some* $0 < s_\pi^f < 1$ *such that when* $0 < s < s_\pi^f$*, keeping the traditional platform is more profitable in the full-compatible market. Otherwise, it is the opposite.*

Proof. See Appendix A.13 ■

Besides the intermediary's profit and the number of users, we also investigate the effect of removing the conventional platform on social welfare in the two-sided market. Specifically, we check the change of consumer surplus and the change of producer surplus due to the removal of the conventional platform. We find that removing the conventional platform reduces consumer surplus in the two-sided market when the tech surplus s is sufficiently large or small. More precisely, our finding could be summarized as follows:

Corollary 7 *Under Assumption 1, there must exist* e_{cs}^c *and* e_{cs}^f *such that*

- *If platform A and platform B are not compatible and* $e < e_{cs}^c$*, there exist some* $0 < s_{cs}^c < s_{cs}^{c'}$ *such that removing platform A increases consumer surplus when* $s \in (s_{cs}^c, s_{cs}^{c'})$*. Otherwise, removing platform A always decreases consumer surplus in the non-compatible market.*
- *If platform A and platform B are fully compatible and* $e < e_{cs}^f$*, there exist some* $0 < s_{cs}^f < s_{cs}^{f'}$ *such that removing platform A increases consumer surplus when* $s \in (s_{cs}^f, s_{cs}^{f'})$*. Otherwise, removing platform A always decreases consumer surplus in the fully-compatible market.*

Proof. See Appendix A.14 ■

We also investigate the change in producer surplus due to the removal of the conventional platform. Different from consumer surplus, we find that removing the conventional platform always reduces producer surplus in the two-sided market. More precisely, our finding could be summarized as follows:

Corollary 8 *Under Assumption 1, removing platform A reduces the producer surplus in both the non-compatible market and the fully compatible market.*

Proof. See Appendix A.15 ■

6. Conclusion

In this paper we studied the optimal strategies of an intermediary regarding the introduction of an AI technology platform. In our model the intermediary owns a conventional platform (for instance Amazon owns the Amazon website) and is considering the possibility of introducing a new platform that uses the AI technology. The intermediary faces the following trade-off: on the one hand the introduction of the new platform could attract more users to the intermediary, on the other hand the introduction of the new platform can hurt the intermediary by generating competition between the traditional and the new tech platform. Buyers value the number of sellers that adopt the same platform offered by the intermediary. Likewise, the sellers value the number of buyers who adopt their same platform. As such, we are analysing a two-sided market. We also consider the existence of an outside option which can be thought of as the brick-and-mortar business. The AI technology platform yields extra utility to the buyers that we interpret as a reduction in search cost. The intermediary sells his service both to buyers and sellers and charges a different member fee on each side. We obtain results on the optimal member fees and conditions under which it is optimal to introduce the new tech platform. First of all, we find that the number of users on the new tech platform increases on the additional surplus of the AI technology, while the number of users of the conventional platform decreases. However the influence of the additional surplus of the AI technology on the intermediary's pricing strategy is uncertain. Specifically, it depends on the relative network externalities on each side of the two-sided market.

The introduction of the new tech platform brings about changes in the optimal buyer's fee and seller's fee on the conventional platform. We find that if the buyers generate more network externality to the sellers, then the intermediary will charge a higher buyer's fee after the introduction of the new tech platform, and vice-versa. The intuition is as follows: in our setting, the intermediary runs both the conventional platform and new tech platform so, it uses all the member fees to maximize its profit. To attract more users to the new tech platform and generate more network effect there, the intermediary increases the member fee on the conventional platform, moving the users who generate a larger network externality on the other side to the new platform.

In addition, we find that the introduction of the new platform may not always benefit the intermediary, in which case he would keep the traditional platform only. This is an interesting result specially when we think that the intermediary may choose which products are sold through the new tech platform. For the products that have large network externality, the introduction of the new platform may reduce the total number of users of the intermediary. Moreover, it may also diminish the intermediary's profit. When the network externalities in the market are large, the intermediary is able to benefit from the introduction of the new platform only when the technology is able to bring sufficient additional surplus to the buyers. For the products that have small network externality, the introduction of the new platform can always bring more users to the intermediary and generate more profit. This theoretical prediction is consistent with the behavior of certain intermediaries. Take Amazon, for instance and the introduction of the Amazon Dash Button. Since one Dash Button could only represent one brand for each button, the use of the tool represents a great decrease in buyers' product diversity. It is reasonable for us to believe the users who choose Amazon Dash Button should have a low preference for variety thus can get a low network externality from the seller side of the market. As indicated in our model, because of the low preference for variety, the introduction of Dash Button can always bring more profit to the company. Currently, Amazon is working on its intelligent system Alexa which brings a very high additional surplus to the buyers due to the reduction of search cost. In this case the introduction of the new technology benefits Amazon significantly, regardless of the network effects. Lastly, our research predicts that when the additional surplus s on tech platfrom is sufficiently large, the intermediary would find it optimal to replace the conventional platform with the new tech platform altogether.

This paper is the first to provide a theoretical framework to study the influence of the introduction of AI technology in two-sided markets. In its backbone, the model boils down to a model where a monopolist intermediary offers multiple platforms differentiated by the level of surplus that they provide to the buyers. The model is suitable to be applied to different questions and have several extensions. In particular, we are currently exploring the extension of the model to study the effect of AI on competition.

A. Appendix

A.1. Proof of Proposition 3.1

By solving the simultaneous equation 3 we obtain the following demand and supply for platform A.

$$q_1^b = \frac{1}{2(1-e^2)}[(d_b^{AO} + d_b^{AB} + d_b^{BO}) + e(d_s^{AB} + d_s^{AO} + d_s^{BO}) - 2ep_1^s - 2p_1^b]$$
$$q_1^s = \frac{1}{2(1-e^2)}[(d_s^{AO} + d_s^{AB} + d_s^{BO}) + e(d_b^{AB} + d_b^{AO} + d_b^{BO}) - 2ep_1^b - 2p_1^s]$$

Note that under Assumption 1 both q^b and q^s are positive as $e^2 < \frac{1}{4} < 1$. The optimization of the intermediary's profit yields the following first order conditions which are sufficient for optimality.

$$p_1^b = \frac{e(d_s^{AO} + d_s^{AB} + d_s^{BO})}{4} + \frac{d_b^{AO} + d_b^{AB} + d_b^{BO}}{4} - \frac{4ep_1^s}{4} \tag{52}$$
$$p_1^s = \frac{e(d_b^{AO} + d_b^{AB} + d_b^{BO})}{4} + \frac{d_s^{AO} + d_s^{AB} + d_s^{BO}}{4} - \frac{4ep_1^b}{4} \tag{53}$$

By solving the system of simultaneous equations, we obtain the following optimal member fees:

$$p_1^b* = \frac{d_b^{AO} + d_b^{AB} + d_b^{BO}}{4} \tag{54}$$
$$p_1^s* = \frac{d_s^{AO} + d_s^{AB} + d_s^{BO}}{4} \tag{55}$$

Plugging the optimal member fees (8) and (9) onto the demand functions (4) on both sides of the market, we derive the equlibrium demand and supply before the introduction of the new platform.

$$q_1^b* = \frac{2[d_b^{AO} + d_b^{AB} + d_b^{BO}] + 2e[d_s^{AO} + d_s^{AB} + d_s^{BO}]}{8(1-e)(e+1)} \tag{56}$$
$$q_1^s* = \frac{2[d_s^{AO} + d_s^{AB} + d_s^{BO}] + 2e[d_b^{AO} + d_b^{AB} + d_b^{BO}]}{8(1-e)(e+1)} \tag{57}$$

A.2. Explicit Demand and Supply of Platforms of Monopoly Scenario 2

$$q^b_{A2} = -\frac{1}{(-2+e+e\gamma)(2+e+e\gamma)(-2-3e+3e\gamma)(2-3e+3e\gamma)}[d_b^{BO}(8e^2-20e^2\gamma+8e^2\gamma^2)+d_b^{AO}(-8+10e^2-16e^2\gamma+10e^2\gamma^2)$$
$$+d_b^{AB}(-8+18e^2-36e^2\gamma+18e^2\gamma^2)+d_s^{AO}(-8e+6e^3+4e\gamma-3e^3\gamma-6e^3\gamma^2+3e^3\gamma^3)$$
$$+d_s^{BO}(4e+3e^3-8e\gamma-6e^3\gamma-3e^3\gamma^2+6e^3\gamma^3)+d_s^{AB}(-4e+9e^3-4e\gamma-9e^3\gamma-9e^3\gamma^2+9e^3\gamma^3)$$
$$+(16-12e^2+12e^2\gamma-12e^2\gamma^2)p_A^b+(20e-9e^3-16e\gamma+9e^3\gamma^2)p_A^s+(-8-6e^2+24e^2\gamma-6e^2\gamma^2)p_B^b$$
$$+(-16e+20e\gamma+9e^3\gamma-9e^3\gamma^3)p_B^s+(8+6e^2-24e^2\gamma+6e^2\gamma2)s]$$

$$q^s_{A2} = -\frac{1}{(-2+e+e\gamma)(2+e+e\gamma)(-2-3e+3e\gamma)(2-3e+3e\gamma)}[d_s^{BO}(8e^2-20e^2\gamma+8e^2\gamma^2)+d_s^{AO}(-8+10e^2-16e^2\gamma+10e^2\gamma^2)$$
$$+d_s^{AB}(-8+18e^2-36e^2\gamma+18e^2\gamma^2)+d_b^{AO}(-8e+6e^3+4e\gamma-3e^3\gamma-6e^3\gamma^2+3e^3\gamma^3)$$
$$+d_b^{BO}(4e+3e^3-8e\gamma-6e^3\gamma-3e^3\gamma^2+6e^3\gamma^3)+d_b^{AO}(-4e+9e^3-4e\gamma-9e^3\gamma-9e^3\gamma^2+9e^3\gamma^3)$$
$$+(16-12e^2+12e^2\gamma-12e^2\gamma^2)p_A^s+(20e-9e^3-16e\gamma+9e^3\gamma^2)p_A^b+(-8-6e^2+24e^2\gamma-6e^2\gamma^2)p_B^s$$
$$+(-16e+20e\gamma+9e^3\gamma-9e^3\gamma^3)p_B^b+(16e-20e\gamma-9e^3\gamma+9e^3\gamma^3)s]$$

$$q^b_{B2} = -\frac{1}{(-2+e+e\gamma)(2+e+e\gamma)(-2-3e+3e\gamma)(2-3e+3e\gamma)}[d_b^{AO}(8e^2-20e^2\gamma+8e^2\gamma^2)+d_b^{BO}(-8+10e^2-16e^2\gamma+10e^2\gamma^2)$$
$$+d_b^{AB}(-8+18e^2-36e^2\gamma+18e^2\gamma^2)+d_s^{BO}(-8e+6e^3+4e\gamma-3e^3\gamma-6e^3\gamma^2+3e^3\gamma^3)$$
$$+d_s^{AO}(4e+3e^3-8e\gamma-6e^3\gamma-3e^3\gamma^2+6e^3\gamma^3)+d_s^{AB}(-4e+9e^3-4e\gamma-9e^3\gamma-9e^3\gamma^2+9e^3\gamma^3)$$
$$+(16-12e^2+12e^2\gamma-12e^2\gamma^2)p_B^b+(20e-9e^3-16e\gamma+9e^3\gamma^2)p_B^s+(-8-6e^2+24e^2\gamma-6e^2\gamma^2)p_A^b$$
$$+(-16e+20e\gamma+9e^3\gamma-9e^3\gamma^3)p_A^s+(-16+12e^2-12e^2\gamma+12e^2\gamma^2)s]$$

$$q^s_{B2} = -\frac{1}{(-2+e+e\gamma)(2+e+e\gamma)(-2-3e+3e\gamma)(2-3e+3e\gamma)}[d_s^{AO}(8e^2-20e^2\gamma+8e^2\gamma^2)+d_s^{BO}(-8+10e^2-16e^2\gamma+10e^2\gamma^2)$$
$$+d_s^{AB}(-8+18e^2-36e^2\gamma+18e^2\gamma^2)+d_b^{BO}(-8e+6e^3+4e\gamma-3e^3\gamma-6e^3\gamma^2+3e^3\gamma^3)$$
$$+d_b^{AO}(4e+3e^3-8e\gamma-6e^3\gamma-3e^3\gamma^2+6e^3\gamma^3)+d_b^{AB}(-4e+9e^3-4e\gamma-9e^3\gamma-9e^3\gamma^2+9e^3\gamma^3)$$
$$+(16-12e^2+12e^2\gamma-12e^2\gamma^2)p_B^s+(20e-9e^3-16e\gamma+9e^3\gamma^2)p_B^b+(-8-6e^2+24e^2\gamma-6e^2\gamma^2)p_A^s$$
$$+(-16e+20e\gamma+9e^3\gamma-9e^3\gamma^3)p_A^b+(-20e+9e^3+16e\gamma-9e^3\gamma^2)s]$$

A.3. Proof of Proposition 3.2

The profit of the intermediary that owns both platform A and platform B equals:

$$\pi_2(p^b_{A2},p^b_{B2},p^s_{A2},p^s_{B2}) = p^b_{A2}*q^b_{A2}(p^b_{A2},p^b_{B2},p^s_{A2},p^s_{B2})+p^b_{B2}*q^b_{B2}(p^b_{A2},p^b_{B2},p^s_{A2},p^s_{B2})$$
$$+p^s_{A2}*q^s_{A2}(p^b_{A2},p^b_{B2},p^s_{A2},p^s_{B2})+p^s_{B2}*q^s_{B2}(p^b_{A2},p^b_{B2},p^s_{A2},p^s_{B2})$$

The intermediary maximizes its profit by choosing seller fee and buyer fee on both platforms. Consequently, we are able to derive the first order conditions as follows:

$$\begin{aligned}
p^{b*}_{A2} = &-\frac{1}{8(-4+3e^2-3e^2\gamma+3e^2\gamma^2)}\{d^{AO}_b(-8+10e^2-16e^2\gamma+10e^2\gamma^2)+d^{AB}_b(-8+18e^2-36e^2\gamma+18e^2\gamma^2)\\
&+d^{BO}_b((8e^2-20e^2\gamma+8e^2\gamma^2))+d^{AO}_s(-8e+6e^3+4e\gamma-3e^3\gamma-6e^3\gamma^2+3e^3\gamma^3)\\
&+d^{AB}_s(-4e+9e^3-4e\gamma-9e^3\gamma-9e^3\gamma^2+9e^3\gamma^3)+d^{BO}_s(4e+3e^3-8e\gamma-6e^3\gamma-3e^3\gamma^2+6e^3\gamma^3)\\
&+p^{s*}_{A2}(40e-18e^3-32e\gamma+18e^3\gamma^2)-p^{b*}_{B2}(-16-12e^2+48e^2\gamma-12e^2\gamma^2)-16p^{s*}_{B2}(-32e+40e\gamma+18e^3\gamma-18e^3\gamma^3)\\
&+s(8+6e^2-24e^2\gamma+6e^2\gamma^2)\}\\
p^{s*}_{A2} = &-\frac{1}{8(-4+3e^2-3e^2\gamma+3e^2\gamma^2)}\{d^{AO}_s(-8+10e^2-16e^2\gamma+10e^2\gamma^2)+d^{AB}_s(-8+18e^2-36e^2\gamma+18e^2\gamma^2)\\
&+d^{BO}_s((8e^2-20e^2\gamma+8e^2\gamma^2))+d^{AO}_b(-8e+6e^3+4e\gamma-3e^3\gamma-6e^3\gamma^2+3e^3\gamma^3)\\
&+d^{AB}_b(-4e+9e^3-4e\gamma-9e^3\gamma-9e^3\gamma^2+9e^3\gamma^3)+d^{BO}_b(4e+3e^3-8e\gamma-6e^3\gamma-3e^3\gamma^2\\
&+6e^3\gamma^3)+p^{b*}_{A2}(40e-18e^3-32e\gamma+18e^3\gamma^2)-p^{s*}_{B2}(-16-12e^2+48e^2\gamma-12e^2\gamma^2)-16p^{b*}_{B2}(-32e+40e\gamma+18e^3\gamma-18e^3\gamma^3)\\
&+s(16e-20e\gamma-9e^3\gamma+9e^3\gamma^3)\}\\
p^{b*}_{B2} = &-\frac{1}{8(-4+3e^2-3e^2\gamma+3e^2\gamma^2)}\{d^{BO}_b(-8+10e^2-16e^2\gamma+10e^2\gamma^2)+d^{AB}_b(-8+18e^2-36e^2\gamma+18e^2\gamma^2)\\
&+d^{AO}_b((8e^2-20e^2\gamma+8e^2\gamma^2))+d^{BO}_s(-8e+6e^3+4e\gamma-3e^3\gamma-6e^3\gamma^2+3e^3\gamma^3)\\
&+d^{AB}_s(-4e+9e^3-4e\gamma-9e^3\gamma-9e^3\gamma^2+9e^3\gamma^3)+d^{AO}_s(4e+3e^3-8e\gamma-6e^3\gamma-3e^3\gamma^2+6e^3\gamma^3)\\
&+p^{s*}_{B2}(40e-18e^3-32e\gamma+18e^3\gamma^2)-p^{b*}_{A2}(-16-12e^2+48e^2\gamma-12e^2\gamma^2)-16p^{s*}_{A2}(-32e+40e\gamma+18e^3\gamma-18e^3\gamma^3)\\
&+s(-16+12e^2-12e^2\gamma+12e^2\gamma^2)\}\\
p^{s*}_{B2} = &-\frac{1}{8(-4+3e^2-3e^2\gamma+3e^2\gamma^2)}\{d^{BO}_s(-8+10e^2-16e^2\gamma+10e^2\gamma^2)+d^{AB}_s(-8+18e^2-36e^2\gamma+18e^2\gamma^2)\\
&+d^{AO}_s((8e^2-20e^2\gamma+8e^2\gamma^2))+d^{BO}_b(-8e+6e^3+4e\gamma-3e^3\gamma-6e^3\gamma^2+3e^3\gamma^3)\\
&+d^{AB}_b(-4e+9e^3-4e\gamma-9e^3\gamma-9e^3\gamma^2+9e^3\gamma^3)+d^{AO}_b(4e+3e^3-8e\gamma-6e^3\gamma-3e^3\gamma^2+6e^3\gamma^3)\\
&+p^{b*}_{B2}(40e-18e^3-32e\gamma+18e^3\gamma^2)-p^{s*}_{A2}(-16-12e^2+48e^2\gamma-12e^2\gamma^2)-16p^{b*}_{A2}(-32e+40e\gamma+18e^3\gamma-18e^3\gamma^3)\\
&+s(-20e+9e^3+16e\gamma-9e^3\gamma^2)\}
\end{aligned}$$

Solving the first order conditions, we yield the optimal member fees as listed in equations (16)-(19)

A.4. Explicit Demand and Supply of Scenario 3

$$q^b = \frac{1}{2-2e^2}[3d+3de-2ep_s-2p_b-2s] \tag{58}$$

$$q^s = \frac{1}{2-2e^2}[3d+3de-2ep_b-2p_s-2es] \tag{59}$$

A.5. Explicit Demand and Supply of Competitive Scenario 1

By solving the simultaneous equation 33 we obtain the following explicit demand and supply in scenario 1:

$$q^b_k = \frac{d^b_{AO}+d^b_{AB}+d^b_{BO}-4e^2(d^s_{AO}+d^s_{AB}+d^s_{BO})+4e(p^s_{-k}-p^s_k)+2(p^b_{-k}-p^b_k)}{8ef-2}$$

$$q^s_k = \frac{d^s_{AO}+d^s_{AB}+d^s_{BO}-4e^2(d^b_{AO}+d^b_{AB}+d^b_{BO})+4e(p^b_{-k}-p^b_k)+2(p^s_{-k}-p^s_k)}{8ef-2}$$

A.6. Proof of Proposition 4.1

Under Assumption 1, both the competitive fringe and the intermediary have concave profit functions. The optimization of the intermediary's profit and the optimization of the competitive fringe yield the following first order conditions, which are sufficient for optimality:

$$p_k^b = \frac{d_{AB}^b + d_{AO}^b + d_{BO}^b - 4e^2 d_{AB}^b - 4e^2 d_{AO}^b - 4e^2 d_{BO}^b - 4ep_k^s - 4ep_k^s + 2p_{-k}^b + 4ep_{-k}^s}{4} \tag{60}$$

$$p_k^s = \frac{d_{AB}^s + d_{AO}^s + d_{BO}^s - 4e^2 d_{AB}^s - 4e^2 d_{AO}^s - 4e^2 d_{BO}^s - 4ep_k^b - 4ep_k^b + 2p_{-k}^s + 4ep_{-k}^b}{4} \tag{61}$$

With Assumption 1, one can easily check that there are no asymmetric equilibria. By solving the system of simultaneous equations, we derive the equlibrium demand and supply on both platform A and platform O before the introduction of the new platform. as:

$$p^b{*} = \frac{d_{AO}^b + d_{AB}^b + d_{BO}^b - 2e(d_{AO}^s + d_{AB}^s + d_{BO}^s)}{2} \tag{62}$$

$$p^s{*} = \frac{d_{AO}^s + d_{AB}^s + d_{BO}^s - 2e(d_{AO}^b + d_{AB}^b + d_{BO}^b)}{2} \tag{63}$$

A.7. Explicit Demand and Supply of Platforms of Competitive Scenario 2

$$q_A^b = \frac{1}{(-2+3e+e\gamma)(2+3e+e\gamma)(-2-3e+3e\gamma)(2-3e+3e\gamma)}[d_s^{BO}(-8e+18e^3+8e\gamma-18e^3\gamma+6e^3\gamma^2-6e^3\gamma^3)+d_s^{AO}(4e-9e^3-4e\gamma-9e^3\gamma$$
$$+d_s^{AB}(4e-9e^3+4e\gamma+9e^3\gamma+9e^3\gamma^2-9e^3\gamma^3)+d_b^{AO}(-8-30e^2+27e^4+8e^2\gamma-45e^4\gamma-10e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3)$$
$$+d_b^{BO}(-12e^2+27e^4+20e^2\gamma-45e^4\gamma-8e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3)+d_b^{AB}(8-30e^2+27e^4+32e^2\gamma-45e^4\gamma-18e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3)$$
$$+(-16+36e^2+12e^2\gamma^2)p_A^b+(-24e+54e^3+16e\gamma-36e^3\gamma-18e^3\gamma^2)p_A^s+(8-18e^2-36e^2\gamma+6e^2\gamma^2)p_B^b$$
$$+(12e-27e^3-20e\gamma-9e^3\gamma+27e^3\gamma^2+9e^3\gamma^3)p_B^s+(8-18e^2+36e^2\gamma-18e^2\gamma^2)p_O^b$$
$$+(12e-27e^3+4e\gamma+45e^3\gamma-9e^3\gamma^2-9e^3\gamma^3)p_O^s+(-8+18e^2+36e^2\gamma-6e^2\gamma^2)s]$$

$$q_A^s = \frac{1}{(-2+3e+e\gamma)(2+3e+e\gamma)(-2-3e+3e\gamma)(2-3e+3e\gamma)}[d_b^{BO}(-8e+18e^3+8e\gamma-18e^3\gamma+6e^3\gamma^2-6e^3\gamma^3)+d_b^{AO}(4e-9e^3-4e\gamma-9e^3\gamma$$
$$+d_b^{AB}(4e-9e^3+4e\gamma+9e^3\gamma+9e^3\gamma^2-9e^3\gamma^3)+d_s^{AO}(-8-30e^2+27e^4+8e^2\gamma-45e^4\gamma-10e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3)$$
$$+d_s^{BO}(-12e^2+27e^4+20e^2\gamma-45e^4\gamma-8e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3)+d_s^{AB}(8-30e^2+27e^4+32e^2\gamma-45e^4\gamma-18e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3)$$
$$+(-16+36e^2+12e^2\gamma^2)p_A^s+(-24e+54e^3+16e\gamma-36e^3\gamma-18e^3\gamma^2)p_A^b+(8-18e^2-36e^2\gamma+6e^2\gamma^2)p_B^s$$
$$+(12e-27e^3-20e\gamma-9e^3\gamma+27e^3\gamma^2+9e^3\gamma^3)p_B^b+(8-18e^2+36e^2\gamma-18e^2\gamma^2)p_O^s$$
$$+(12e-27e^3+4e\gamma+45e^3\gamma-9e^3\gamma^2-9e^3\gamma^3)p_O^b+(-12e+27e^3+20e\gamma+9e^3\gamma-27e^3\gamma^2-9e^3\gamma^3)s]$$

$$q_B^b = \frac{1}{(-2+3e+e\gamma)(2+3e+e\gamma)(-2-3e+3e\gamma)(2-3e+3e\gamma)}[d_b^{BO}(8-30e^2+27e^4+8e^2\gamma-45e^4\gamma-10e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3)+d_b^{AO}(-12e^2$$
$$+d_b^{AB}(8-30e^2+27e^4+32e^2\gamma-45e^4\gamma-18e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3)+d_s^{AO}(-8e+18e^3+8e\gamma-18e^3\gamma+6e^3\gamma^2-6e^3\gamma^3)$$
$$+d_s^{BO}(4e-9e^3-4e\gamma-9e^3\gamma+21e^3\gamma^2-3e^3\gamma^3)+d_s^{AB}(8-30e^2+27e^4+32e^2\gamma-45e^4\gamma-18e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3)$$
$$+(12e-27e^3-20e\gamma-9e^3\gamma+27e^3\gamma^2+9e^3\gamma^3)p_A^s+(8-18e^2-36e^2\gamma+6e^2\gamma^2)p_A^b+(-24e+54e^3+16e\gamma-36e^3\gamma-18e^3\gamma^2)p_B^s$$
$$+(-16+36e^2+12e^2\gamma^2)p_B^b+(12e-27e^3+4e\gamma+45e^3\gamma-9e^3\gamma^2-9e^3\gamma^3)p_O^s$$
$$+(8-18e^2+36e^2\gamma-18e^2\gamma^2)p_O^b+(16-36e^2-12e^2\gamma^2)s]$$

$$q_B^s = \frac{1}{(-2+3e+e\gamma)(2+3e+e\gamma)(-2-3e+3e\gamma)(2-3e+3e\gamma)}[d_s^{BO}(8-30e^2+27e^4+8e^2\gamma-45e^4\gamma-10e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3)+d_s^{AO}(-12e^2$$
$$+d_s^{AB}(8-30e^2+27e^4+32e^2\gamma-45e^4\gamma-18e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3)+d_b^{AO}(-8e+18e^3+8e\gamma-18e^3\gamma+6e^3\gamma^2-6e^3\gamma^3)$$
$$+d_b^{BO}(4e-9e^3-4e\gamma-9e^3\gamma+21e^3\gamma^2-3e^3\gamma^3)+d_b^{AB}(8-30e^2+27e^4+32e^2\gamma-45e^4\gamma-18e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3)$$
$$+(12e-27e^3-20e\gamma-9e^3\gamma+27e^3\gamma^2+9e^3\gamma^3)p_A^b+(8-18e^2-36e^2\gamma+6e^2\gamma^2)p_A^s+(-24e+54e^3+16e\gamma-36e^3\gamma-18e^3\gamma^2)p_B^b$$
$$+(-16+36e^2+12e^2\gamma^2)p_B^s+(12e-27e^3+4e\gamma+45e^3\gamma-9e^3\gamma^2-9e^3\gamma^3)p_O^b$$
$$+(8-18e^2+36e^2\gamma-18e^2\gamma^2)p_O^s+(24e-54e^3-16e\gamma+36e^3\gamma+18e^3\gamma^2)s]$$

$$q_O^b = \frac{1}{(-2+3e+e\gamma)(2+3e+e\gamma)}[d_b^{BO}(-e+e\gamma)+d_b^{AO}(-e+e\gamma)+d_b^{AB}(2e+2e\gamma)+d_s^{AO}(-2+3e^2+4e^2\gamma+e^2\gamma^2)$$
$$+d_s^{BO}(-2+3e^2+4e^2\gamma+e^2\gamma^2)+d_s^{AB}(3e^2+4e^2\gamma+e^2\gamma^2)+(-2)p_A^s+(-3e-e\gamma)p_A^b+(-2)p_B^s+(-3e-e\gamma)p_B^b+4p_O^s$$
$$+(6e+2e\gamma)p_O^b+(3e+e\gamma)s]$$

$$q_O^s = \frac{1}{(-2+3e+e\gamma)(2+3e+e\gamma)}[d_s^{BO}(-e+e\gamma)+d_s^{AO}(-e+e\gamma)+d_s^{AB}(2e+2e\gamma)+d_b^{AO}(-2+3e^2+4e^2\gamma+e^2\gamma^2)$$
$$+d_b^{BO}(-2+3e^2+4e^2\gamma+e^2\gamma^2)+d_b^{AB}(3e^2+4e^2\gamma+e^2\gamma^2)+(-2)p_A^b+(-3e-e\gamma)p_A^s+(-2)p_B^b+(-3e-e\gamma)p_B^s+4p_O^b$$
$$+(6e+2e\gamma)p_O^s+2s]$$

A.8. Proof of Proposition 4.2

The profit of the intermediary that owns both platform A and platform B equals:

$$\pi_p(p_A^b,p_B^b,p_A^s,p_B^s,p_O^b,p_O^s) = p_A^b * q_A^b(p_A^b,p_B^b,p_A^s,p_B^s,p_O^b,p_O^s)+p_B^b * q_B^b(p_A^b,p_B^b,p_A^s,p_B^s,p_O^b,p_O^s)$$
$$+p_A^s * q_A^s(p_A^b,p_B^b,p_A^s,p_B^s,p_O^b,p_O^s)+p_B^s * q_B^s(p_A^b,p_B^b,p_A^s,p_B^s,p_O^b,p_O^s)$$

The profit of the competitive fringe that owns platform O equals:

$$\pi_O(p^b_A, p^b_B, p^s_A, p^s_B, p^b_O, p^s_O) = p^b_O * q^b_O(p^b_A, p^b_B, p^s_A, p^s_B, p^b_O, p^s_O) + p^s_O * q^s_O(p^b_A, p^b_B, p^s_A, p^s_B, p^b_O, p^s_O)$$

Both the intermediary and the competitive fringe maximize their profit by choosing the seller fee and buyer fee on its platform(s). Consequently, we are able to derive first-order conditions as follows:

$$
\begin{aligned}
p_A^{b*} = &-\frac{1}{8(-4+9e^2+3e^2\gamma^2)}[d_s^{BO}(-8e+18e^3+8e\gamma-18e^3\gamma+6e^3\gamma^2-6e^3\gamma^3) \\
&+d_s^{AO}(4e-9e^3-4e\gamma-9e^3\gamma+21e^3\gamma^2-3e^3\gamma^3)+d_s^{AB}(4e-9e^3+4e\gamma+9e^3\gamma+9e^3\gamma^2-9e^3\gamma^3) \\
&+d_b^{AO}(8-30e^2+27e^4+8e^2\gamma-45e^4\gamma-10e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3) \\
&+d_b^{BO}(-12e^2+27e^4+20e^2\gamma-45e^4\gamma-8e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3) \\
&+d_b^{AB}(8-30e^2+27e^4+32e^2\gamma-45e^4\gamma-18e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3) \\
&+(-48e+108e^3+32e\gamma-72e^3\gamma-36e^3\gamma^2)p_A^s+(16-36e^2-72e^2\gamma+12e^2\gamma^2)p_B^b \\
&+(24e-54e^3-40e\gamma-18e^3\gamma+54e^3\gamma^2+18e^3\gamma^3)p_B^s+(8-18e^2+36e^2\gamma-18e^2\gamma^2)p_O^b \\
&+(12e-27e^3+4e\gamma+45e^3\gamma-9e^3\gamma^2-9e^3\gamma^3)p_O^s+(-8+18e^2+36e^2\gamma-6e^2\gamma^2)s] \\
p_A^{s*} = &-\frac{1}{8(-4+9e^2+3e^2\gamma^2)}[d_b^{BO}(-8e+18e^3+8e\gamma-18e^3\gamma+6e^3\gamma^2-6e^3\gamma^3) \\
&+d_b^{AO}(4e-9e^3-4e\gamma-9e^3\gamma+21e^3\gamma^2-3e^3\gamma^3) \\
&+d_b^{AB}(4e-9e^3+4e\gamma+9e^3\gamma+9e^3\gamma^2-9e^3\gamma^3)+d_s^{AO}(8-30e^2+27e^4+8e^2\gamma-45e^4\gamma-10e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3) \\
&+d_s^{BO}(-12e^2+27e^4+20e^2\gamma-45e^4\gamma-8e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3) \\
&+d_s^{AB}(8-30e^2+27e^4+32e^2\gamma-45e^4\gamma-18e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3) \\
&+(-48e+108e^3+32e\gamma-72e^3\gamma-36e^3\gamma^2)p_A^b+(16-36e^2-72e^2\gamma+12e^2\gamma^2)p_B^s \\
&+(24e-54e^3-40e\gamma-18e^3\gamma+54e^3\gamma^2+18e^3\gamma^3)p_B^b+(8-18e^2+36e^2\gamma-18e^2\gamma^2)p_O^s \\
&+(12e-27e^3+4e\gamma+45e^3\gamma-9e^3\gamma^2-9e^3\gamma^3)p_O^b+(-12e+27e^3+20e\gamma+9e^3\gamma-27e^3\gamma^2-9e^3\gamma^3)s] \\
p_B^{b*} = &-\frac{1}{8(-4+9e^2+3e^2\gamma^2)}[d_s^{AO}(-8e+18e^3+8e\gamma-18e^3\gamma+6e^3\gamma^2-6e^3\gamma^3) \\
&+d_s^{BO}(4e-9e^3-4e\gamma-9e^3\gamma+21e^3\gamma^2-3e^3\gamma^3) \\
&+d_s^{AB}(4e-9e^3+4e\gamma+9e^3\gamma+9e^3\gamma^2-9e^3\gamma^3)+d_b^{BO}(8-30e^2+27e^4+8e^2\gamma-45e^4\gamma-10e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3) \\
&+d_b^{AO}(-12e^2+27e^4+20e^2\gamma-45e^4\gamma-8e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3) \\
&+d_b^{AB}(8-30e^2+27e^4+32e^2\gamma-45e^4\gamma-18e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3) \\
&+(-48e+108e^3+32e\gamma-72e^3\gamma-36e^3\gamma^2)p_B^s+(16-36e^2-72e^2\gamma+12e^2\gamma^2)p_A^b \\
&+(24e-54e^3-40e\gamma-18e^3\gamma+54e^3\gamma^2+18e^3\gamma^3)p_A^s+(8-18e^2+36e^2\gamma-18e^2\gamma^2)p_O^b \\
&+(12e-27e^3+4e\gamma+45e^3\gamma-9e^3\gamma^2-9e^3\gamma^3)p_O^s+(16-36e^2-12e^2\gamma^2)s] \\
p_B^{s*} = &-\frac{1}{8(-4+9e^2+3e^2\gamma^2)}[d_b^{AO}(-8e+18e^3+8e\gamma-18e^3\gamma+6e^3\gamma^2-6e^3\gamma^3) \\
&+d_b^{BO}(4e-9e^3-4e\gamma-9e^3\gamma+21e^3\gamma^2-3e^3\gamma^3) \\
&+d_b^{AB}(4e-9e^3+4e\gamma+9e^3\gamma+9e^3\gamma^2-9e^3\gamma^3)+d_s^{BO}(8-30e^2+27e^4+8e^2\gamma-45e^4\gamma-10e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3) \\
&+d_s^{AO}(-12e^2+27e^4+20e^2\gamma-45e^4\gamma-8e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3) \\
&+d_s^{AB}(8-30e^2+27e^4+32e^2\gamma-45e^4\gamma-18e^2\gamma^2+9e^4\gamma^2+9e^4\gamma^3) \\
&+(-48e+108e^3+32e\gamma-72e^3\gamma-36e^3\gamma^2)p_B^b+(16-36e^2-72e^2\gamma+12e^2\gamma^2)p_A^s \\
&+(24e-54e^3-40e\gamma-18e^3\gamma+54e^3\gamma^2+18e^3\gamma^3)p_A^b+(8-18e^2+36e^2\gamma-18e^2\gamma^2)p_O^s \\
&+(12e-27e^3+4e\gamma+45e^3\gamma-9e^3\gamma^2-9e^3\gamma^3)p_O^b+(24e-54e^3-16e\gamma+36e^3\gamma+18e^3\gamma^2)s] \\
p_O^{b*} = &\frac{-2e-2e\gamma}{8}d_s^{AB}+\frac{e-e\gamma}{8}d_s^{AO}+\frac{e-e\gamma}{8}d_s^{BO}+\frac{-3e^2-4e^2\gamma-e^2\gamma^2}{8}d_b^{AB}+\frac{2-3e^2-4e^2\gamma-e^2\gamma^2}{8}d_b^{AO} \\
&+\frac{2-3e^2-4e^2\gamma-e^2\gamma^2}{8}d_b^{BO}+\frac{p_A^b}{4}+\frac{3e+e\gamma}{8}p_A^s+\frac{p_B^b}{4}+\frac{3e+e\gamma}{8}p_B^s+\frac{-12e-4e\gamma}{8}p_O^s-\frac{s}{4} \\
p_O^{s*} = &\frac{-2e-2e\gamma}{8}d_b^{AB}+\frac{e-e\gamma}{8}d_b^{AO}+\frac{e-e\gamma}{8}d_b^{BO}+\frac{-3e^2-4e^2\gamma-e^2\gamma^2}{8}d_s^{AB}+\frac{2-3e^2-4e^2\gamma-e^2\gamma^2}{8}d_s^{AO} \\
&+\frac{2-3e^2-4e^2\gamma-e^2\gamma^2}{8}d_s^{BO}+\frac{p_A^s}{4}+\frac{3e+e\gamma}{8}p_A^b+\frac{p_B^s}{4}+\frac{3e+e\gamma}{8}p_B^b+\frac{-12e-4e\gamma}{8}p_O^s-\frac{(-3e-e\gamma)s}{8}
\end{aligned}
$$

Solving the first order conditions, we yield the optimal member fees as listed in Prosposition 4.2.

A.9. Proof of Corollary 1

In order to investigate how the introduction of the new tech platform B changes the number of users on the intermediary in the monopolistic market, we first caculate the change of quantity Δq_b and Δq_s. Specifically, Δq_g equals the number of users q_2^g in scenario 2 on side $g\{b,s\}$ minus the number of users q_1^g in scenario 1 on side $g\{b,s\}$. Consequently, we derive that

$$\Delta q_b = \frac{d(2+e(-5+3\gamma))}{4(-1+e)(-2+e+e\gamma)} + \frac{-4(-1+e)s}{4(-1+e)(-4+e^2(1+\gamma)^2)}$$

$$\Delta q_S = \frac{d(2+e(-5+3\gamma))}{4(-1+e)(-2+e+e\gamma)} + \frac{-2(-1+e)e(1+\gamma)s}{4(-1+e)(-4+e^2(1+\gamma)^2)}$$

Under Assumption 1, we could easily seen that both Δq_b and Δq_s are linear increasing in the tech surplus s generated by the new platform. In addition, we find their value at $s=0$ to be negative only when $e > \frac{2}{5-3\gamma}$. This indicates that only when $e > \frac{2}{5-3\gamma}$ there exists some $\hat{s_q^g} > 0$ on side $g \in \{b,g\}$ such that when $s > \hat{s_q^g}$ on on side $g \in \{b,g\}$, there are more users of the intermediary on the side $g \in \{b,g\}$ after the introduction of tech platform B. Otherwise, it is the opposite. However, when $e < \frac{2}{5-3\gamma}$, the introduction of new tech platform always attracts more user to the platform.

A.10. Proof of Corollary 3

To investigate the change of consumer surplus due to the introduction of tech platform in the two-sided market, we first calculate the change in the consumer surplus ΔCS, which equals to the consumer surplus after introducing the tech platform minus the consumer surplus before introducing the tech platform. Specifically, we get

$$\begin{aligned}\Delta CS = &\frac{d^2(-4+28e-21e^2+6e^3-12e\gamma-18e^2\gamma+12e^3\gamma+3e^2\gamma^2+6e^3\gamma^2)}{8(-1+e)(-2+e+e\gamma)^2}\\ &+\frac{2ds}{(-2+e+e\gamma)^2(2+e+e\gamma)}\\ &+\frac{2(16-24e^2(1-\gamma+\gamma^2)+3e^4(7-26\gamma+42\gamma^2-26\gamma^3+7\gamma^4))s^2}{(-2+e+e\gamma)^2(2+e+e\gamma)^2(-2-3e+3e\gamma)^2(2-3e+3e\gamma)^2}\end{aligned} \tag{64}$$

Under Assumption 1, we can proof that ΔCS is increasing in s. Specifically, we can easily find that the parameter of s is positive. For the parmameter of s^2, its denominator is also positive. Consequently, the sign of $\frac{2(16-24e^2(1-\gamma+\gamma^2)+3e^4(7-26\gamma+42\gamma^2-26\gamma^3+7\gamma^4))}{(-2+e+e\gamma)^2(2+e+e\gamma)^2(-2-3e+3e\gamma)^2(2-3e+3e\gamma)^2}$ is determined by the function $16-24e^2(1-\gamma+\gamma^2)+3e^4(7-26\gamma+42\gamma^2-26\gamma^3+7\gamma^4)$. Under Assumption 1, we have

$$\begin{aligned}&16-24e^2(1-\gamma+\gamma^2)+3e^4(7-26\gamma+42\gamma^2-26\gamma^3+7\gamma^4)\\ &\geq 16-24e^2+3e^4[7+\gamma^2(42-26\gamma)-\gamma(26-7\gamma^3)]\\ &\geq 16-24e^2+3e^4[7-26] \geq 16-\frac{24}{4}-\frac{57}{8}>0\end{aligned} \tag{65}$$

Since ΔCS is increasing in s, we then need to check the value of ΔCS when s equals zero. Specifically, we find that the sign of ΔCS at $s=0$ is the opposite to the square function $-4+28e-21e^2+6e^3-12e\gamma-18e^2\gamma+12e^3\gamma+3e^2\gamma^2+6e^3\gamma^2$ of γ. According to the function form, the square function is decreasing in γ under Assumption 1. In addition, we find its value at $\gamma=0$ is increasing in e. Since the function $-4+28e-21e^2+6e^3$ is positive when $e=\frac{2}{3}$ while negative when $e=0$. There must exist some there exists some $e_{cs} \in (0, \frac{1}{2})$ such that the value of ΔCS at $s=0$ and $\gamma=0$ is positive when $e < e_{cs}$. Otherwise, there exist some $\gamma_{cs} \in (0,1)$ such that the value of ΔCS at $s = 0$ is negative when $\gamma < \gamma_{cs}$, while the value of ΔCS at $s = 0$ is positive when $\gamma > \gamma_{cs}$. In summary, ΔCS is always positive when $e < e_{cs}$. If $e > e_{cs}$, there exist some $\gamma_{cs} \in (0,1)$ such that ΔCS is still always positive when $\gamma > \gamma_{cs}$. Otherwise, there exists some $s_{cs} > 0$ such that the introduction of the new tech platform always increases the consumer surplus in the market when $s > s_{cs}$, while reduces the consumer surplus when $s < s_{cs}$

A.11. Proof of Corollary 4

To investigate the change of producer surplus due to the introduction of tech platform in the monopolistic market, we first calculate the change in the producer surplus ΔPS, which equals to the producer surplus after introducing the tech platform minus the producer surplus before introducing the tech platform. Specifically, we get

$$\begin{aligned}\Delta PS = &\frac{d^2(20-52e+101e^2-72e^3+12e^4-84e\gamma+138e^2\gamma-96e^3\gamma+24e^4\gamma+21e^2\gamma^2-24e^3\gamma^2+12e^4\gamma^2)}{-32(-1+e)^2(-2+e+e\gamma)^2}\\ &+\frac{de(1+\gamma)s}{(-2+e+e\gamma)^2(2+e+e\gamma)}\\ &+\frac{e^2(-72e^2(-1+\gamma^2)^2+27e^4(-1+\gamma^2)^2(1-\gamma+\gamma^2)+16(7-13\gamma+7\gamma^2))s^2}{2(4-9e^2(-1+\gamma)^2)^2(-4+e^2(1+\gamma)^2)^2}\end{aligned} \tag{66}$$

Under Assumption 1, we can proof that ΔPS is increasing in s. Specifically, we can easily find that the parameter of s is positive. For the parmameter of s^2, its denominator is also positive. Consequently, the parameter sign of s^2 is the opposite to the function $-72e^2(-1+\gamma^2)^2+27e^4(-1+\gamma^2)^2(1-\gamma+\gamma^2)+16(7-13\gamma+7\gamma^2)$. Specifically, we find this function to be convex function in e^2 which is decreasing in e^2 first then increasing. Under Assumption 1, we can easily prove that the minimum value of $-72e^2(-1+\gamma^2)^2+27e^4(-1+\gamma^2)^2(1-\gamma+\gamma^2)+16(7-13\gamma+7\gamma^2)$ is always positive. Since ΔPS is increasing in s, we then need to check the value of ΔPS when s equals zero. Specifically, we find that the sign of $d^M PS$ at $s = 0$ is the opposite to the square function $20-52e+101e^2-72e^3+12e^4-84e\gamma+138e^2\gamma-96e^3\gamma+24e^4\gamma+21e^2\gamma^2-24e^3\gamma^2+12e^4\gamma^2$ of γ. According to the function form, the square function is decreasing in γ under Assumption 1. Specifically, its value at $\gamma = 0$ is always positive. In addition, we find its value at $\gamma = 1$ equals $d^2(5-24e+12e^2)$ which is decreasing in $e \in \{0,1\}$. Since the function $d^2(5-24e+12e^2)$ is positive when $e = 0$ while negative when $e = \frac{2}{3}$. There must exist some $e^p_{ps} \in (0, \frac{2}{3})$ such that the value of ΔPS at $s = 0$ and $\gamma = 1$ is positive when $e > e_{ps}$. In other words, when $e > e_{ps}$, there exist some $\gamma_{ps} \in (0,1)$ such that the value of ΔPS at $s = 0$ is negative when $\gamma < \gamma_{ps}$, while the value of ΔPS at $s = 0$ is positive when $\gamma > \gamma_{ps}$. Otherwise, the value of ΔPS at $s = 0$ is always negative. In summary, the introduction of new tech platform influences the producer surplus in the two-sided market as follows. When $e > e_{ps}$, there exist some $\gamma_{ps} \in (0,1)$ such that ΔPS is still always positive when $\gamma > \gamma_{ps}$. Otherwise, there exists some $s_{ps} > 0$ such that the introduction of the new tech platform always increases the consumer surplus in the market when $s > s_{ps}$, while reduces the consumer surplus when $s < s_{ps}$.

A.12. Proof of Corollary 5

In order to investigate how the removal of the conventional platform A changes the number of users on the intermediary in the two-sided market, we first caculate the change of quantity $\Delta q'_b$ and $\Delta q'_s$. Specifically, $\Delta q'_g$ equals the number of users q^g_3 in scenario 3 on side $g\{b,s\}$ minus the number of users q^g_2

in scenario 2 on side $g\{b,s\}$. Consequently, we derive that

$$\Delta q_b' = \frac{d(2-5e+3e\gamma)}{4(1-e)(-2+e+e\gamma)} - \frac{-2-e^2+2e^2\gamma+e^2\gamma^2 s}{2(-1+e)(1+e)(-2+e+e\gamma)(2+e+e\gamma)}$$

$$\Delta q_S' = \frac{d(2-5e+3e\gamma)}{4(1-e)(-2+e+e\gamma)} - \frac{e(-3+\gamma+e^2\gamma+e^2\gamma^2)s}{2(-1+e)(1+e)(-2+e+e\gamma)(2+e+e\gamma)}$$

Under Assumption 1, we could easily seen that both $\Delta q_b'$ and $\Delta q_s'$ are linear increasing in the tech surplus s generated by the new platform. In addition, we find their value at $s=0$ to be negative only when $e < \frac{2}{5-3\gamma}$. This indicates that only when $e < \frac{2}{5-3\gamma}$ there exists some $\hat{s_q}^g > 0$ on side $g \in \{b,g\}$ such that when $s > \tilde{\tilde{s}}_q^g$ on on side $g \in \{b,g\}$, there are more users of the intermediary on the side $g \in \{b,g\}$ after removing platform A. Otherwise, it is the opposite. When $e > \frac{2}{5-3\gamma}$, removing the traditional tech platform always attracts more user to the platform.

A.13. Proof of Corollary 6

To investigate the profit change when the conventional platform is completely removed, we calculate the change in the intermediary's profit $\Delta\pi'$, which equals to the profit after removing the traditional platform minus the profit before removing the conventional platform. In the non-compatible market, we get

$$\Delta\pi' = \frac{d^2(112-16e-472e^2-56e^3+495e^4+207e^5)}{8(-2+e)(-1+e)(1+e)(2+e)(-2+3e)(2+3e)} + \frac{d(-32-64e+32e^2+136e^3+90e^4+18e^5)s}{8(-2+e)(-1+e)(1+e)(2+e)(-2+3e)(2+3e)} + \frac{(24e^2+6e^4)s^2}{8(-2+e)(-1+e)(1+e)(2+e)(-2+3e)(2+3e)}$$

We first find that the function of $d^{AB}\pi'$ is concave in s. In addition, there exist some $s'>0$ such that $d^{AB}\pi'$ is increasing in s when $s \in [0, s']$ and it is decreasing in s when $s > s'$. We also find the maximum value of $d^{AB}\pi'$ at s' is positive. Then we investigate the value of $d^{AB}\pi'$ when s equals zero. Consequently, we find that $d^{AB}\pi'$ is postive at zero when $e > \frac{14}{23}$. Otherwise, $d^{AB}\pi'$ is non-positive when the tech surplus is zero.

Consequently, If platform A and platform B are not compatible and nework $e \leq \frac{14}{23}$, then there must exist some $\tilde{\tilde{s}}_{pi}^n > \tilde{s}_{pi}^n \geq 0$ such that the removing platform a is more profitable when $s \in [\tilde{\tilde{s}}_{pi}^n, \tilde{s}_{pi}^n]$. Otherwise, it is more profitable to keep both platform A and platform B. However, if nework $e > \frac{14}{23}$, then there must exist some $s_{pi}^n > 0$ such that the removing platform a is more profitable when $s < s_{pi}^n$. Otherwise, it is more profitable to keep both platform A and platform B.

In the full-compatible market, we get

$$\Delta\pi_F' = -\frac{3e^2s^2}{16(1-e)(1+e)} - \frac{d(4+4e)s}{16(1-e)(1+e)} - \frac{d^2(-14-14e)}{16(-1+e)(1+e)}$$

Clearly, the change of profit $\Delta\pi_F'$ is increasing in the tech surplus s and has a negative value when s equals zero. Consequently, there must exist some $0 < s^f < 1$ such that when $0 < s < s^f$, keeping the conventional platform is more profitable in the full-compatible market. Otherwise, it is the opposite.

A.14. Proof of Corollary 7

To investigate the change of consumer surplus due to the introduction of tech platform in the two-sided market, we first calculate the change in the consumer surplus ΔCS^n in the non-compatible case, which equals to the consumer surplus after introducing the tech platform minus the consumer surplus before introducing the tech platform. Specifically, we get

$$\Delta CS^n = \frac{d^2e(2+e)}{2(-4+e^2)} + \frac{d(44-2e-116e^2+27e^4)s}{(-2+e)(2+e)(-2+3e)(2+3e)} + \frac{(-80+324e^2-396e^4+81e^6)s^2}{-2(-2+e)(2+e)(-2+3e)^2(2+3e)^2} \tag{67}$$

According to the above function, we can easily find that ΔCS^n is a concave function with respect to s. Since the function $44-2e-116e^2+27e^4$ is strictly decreasing in $[0, \frac{2}{3}]$ and its value at $e=0$ is postive while at $e=\frac{2}{3}$ is negative, there must exist some $e_{cs} \in \{0, \frac{2}{3}\}$ such that ΔCS^n is first increasing in s then becomes decrasing in s when $e < e_{ps}$. Otherwise, $d^N CS$ is strictly decreasing in s. Since the value of ΔCS^n when $s=0$ is negative, ΔCS^n is always negative if $e > e_{ps}$. When $e < e_{ps}$, we need to check the maximum value of ΔCS^n. Specifically, its maximum value at $\frac{d(-4+9e^2)(44-2e-116e^2+27e^4)}{-80+324e^2-396e^4+81e^6}$ equals $\frac{d^2(-2+3e)(-484-642e+1608e^2+2134e^3-838e^4-1032e^5+117e^6+135e^7)}{(-4+e^2)(-80+324e^2-396e^4+81e^6)}$. Since its value at $e=0$ is positive while its value at $e=e_{ps}$ is negative, there must exist some $e'_{cs} \in \{0, e_{ps}\}$ such that the maximum value of ΔCS^n is positive when $e < e'_{cs}$. Consequently, we could conclude that if $e < e'_{cs}$ there exist some $0 < s_{cs} < s'_{cs}$ such that removing platform A increases consumer surplus when $s \in (s_{cs}, s'_{cs})$. Otherwise, removing platform A always decreases consumer surplus in the non-compatible market.

When platform A and platform B are fully compatible, we follow the same steps and derive the the producer surplus ΔCS^n in the non-compatible case, which equals to the consumer surplus after introducing the tech platform minus the consumer surplus before introducing the tech platform. Specifically, we get

$$\Delta CS^f = \frac{3d^2(-2+e)e(1+e)^2}{8(-1+e^2)^2} + \frac{d(44-48e-47e^2+48e^3)s}{16(-1+e)^2(1+e)} + \frac{(-80+152e^2-75e^4)s^2}{128(-1+e^2)^2} \tag{68}$$

According to the above function, we can easily find that ΔCS^f is a concave function with respect to s. Since the function $44-48e-47e^2+48e^3$ is first decreasing than increasing in e and its value at $e=0$ is postive while at $e=\frac{2}{3}$ is negative, there must exist some $e^f_{cs} \in \{0, \frac{2}{3}\}$ such that ΔCS^f is first increasing in s then becomes decrasing in s when $e < e^f_{ps}$. Otherwise, ΔCS^f is strictly decreasing in s. Since the value of ΔCS^f when $s=0$ is negative, ΔCS^f is always negative if $e > e_{ps}$. When $e < e^f_{ps}$, we need to check the maximum value of $d^F CS$. Specifically, its maximum value at $\frac{4d(1+e)(44-48e-47e^2+48e^3)}{80-152e^2+75e^4}$ equals $\frac{(d^2(1936-832e-5192e^2+96e^3+2529e^4))}{(8(80-152e^2+75e^4))}$. Since its value at $e=0$ is positive while its value at $e=e_{ps}$ is negative, there must exist some $\hat{e^f_{cs}} \in \{0, e^f_{ps}\}$ such that the maximum value of ΔCS^f is positive when $e < \hat{e^f_{cs}}$. Consequently, we could conclude that if $e < \hat{e^f_{cs}}$ there exist some $0 < s^f_{cs} < s^{f'}_{cs}$ such that removing platform A increases consumer surplus when $s \in (s^f_{cs}, s^{f'}_{cs})$. Otherwise, removing platform A always decreases consumer surplus in the non-compatible market.

A.15. Proof of Corollary 8

To investigate the change of producer surplus due to the introduction of tech platform in the monopolistic market, we first calculate the change in the producer surplus ΔPS in the non-compatible case, which equals to the producer surplus after introducing the tech platform minus the producer surplus before introducing the tech platform. Specifically, we get

$$\begin{aligned}\Delta PS = & \frac{d^2 e(2+e)}{2(-4+e^2)} + \frac{de(-2+3e)(2+3e)(-8-6e+3e^2)s}{2(4-9e^2)^2(-4+e^2)} \\ & + \frac{3e^2(4-3e^2)s^2}{(4-9e^2)^2(-4+e^2)}\end{aligned} \tag{69}$$

According to the above function, we find that ΔPS is strictly decreasing in s when $s > 0$. Since its value when $s = 0$ is negative, we can conclude ΔPS is always negative thus removing the traditional surplus always reduces producer surplus in the two sided marekt.

When platform A and platform B are fully compatible, we follow the same steps and derive the the producer surplus ΔPS^f in the non-compatible case, which equals to the producer surplus after introducing the tech platform minus the producer surplus before introducing the tech platform. Specifically, we get

$$\begin{aligned}\Delta PS^f = & \frac{3d^2(-2+e)e(1+e)^2}{8(-1+e^2)^2} + \frac{3de(-2-2e+e^2+e^3)s}{16(-1+e^2)^2} \\ & + \frac{3e^4(-4+3e^2)s^2}{128(-1+e^2)^2}\end{aligned} \tag{70}$$

According to the above function, we find that ΔPS^f is strictly decreasing in s when $s > 0$. Since its value when $s = 0$ is negative, we can conclude ΔPS^f is always negative thus removing the traditional surplus always reduces producer surplus in the two sided marekt.

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