Platform Competition under Asymmetric Information

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Abstract

In the context of platform competition in a two-sided market, we study how ex-ante uncertainty and ex-post asymmetric information concerning the value of a new technology affects the strategies of the platforms and the market outcome. We find that the incumbent dominates the market by setting the welfare-maximizing level of trade when the difference in the degree of asymmetric information between buyers and sellers is significant. However, if this difference is below a certain threshold, then even the incumbent platform will distort the trade downward. Since a monopoly incumbent would set the welfare-maximizing level of trade, this result indicates that platform competition may lead to a market failure: Competition results in a lower level of trade and lower welfare than a monopoly. We also consider multi-homing. We find that multi-homing solves the market failure resulting from asymmetric information. However, if platforms can impose exclusive dealing, then they will do so, which results in market inefficiency.

Keywords: asymmetric information, platform competition, exclusive dealing

JEL: L15, L41

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1 Introduction

When platforms adopt new technologies, the users often do not know how much utility they will obtain from a new technology until they join the platform. However, they can privately learn this utility afterward. A new generation of operating systems for smartphones, such as Apple's iOS or Google's Android, creates uncertainty among agents on both sides of the market. Application developers may not know the costs of developing an application for this new generation. Likewise, users may not know their utility from using the new software. After developers and users join the platform, they privately learn their respective costs and using habits, and thus, uncertainty is replaced with asymmetric information. Similar examples abound. Gamers and third-part videogame developers may privately lean their utility and cost from using a new technology for a videogame console — such as Microsoft's Xbox, Sony's PlayStation or Nintendo's Wii — but only after they adopt it.

This paper considers platform competition in a two-sided market when agents on both sides of the market face the above informational problem: they are ex-ante uninformed about their valuations from joining a platform and are ex-post privately informed. In this context we ask several questions. First, we ask how the informational problem affects profits, prices, and market efficiency. We find that asymmetric information may lead to a downward distortion of trade under competition, while under monopoly full efficiency is achieved. Second, previous literature has shown that platforms use a divide-and-conquer strategy by subsidizing one side of the market in order to attract it. This raises the question of how the informational problem affects the decision which side to subsidize. We show that it is optimal for a monopoly platform to subsidize the side with the smaller information problem. Under competition, the decision which side to subsidize is also affected by asymmetric information, though the relation is not as straightforward. Given the results for the competition between platforms, we study the extension to multi-homing. In multi-homing environment agents are allowed to register to both competing platforms simultaneously. We ask whether platforms benefit from multi-homing or have an incentive to restrict the agents' ability to multi-home by imposing exclusive dealing. We find that the incumbent dominates the market and earns higher profit under multi-homing than under single-homing. Moreover, multi-homing solves the market failure resulting from asymmetric information in that the incumbent can always induce the efficient level of trade. However, if platforms can impose exclusive dealing, they will do so, resulting in an inefficiently low level of trade.

We study competition between two platforms in a two-sided market that is composed of buyers and sellers. The platforms are undifferentiated except for the beliefs they are facing. One of the platforms is an incumbent that benefits from agents' favorable beliefs. Under favorable beliefs, agents expect all other agents to join the incumbent unless it is a dominant strategy for them not to join the platform. The favorable beliefs that the incumbent enjoys make it difficult for the second platform, the entrant, to gain market share. The two platforms implement a new technology, such as a new generation of video game consoles or operating systems. All players are ex-ante uninformed about the buyers' valuation and sellers' costs from using the new technology. Buyers and sellers privately learn this information after joining a platform but before they trade. They can only trade through a platform. Notice that one of the main features of our model is that agents are ex-ante uninformed and are therefore ex-ante identical. We discuss this feature in the conclusion.

We assume that the two platforms compete by offering fixed access fees as well as menus of quantities and transaction fees as a function of buyers' valuation parameter and sellers' costs. Buyers and sellers then choose which platform to join and pay the relevant access fees. Once they join the platform, they privately observe their valuation and cost, and choose a line from the menu. Given their choices, they trade for the specified quantity.

Before studying competition, we first consider a monopoly benchmark. We find that a monopolist who benefits from favorable beliefs sets a contract which motivates the sellers and buyers to trade the quantity that maximizes total social welfare (i.e., maximizes the gains from trade). A monopolist that suffers from unfavorable beliefs, however, sets a contract that distorts the quantity below the welfare-maximizing level. Moreover, the monopolist facing unfavorable beliefs charges zero access fees from the side with the lowest informational problem. Intuitively, both monopoly platforms need to pay ex-post information rents to the buyers and sellers for motivating them to reveal their private information after they joined the platform. A monopolist that benefits from favorable beliefs can ex-ante capture these expected information rents through access fees. In contrast, a monopolist that faces unfavorable beliefs needs to subsidize one side of the market in order to attract it and therefore cannot extract the expected information rents from both sides. Thus, such a monopolist has an incentive to distort the quantity downward in order to reduce the information rents.

We then consider competition between the incumbent and the entrant, facing favorable and unfavorable beliefs respectively. Under competition, we find that the incumbent dominates the market by setting the welfare-maximizing quantity — i.e., the same as under

monopoly — only if the difference in the degree of asymmetric information between buyers and sellers is significant. However, if this difference is below a certain threshold, then even the incumbent platform will distort its quantity downward. Since a monopolist benefiting from favorable beliefs always sets the welfare-maximizing quantity, this result indicates that platform competition might result in a market failure: Competition results in a lower quantity and lower welfare than monopoly.[1] In this case, competition also leads the two platforms to subsidize opposite sides in their divide-and-conquer strategies.

We also examine how the market outcome is affected by the sellers' ability to multi-home (i.e., join both platforms). A developer of a smartphone's application, for example, might choose to develop an application for more than one operating system. Likewise, a videogame developer might choose to develop a videogame for more than one videogame console. We find that the incumbent dominates the market and earns a higher profit under multi-homing than under single-homing. Multi-homing solves the market failure resulting from asymmetric information in that the incumbent can motivate the two sides to trade for the welfare-maximizing quantity even if the difference in the degree of asymmetric information between the two sides is small. However, if the incumbent offers the optimal contract under multi-homing, the entrant can take the market over from the incumbent by preventing the seller from multi-homing (e.g., imposing exclusive dealing or making the technologies of the two platforms incompatible. This leads to the single-homing equilibrium and the resulting market failure, where the trade level is below the welfare-maximizing level.

1.1 Related Literature

The economic literature on competing platforms extends the work of Katz and Shapiro (1985) on competition with network effects, where the size of the network creates additional value to the customers (e.g. telephone network). Spiegler (2000) considers a model with positive externality among two agents and finds that a third party, such as a platform, can extract these externalities by using exclusive interaction contracts, that includes reducing the payment to one of the agent if the other agent also signs with the third party. Caillaud and Jullien (2001) analyze a market with price competition between two platforms. The plat-

[1]In our model we focus exclusively on the combination of informational problem and coordination problem (typical for two-sided platforms). It is possible that additional constraints and problems may lead a monopoly platform to induce inefficient quantity. We abstract from those in the main part of the paper, but we show how limited liability of a buyer may have such an effect in Appendix C.

forms are undifferentiated, except for the fact that one of the platforms (the incumbent) benefits from favorable beliefs, while the other platform (the entrant) faces unfavorable beliefs. Under favorable beliefs, agents expect all other agents to join the incumbent, unless it is a dominant strategy for them not to join the platform. Caillaud and Jullien show that both platforms will use a divide-and-conquer strategy, where they charge a negative access price from one of the sides of the market and positive from the other side. Moreover, their paper finds that if platforms cannot use transaction fees, then the incumbent makes positive profit even without product differentiation, while with transaction fees, both platforms make zero profit. Caillaud and Jullien extend their results in their (2003) paper. In the (2003) paper, platforms have an imperfect matching technology which identifies correctly and matches agents successfully with probability $\lambda \in [0,1]$. In this modified environment and under single-homing, the only equilibria are dominant firm equilibria. However, because of the imperfect matching technology, there are also efficient multi-homing equilibria. Economides and Katsamakas (2006) consider competition between a propriety platform and an open source platform. They find that the propriety platform dominates the open source platform by having a larger market share and higher profitability. Jullien (2011) considers platform competition in the context of multi-sided markets with vertically differentiated platforms and sequential game, and analyzes the resulting pricing strategies. Our model follows this line of literature by considering two competing platforms where agents' beliefs are favorable toward one of the platforms and unfavorable toward the other. However, our model introduces asymmetric information which has not been considered in this context. Introduction of asymmetric information allows us to study how informational problem affects platform competition.

An optimal strategy of a platform often involves subsidizing one side of the market. The question which side of the market should be subsidized — which we address in our paper — has been also present in the literature. Armstrong (2006) considers differentiated competing matchmakers with a positive network externality. He shows that matchmakers compete more aggressively on the side that generates larger benefits to the other side (i.e., the one that has lower value from matching). This competition results in lower prices for the agents on the lower-valuation side. Hagiu (2006) considers a model of competing platforms when agents are sellers and buyers. Moreover, the platforms first compete on one of the sides, and only then move to compete on the other side. He finds that platforms' ability to commit to their second stage prices makes it less likely to have exclusive equilibria. However, the two

papers (Armstrong (2006) and Hagiu (2006)) do not consider the information problem that we investigate.

Several papers consider platforms that face informational problems. Most of the papers focus on ex-ante asymmetric information. Damiano and Li (2008) consider environment with competing platforms and ex-ante heterogeneous agents where prices facilitate self-selection of different types into different platforms. Ambrus and Argenziano (2009) show that with ex-ante heterogeneous agents, the market outcome may involve asymmetric networks, such that one network is cheaper and larger on one side of the market, and the other network is cheaper and larger on the other side. Our paper finds an equilibrium with a somewhat similar feature, in that under some market conditions one platform competes more aggressively on one side while the other platform competes on the other side. However, the focus of our paper is different as we consider a case where the buyers and sellers can make a continuous trade and we show that such platform competition — when it occurs — results in a downward distortion of the level of trade. In the model of Yanelle (1997) competing platforms (banks) coexist and earn positive profits in a market with asymmetric information about one side of the market, about the borrowers. The driving force behind those results is costly acquisition of information or monitoring of borrowers. Peitz, Rady and Trepper (2010) consider an infinite horizon model, when agents have ex-ante information concerning the utility from network externalities, and a monopoly platform that performs experimentation along time to learn the demand of the two sides of the market.

Weyl (2010) and White and Weyl (2011) consider agents that are ex-ante informed about their types. These papers focus on insulating tariffs: fees that directly depend on the number of participants. They show that such insulating fees help platforms mitigate the coordination problem. In our paper, we focus on access fees and transaction fees, where the latter depend on the lever of actual trade, and therefore depend only indirectly on participation. Intuitively, if platforms in our model could use insulating fees, in addition to transaction and access fees, then platforms could use this additional tool to solve the coordination problem and therefore implement the first-best level of trade. However, while there are many cases where platforms use insulating fees (as reported, e.g., in Weyl (2010)), in some cases it is impossible, or too costly from a technological viewpoint, for platforms to commit to a pricing schedule that depends on the realized participation. In our motivating examples (i.e., the markets for smartphones and videogame consoles), platforms usually charge transaction fees but, to

the best of our knowledge, cannot directly commit to insulating tariffs.[2] It is therefore possible to interpret the inefficiency result that our model identifies as the social cost of platforms' inability to commit to insulating tariffs. This is because we find that in the case where platforms can only charge fees based on trade, the platforms cannot overcome the coordination problem and the market may be inefficient.

The above papers consider ex-ante asymmetric information. In our paper, however, we focus on ex-post asymmetric information. To the best of our knowledge, such informational problem is rarely analyzed in the context of platforms. Ellison, Möbius and Fudenberg (2004) analyze competing uniform-price auctions, where the two sides of the market are buyers and sellers. The model in Ellison, Möbius and Fudenberg (2004) shares the same information structure as in our model in that buyers and sellers are uninformed about their valuations before joining the platform, and privately learn their valuations after joining. However, Ellison, Mobius and Fudenberg (2004) consider a very restrictive price competition between platforms (see their Section 7), where a platform can only charge an access price that must be the same in both sides of the market. Therefore, their paper does not allow for divide-and-conquer strategies.

Our model is also related to antitrust issues in two-sided markets. Amelio and Jullien (2007) consider the case where platforms are forbidden to charge negative access price. In such a case, platforms will use tying in order to increase the demand on one side of the market, which in turn increases the demand on the other side. Choi (2010) shows that tying induces consumers to multi-home (i.e., register with more than one matchmaker). Casadesus-Masanell and Ruiz-Aliseda (2009) consider competing platforms that can choose whether to offer compatible systems, and find that incompatibility results in an equilibrium with a dominant platform that earns higher profits than under compatibility. Hagiu and Lee (2011) consider platforms that connect between content providers and consumers. They find that if content providers can directly charge consumers for their content, then a multihoming equilibrium is possible. If platforms are the ones charging consumers for content, then content providers will tend to deal exclusively with one of the platforms. These papers,

[2]Insulating tariffs would involve a menu, where the price paid by the developers would depend on the number of users joining the platform. To the best of our knowledge, in the markets that we consider above, platforms do not commit to such a menu in advance. While we observe prices that may change with the size of the network, we hardly observe a menu. With only one price and one size at a time, the platform is not committing to changing the price accordingly when the size of the network changes.

however, do not allow for asymmetric information in the context of platform competition.

Armstrong and Wright (2007) consider platform competition in a two-sided market, when agents can multi-home and platforms can impose exclusive dealing contracts. They find that if platforms can impose exclusive dealing, then one platform uses exclusive dealing to dominate the market. In their model, exclusive dealing increases welfare because under exclusive dealing both sides of the market coordinate in joining the same side. In our model, we find that exclusive dealing may reduce welfare, even though both sides join the same platform. This is because the informational problem that we consider in this paper results in downward distortion of the level of trade.

2 Model and a Monopoly Platform Benchmark

Consider two sides of a market: seller side (S) and buyer side (B).[3] The seller wishes to sell a good to the buyer. However, the seller and the buyer cannot trade unless they join the platform. For example, the buyer can represent a user of a new operating system while the seller can represent a developer of an application for this new system. They can connect only if they use the same operating system. The two players may also represent a game developer for a new videogame console and a gamer, and they need a game console in order to benefit from trading.

The utilities of the seller and the buyer from trading are $t - C(q,c)$ and $V(q,\theta) - t$, respectively, where $C(q,c)$ is the seller's production cost, $V(q,\theta)$ is the value of the product to the buyer, and t is the monetary transfer from the buyer to the seller. The seller's production cost depends on parameters q and c, while the buyer's value depends on the parameters q and θ. The parameter q describes the good exchanged between the buyer and the seller, where we assume that $V_q > 0$ and $C_q > 0$ (subscripts denote partial derivatives). Specifically, the parameter q can measure the quantity that the seller produces and transfers to the buyer. Alternatively, q may measure quality, in which case the seller sells one indivisible good to the buyer. More generally, we view q as a measure of the level of trade in the market. For

[3] We present the model as if there were only one buyer and one seller in the market. The model is the same if we consider a continuum of buyers and sellers who are matched at random one-to-one to trade on the platform. In Appendix D, we show that our qualitative results hold if the platform chooses any other matching function to connect buyers and sellers. In Section 5 we discuss robustness to the assumption that buyers and sellers are matched one-to-one to trade.

q = 0, $C(0, c) = V(0, \theta) = 0$, so that no trade occurs. The parameters θ and c affect the buyer's willingness to pay and the seller's production cost respectively, where $V_\theta > 0$, $C_c > 0$, $V_{q\theta} > 0$ and $C_{qc} > 0$. One should think of θ as the buyer's taste parameter that positively affects the buyer's marginal valuation of the product, and c as a technology parameter that affects the seller's marginal cost: Higher c increases the marginal cost.

Let $q^*(\theta, c)$ denote the quantity that maximizes the gains from trade for given θ and c, i.e.,

$$q^*(\theta, c) = \arg\max_q \left\{V(q, \theta) - C(q, c)\right\}.$$

Hence, $q^*(\theta, c)$ solves

$$V_q(q^*(\theta, c), \theta) = C_q(q^*(\theta, c), c)\,. \tag{1}$$

Suppose that $V_{qq} \leq 0$ and $C_{qq} \geq 0$ where at least one of these inequalities is strong and $V_q(0, \theta) > C_q(0, c)$, while $V_q(q, \theta) < C_q(q, c)$ for $q \to \infty$. Therefore, $q^*(\theta, c)$ is uniquely defined by (1), and $q^*(\theta, c)$ is increasing with θ and decreasing with c. Let $W^*(\theta, c)$ denote the maximal welfare achievable for given θ and c, i.e., $W^*(\theta, c) = V(q^*(\theta, c), \theta) - C(q^*(\theta, c), c)$.

Throughout the paper, we assume that q is observable by all players and is contractible. Amazon, for example, can easily observe the quantity sold on its website, and can charge transaction fees from buyers, sellers, or both according to this quantity. Likewise, a console manufacturer can make quality specifications for its video games and make a payment contingent on this quality. However, we realize that this assumption does not hold in some other two-sided markets.[4]

Before proceeding to our main analysis of platform competition, in this section we study the benchmark case of a monopolist connecting the two sides of the market. In such a case, the buyer and the seller can either join the monopoly platform or stay out of the market. Before the buyer and the seller join the platform, all players are uninformed about θ and c, and share a commonly known prior that θ is distributed between $[\theta_0, \theta_1]$ according to a distribution function $k(\theta)$ and a cumulative distribution $K(\theta)$, and that c is distributed between $[c_0, c_1]$ according to a distribution function $g(c)$ and a cumulative distribution $G(c)$. We make the standard assumptions that $(1 - K(\theta))/k(\theta)$ is decreasing in θ and $G(c)/g(c)$ is increasing in c. Then, after joining the platform but before trading, the buyer and the seller each observes their private information and chooses whether to trade or not. Moreover, we assume throughout that all players are risk neutral.

[4]The analysis for markets with unobservable q deserves a separate paper.

More precisely, the timing of the game is following: First, the platform offers a contract to the buyer and the seller. We explain the features of this contract below. The buyer and the seller observe the offer and simultaneously decide whether to buy access to the platform or not. At this point, they need to pay the access fees if they decide to join. After joining, each agent observes the realization of his own private information, and decides whether to trade or not. If both sides joined and decided to trade, the trade and transfers occur.

Notice that this model corresponds to a principal-agent problem under asymmetric information, where the platform is the principal and the buyer and seller are the agents. The main features of the specific problem described here are related to Myerson and Satterthwaite (1983) and Spulber (1988), with two exceptions. First, here the principal is a platform (or competing platforms) that aims to "connect" the agents. Second, here players are initially uninformed, and the two sides learn their types only after contracting with a platform. Asymmetric information is a typical feature of principal-agent problems. However, because the principal is a platform, it introduces a novel element: coordination problem between the two sides that allows the platform to use a divide-and-conquer strategy, where it subsidizes one side in order to attract it and charge positive access fees from the other side.

Following the literature on principal-agent problems, suppose that a platform offers a contract

$$Cont = \{F_S, F_B, t_S(\theta, c), t_B(\theta, c), q(\theta, c)\},$$

where F_S and F_B are access fees that the buyer and the seller pay the platform for joining the platform before knowing their private information. These fees can be zero or even negative (as is the case under platform competition). Moreover, $t_S(\theta, c)$, $t_B(\theta, c)$, and $q(\theta, c)$ are all menus given (θ, c), such that after joining the platform and observing their private information, the buyer and the seller simultaneously report θ and c to the platform, and then given these reports, the seller produces $q(\theta, c)$ and delivers it to the buyer. We focus on $q(\theta, c) \geq 0$ for every θ and c.[5] For simplicity, we assume that the buyer and the seller pay $t_S(\theta, c)$ and $t_B(\theta, c)$ directly to the platform instead of to each other. Naturally, we allow $t_S(\theta, c)$ and $t_B(\theta, c)$ to be negative, so it is possible to write an equivalent mechanism where one agent pays the platform and the platform pays the other agent, or where one agent pays directly to the other agent and the platform charges some royalty out of this transaction. Also, suppose that the buyer and the seller can always refuse to trade after observing their

[5] Later we also make assumptions on the level of asymmetric information that assure nonnegativity of q.

private information, in which case they do not need to pay $t_S(\theta, c)$ and $t_B(\theta, c)$. However, F_S and F_B are not refunded.

While we enable platforms to choose within a wide set of potential contracts that includes positive or negative fees, we make the assumption that platforms cannot commit to insulating tariffs: fees that are based on the realized level of the other side's participation. With insulating tariffs, platforms could construct contracts that mitigate the coordination problem. However, as mentioned in Section 1.1, in some cases such insulating fees can be impossible or too costly to implement. In a related assumption, we assume that agents can choose whether to trade or not given that they both joined the same platform. We make this assumption because otherwise, agents have to pay ex-post fees if the other side joined the same platform. Therefore, the transaction fees become insulating fees, as they depend directly on participation and not on trade alone. Again, platforms can use such insulating fees for mitigating the coordination problem. We believe that our assumption — that agents can choose not to trade after joining the platform — is reasonable in many real-life situations. For example, smartphone users can choose how many applications to download. Users that only require the basic features of the smartphone (i.e., email, calendar, camera, etc), can potentially choose not to download any external applications. As most users download applications, we focus attention on market conditions such that trade indeed takes place in equilibrium for all θ and c.

Finally, we follow previous literature on two-sided markets (Caillaud and Jullien (2001), Caillaud and Jullien (2003) and Jullien (2008), in particular) by distinguishing between a platform about which the agents have "favorable" or "optimistic" beliefs, called P_o, and a platform about which they have "unfavorable" or "pessimistic" beliefs, P_p. *Favorable* beliefs mean that side $i = \{B, S\}$ expects the other side $j = \{B, S\}$, $j \neq i$, to join platform P_o if side j gains non-negative payoffs from joining given that side i joins. In other words, given the contract, if there is an equilibrium in which both sides join P_o, they will do so. In contrast, under *unfavorable* beliefs side $i = \{B, S\}$ does not expect side $j = \{B, S\}$, $j \neq i$, to join platform P_p if side j gains negative payoffs from joining given that side i did not join. In other words, given the contract, if there is an equilibrium in which neither side joins P_p, such equilibrium is selected, even if there also exists another equilibrium in which both sides join the platform.

The distinction between favorable and unfavorable beliefs may capture a difference in agents' ability to coordinate on joining an old or a new platform. If a certain platform is

a well-known, established incumbent that had a significant market share in the past, then agents from one side of the market may believe that agents from the other side are most likely to continue using this platform and will decide to join the incumbent based on this belief. A new entrant, however, may find it more difficult to convince agents that agents from the opposite side will also join.

2.1 Full Information

To illustrate the role that information plays in our model, consider first a full information benchmark.

The objective of a platform is to maximize its profit. We assume that the platform does not bear any marginal cost. Therefore, the platform sets the contract to maximize

$$= F_B + F_S + t_B(\theta, c) + t_S(\theta, c) \,.$$

Under full information, θ and c are common knowledge from the beginning of the game, that is, before the buyer and the seller join P. Then, both P_o and P_p can implement the welfare-maximizing outcome, $q^*(\theta, c)$, and earn $W^*(\theta, c)$ — i.e., the whole social surplus — by offering a contract $\{F_S, F_B, t_S(\theta, c), t_B(\theta, c), q(\theta, c)\} = \{0, 0, \ C(q^*(\theta, c), c), V(q^*(\theta, c), \theta), q^*(\theta, c)\}$. In the case of P_p, both sides do not need to pay access fees, and as they can always refuse to participate in the trading stage, they cannot lose from joining P_p. Thus, both sides join the platform if the platform is P_p,[6] and clearly, they join the platform if it is P_o.

Notice that the same argument holds if there is uncertainty but not asymmetric information such that all players are uninformed about θ and c when they sign the contract, but θ and c are ex-post observable and contractible. To conclude, under full information or uncertainty (without ex-post asymmetric information) there is no difference between P_o and P_p.

2.2 Monopoly Platform under Ex-post Asymmetric Information

Contrary to the full information benchmark, for the remainder of the paper we suppose that in the contracting stage no player knows θ and c, and that the buyer and the seller privately

[6] We assume that if an agent is indifferent between joining or not, he joins the platform. If the indifference is resolved otherwise, P_p needs to set one of the access fees to ε, with ε positive but arbitrarily close to 0. Then, in the limit P_p and P_o offer the same contract, which results in the same outcome.

observe θ and c, respectively, after joining the platform but before they decide whether to trade or not. We consider a truthfully revealing mechanism in which the buyer and the seller pay F_S and F_B for joining the platform, and then they are induced by the offered menu to truthfully report θ and c, and trade at the level $q(\theta, c)$ with the payments $t_S(\theta, c)$ and $t_B(\theta, c)$ to the platform.

Consider first the optimal contract for P_o, a monopolistic platform facing favorable (optimistic) expectations. As the buyer and the seller have ex-post private information, P_o will have to leave the buyer and the seller with ex-post utility (gross of the access fees), i.e., information rents, to motivate them to truthfully reveal their private information. Standard calculations[7] show that each side gains ex-post expected information rents of

$$U_B(q, \theta) = \mathbb{E}_c \int_{\theta_0}^{\theta} V_\theta(q(\theta, c), \theta)\mathrm{d}k(\theta)\,, \qquad U_S(q, c) = \mathbb{E}_\theta \int_{c}^{c_1} C_c(q(\theta, c), c)\mathrm{d}g(c)\,. \tag{2}$$

To ensure that the buyer and the seller agree to trade after they joined the platform and learned their private information we need

$$\mathbb{E}_c t_B(\theta, c) = \mathbb{E}_c\big[V(q(\theta, c), \theta)\big] - U_B(q, \theta)\,, \qquad \mathbb{E}_\theta t_S(\theta, c) = -\mathbb{E}_\theta\big[C(q(\theta, c), c)\big] - U_S(q, c)\,. \tag{3}$$

Conditions (2) and (3) along with the property that $q(\theta, c)$ is nondecreasing in θ and nonincreasing with c ensure that once the buyer and the seller joined P_o and privately observed θ and c, they will truthfully report it to P_o. To make sure that both sides agree to participate ex-ante, that is, before they learn their private information, the maximum access fees that P_o can charge are

$$F_B = \mathbb{E}_\theta U_B(q, \theta)\,, \quad F_S = \mathbb{E}_c U_S(q, c)\,. \tag{4}$$

The platform has two sources of revenue: access fees and transaction fees. Therefore, P_o's objective is to set $q(\theta, c)$ to maximize

$$\Pi = F_B + F_S + \mathbb{E}_{\theta c}\big[t_B(\theta, c) + t_S(\theta, c)\big]\,, \tag{5}$$

subject to the constraints (2), (3), and (4). After substituting (2), (3), and (4) into (5) and rearranging, we see that P_o's problem is to set $q(\theta, c)$ to maximize $\mathbb{E}_{\theta c}\big[V(q(\theta, c), \theta) - C(q(\theta, c), c)\big]$. Hence, P_o will set $q^*(\theta, c)$, and will be able to earn $W^* = \mathbb{E}_{\theta c} W^*(\theta, c)$.

[7] See Fudenberg and Tirole (1991). We use $\mathbb{E}_X$ to denote the expectation with respect to variable X.

Intuitively, P_o has to leave ex-post information rents to the two sides, but P_o can charge upfront access fees from the two sides that are equal to their expected ex-post information rents. Therefore, P_o has no incentive to distort the level of trade in order to reduce the agents' information rents.

Next, consider P_p, a platform facing unfavorable (pessimistic) beliefs of agents. The difference in beliefs results in different equilibrium contract, and different outcome. In order to satisfy ex-post incentive compatibility and individual rationality constraints, the constraints (2) and (3) remain the same. The main difference is in F_B and F_S. While a P_o can charge positive F_B and F_S from both sides, P_p cannot. Given positive F_B and F_S, each side loses if it pays access fees and the other side does not join. Therefore, under pessimistic beliefs with respect to P_p, both sides will prefer not to join P_p. Notice that this is indeed rational for the two sides to do so given their expectations: Given that each side believes that the other side does not join, both sides gain higher utility from not joining.

As a result, P_p needs to use a divide-and-conquer strategy, where it charges zero access fee (or minimally negative) from one of the sides in order to attract it, and then charges positive access fee from the other side. Platform P_p therefore has two options. The first option is to attract the buyer by charging

$$F_B = 0\,, \quad F_S = \mathbb{E}_c U_S(q, c)\,. \tag{6}$$

But now, after substituting (2), (3), and (6) into (5), P_p's objective becomes to set $q(\theta, c)$ as to maximize

$$\mathbb{E}_{\theta c}\big[V(q(\theta, c), \theta) - C(q(\theta, c), c)\big] - \mathbb{E}_\theta U_B(q, \theta)\,. \tag{7}$$

Straightforward calculations show that the first order condition for the optimal level of trade is characterized by

$$V_q(q(\theta, c), \theta) = C_q(q(\theta, c), c) + \frac{1 - K(\theta)}{k(\theta)} V_{\theta q}(q(\theta, c), \theta)\,. \tag{8}$$

Let $\widetilde{q}_B(\theta, c)$ denote the solution to (8). It follows that $\widetilde{q}_B(\theta, c) < q^*(\theta, c)$ unless $\theta = \theta_1$. Intuitively, with pessimistic beliefs, when P_p attracts the buyer it cannot capture the buyer's information rents. Consequently, P_p distorts the level of trade downward to reduce the buyer's information rents. To ensure that trade among the two sides always take place, we focus on the case where $(1 - K(\theta))/k(\theta)$ is sufficiently small such that $\widetilde{q}_B(\theta, c) > 0$ for all θ and c. Moreover, notice that since by assumption $(1 - K(\theta))/k(\theta)$ is decreasing with θ,

$\widetilde{q}_B(\theta, c)$ is increasing with θ, which ensures the incentive compatibility constraints. Therefore, P_p earns $\mathbb{E}_{\theta c}\big[V(\widetilde{q}_B(\theta,c),\theta) - C(\widetilde{q}_B(\theta,c),c)\big] - \mathbb{E}_{\theta} U_B(\widetilde{q}_B(\theta,c),\theta)$ when attracting the buyer.

Alternatively, P_p may attract the seller. Using the same logic as before, we find that P_p's profit in this case is $\mathbb{E}_{\theta c}\big[V(\widetilde{q}_S(\theta,c),\theta) - C(\widetilde{q}_S(\theta,c),c)\big] - \mathbb{E}_c U_S(\widetilde{q}_S(\theta,c),c)$, where $\widetilde{q}_S(\theta,c)$ is the solution to

$$V_q(q(\theta,c),\theta) = C_q(q(\theta,c),c) + \frac{G(c)}{g(c)} C_{cq}(q(\theta,c),c)\,. \tag{9}$$

It follows that $\widetilde{q}_S(\theta,c) < q^*(\theta,c)$ unless $c = c_0$. Now P_p cannot capture S's information rents so once again it will distort the level of trade downward to reduce the seller's information rents. Again we focus on the case where $G(c)/g(c)$ is sufficiently small such that $\widetilde{q}_S(\theta,c) > 0$ for all θ and c. Moreover notice that since by assumption $G(c)/g(c)$ is increasing with c, $\widetilde{q}_S(\theta,c)$ is decreasing with c which ensures the incentive compatibility constraints.

Next, we turn to compare between P_p's two options. Let

$$\begin{aligned}\Delta \equiv\ & \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B(\theta,c),\theta) - C(\widetilde{q}_B(\theta,c),c) - U_B(\widetilde{q}_B(\theta,c),\theta)\right] \\ & - \mathbb{E}_{\theta c}\left[V(\widetilde{q}_S(\theta,c),\theta) - C(\widetilde{q}_S(\theta,c),c) - U_S(\widetilde{q}_S(\theta,c),c)\right].\end{aligned}$$

The parameter Δ measures the difference in the degree of ex-post asymmetric information between the buyer and the seller. If $\Delta > 0$, then the information problem is stronger on the seller side, in that $\mathbb{E}_{\theta c}\left[U_S(q,\theta)\right] > \mathbb{E}_{\theta c}\left[U_B(q,c)\right]$ for all q. Conversely, when $\Delta < 0$, the information problem is more prominent on the buyer's side. As it turns out, Δ plays a crucial role in our analysis as it is convenient to characterize the equilibrium outcome of the competitive case given Δ.[8] To illustrate the intuition behind Δ, consider the following example.

Example 1 (uniform distributions of types) *Suppose that the buyer has linear demand and the seller has linear costs such that $V(q,\theta) = \theta q - \frac{q^2}{2}$ and $C(q,c) = cq$. Also, suppose that θ and c are distributed uniformly along the intervals $[\mu_\theta - \sigma_\theta, \mu_\theta + \sigma_\theta]$ and $[\mu_c - \sigma_c, \mu_c + \sigma_c]$. The parameters μ_θ and μ_c are the mean values of θ and c. The parameters σ_θ and σ_c measure the degree to which P_p is uninformed about θ and c. To ensure that the market is fully covered,*

[8] Even though the sign of the difference $\mathbb{E}_{\theta c}\left[U_S(q,\theta)\right] - \mathbb{E}_{\theta c}\left[U_B(q,c)\right]$ determines the sign of Δ, for further representation it is more convenient to characterize the solution in terms of Δ instead of $\mathbb{E}_{\theta c}\left[U_S(q,\theta)\right] - \mathbb{E}_{\theta c}\left[U_B(q,c)\right]$.

suppose that $\mu_\theta \quad \mu_c > \max\{3\sigma_\theta + \sigma_c, \sigma_\theta + 3\sigma_c\}$. *Then*

$$\sigma_c > \sigma_\theta \implies \quad > 0\,,$$
$$\sigma_c < \sigma_\theta \implies \quad < 0\,,$$
$$\sigma_c = \sigma_\theta \implies \quad = 0\,.$$

Given , the solution for the monopoly case becomes evident: If > 0, platform P_p prefers to attract the buyer by charging him zero | or minimally negative | access fee. Conversely, for < 0, P_p prefers to attract the seller. Lemma 1 below is a direct consequence of the discussion above.

Lemma 1 *Under ex-post asymmetric information, a monopolistic platform facing optimistic beliefs, P_o sets the welfare-maximizing level of trade, q^*. A monopolistic platform that faces pessimistic beliefs, P_p, distorts the level of trade downward. Specifically,*

(i) If > 0, *then it is optimal for platform P_p to subsidize the buyer* $(F_B = 0)$ *and to set* $q = \widetilde{q}_B(\theta, c) < q^*(\theta, c)$.

(ii) If < 0, *then it is optimal for platform P_p to subsidize the seller* $(F_S = 0)$ *and to set* $q = \widetilde{q}_S(\theta, c) < q^*(\theta, c)$.

(iii) It is optimal for platform P_p to set $q = q^*(\theta, c)$ only if there is no adverse selection on either buyer or seller side, i.e., $(1 \quad K(\theta))/k(\theta) = G(c)/g(c) = 0$ *for all θ and c. In such a case, it earns W^*.*

As Lemma 1 reveals, divide-and-conquer strategy emerges in the context of this model as a direct consequence of ex-post asymmetric information: P_p implements the trade maximizing q^* only if there is no adverse selection on either buyer or seller side. Moreover, Lemma 1 predicts that P_p nds it optimal to attract the side with the lowest informational problem, in the sense that this side is not expected to learn much about its value from trade after joining the platform. If > 0, asymmetric information is stronger on the seller side. Consequently, P_p has to leave higher ex-post information rents for the seller. Since under divide-and-conquer P_p loses the expected information rents of the side that P_p subsidizes, it will choose to lose the information rents of the buyer. The opposite case holds if asymmetric information is stronger on the buyer side.

In the context of Example 1, Lemma 1 indicates that if $\sigma_c > \sigma_\theta$, then the spread of the potential realizations of c is wider than θ, implying that the informational problem is more significant from the seller side. Consequently, > 0, so the platform attracts the buyer and sets $\widetilde{q}_B(\theta, c)$. The opposite case holds when $\sigma_c > \sigma_\theta$. Moreover, if $\sigma_c = \sigma_\theta = 0$, then the informational problem vanishes and platform P_p implements the welfare-maximizing level of trade.

3 Competition between Platforms

In this section we consider platform competition. In contrast to the monopoly benchmark in Section 2, we find that under competition the platform benefiting from favorable beliefs sometimes also distorts downward the level of trade. This is the result of ex-post asymmetric information.

Suppose that there are two platforms competing in the market. The platforms are undifferentiated, except for the beliefs each is facing. We call one of the platforms *incumbent* (I), and the other *entrant* (E). The incumbent benefits from favorable beliefs, in the same way as P_o, while the entrant faces unfavorable beliefs, in the same way as P_p. Because of the favorable beliefs, both sides join the incumbent whenever it is an equilibrium, even if there also exists an equilibrium where they both join the entrant. Conversely, both sides join the entrant only when there is no other equilibrium.

Each platform sets contract $Cont^P = \{F_B^P, F_S^P, t_B^P(\theta, c), t_S^P(\theta, c), q^P(\theta, c)\}$, for $P = I, E$ with the objective to maximize its profit. We focus on a sequential game where the incumbent announces its contract slightly before the entrant.[9] Users decide which platform to join after observing both contracts.

We solve for the subgame perfect equilibrium. Given the incumbent's strategy, $Cont^I$, the entrant has two options to win the market: one is to attract the buyer side, and the other to attract the seller side. For tractability, from now on we refer to any $q(\theta, c)$ as just q, whenever possible.

[9] We analyze a simultaneous game between the two platforms in Appendix A. There we show that, for some parameter values there is no pure-strategy Nash equilibrium with favorable beliefs in the simultaneous game. Where a pure-strategy Nash equilibrium with favorable beliefs exists for the simultaneous game, it has similar qualitative features as subgame perfect equilibrium in the sequential game considered here. To generate clean and tractable results we therefore focus on the sequential game.

To attract the buyer under unfavorable beliefs, the entrant needs to charge

$$F_B^E \gtrapprox \mathbb{E}_{\theta c} U_B(q^I) - F_B^I\,, \tag{10}$$

where $\mathbb{E}_{\theta c} U_B(q^I)$ is the expected information rent that the buyer obtains from the incumbent if both sides join the incumbent under $Cont^I$, and symbol $\gtrapprox$ stands for "slightly greater but almost equal." Condition (10) ensures that even when the buyer believes that the seller joins the incumbent, the buyer still prefers to join the entrant. Therefore, when condition (10) is satisfied, there is no equilibrium in which both sides join the incumbent. Given that the buyer joins the entrant independently of the seller, the seller finds it attractive to join the entrant when

$$F_S^E + \mathbb{E}_{\theta c} U_S(q^E) \gtrapprox - \min\{F_S^I, 0\}\,. \tag{11}$$

Given constraints (10) and (11), the entrant who attracts the buyer earns at most

$$\Pi^E(\text{attracting } B|\widetilde{q}_B, Cont^I) = \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) - C(\widetilde{q}_B,c) - U_B(\widetilde{q}_B,\theta)\right] - \mathbb{E}_{\theta c} U_B(q^I,\theta) + F_B^I + \min\{F_S^I, 0\}\,,$$

where $\widetilde{q}_B$ is the same as q maximizing (7).

It is possible, however, that the entrant prefers to attract the seller side. Applying the same logic and replacing the buyer with the seller, we find that the entrant earns

$$\Pi^E(\text{attracting } S|\widetilde{q}_S, Cont^I) = \mathbb{E}_{\theta c}\left[V(\widetilde{q}_S,\theta) - C(\widetilde{q}_S,c) - U_S(\widetilde{q}_S,c)\right] - \mathbb{E}_{\theta c} U_S(q^I,c) + F_S^I + \min\{F_B^I, 0\}\,.$$

Knowing the subsequent strategies of the entrant, the incumbent sets its contract to maximize the expected profit. However, the incumbent needs to account for several constraints. First, the incumbent must assure that the entrant has no profitable way of winning the market. That is, whether the entrant aims at attracting the buyer or the seller, it does not earn positive profit. Second, the incumbent also needs to take into account that the buyer or the seller may prefer to stay out of either platforms if the access fees are too high.[10]

As the entrant's profits reveal, ex-post asymmetric information hurts the entrant. When the expected information rents are sufficiently high, the entrant does not impose significant competitive pressure on the incumbent. To rule out this uninteresting possibility, we adopt the Spulber (1988) condition that ensures that a mechanism designer can implement the

[10] The formal statement of the incumbent's maximization problem, including the constraints, is included in the proof of Proposition 1.

welfare-maximizing quantity while maintaining a balanced budget[11]

$$\mathbb{E}_{\theta c}\big[V(q^*(\theta,c),\theta) - C(q^*(\theta,c),c) - U_B(q^*,\theta) - U_S(q^*,c)\big] > 0\,. \qquad (12)$$

Under the assumptions of Example 1, condition (12) is satisfied for any parameter values as long as q^* is always positive. The proof of Proposition 1 below shows that with condition (12), the entrant forces the incumbent to set negative access fees to one of the sides. This may lead the incumbent to distort its quantity downward.

Proposition 1 also states that the entrant never wins the market. Since the incumbent sets its contract slightly earlier than the entrant, the entrant is indifferent between a wide range of contracts, as it earns zero profit either way. For example, the entrant could offer $Cont^E = \{0,0,0,0,0\}$. However, if the incumbent were to set a more profitable contract in anticipation of $Cont^E = \{0,0,0,0,0\}$, then the entrant could set a different contract that would enable it to win the market with a strictly positive profit. The contract that would bring the highest profits to the entrant in such a case is the *best* contract. Therefore, the incumbent needs to prevent profitability of the entrant's best contract.

Proposition 1 *Suppose that* ≥ 0. *In equilibrium, the incumbent always dominates the market and attracts the buyer (by charging $F_B^I < 0$), while extracting all the seller's expected information rents through F_S^I. Moreover,*

(i) If $> \mathbb{E}_{\theta c}[U_B(q^*,\theta)]$, *then the entrant in its best contract also attracts the buyer ($F_B^E < 0$) and sets $q^E = \widetilde{q}_B$. The incumbent sets the welfare-maximizing quantity, $q^I = q^*$, and earns*

$$^{I} = \mathbb{E}_{\theta c}[V(q^*,\theta) - C(q^*,c)] - \mathbb{E}_{\theta c}[V(\widetilde{q}_B,\theta) - C(\widetilde{q}_B,c) - U_B(\widetilde{q}_B,\theta)]\,.$$

(ii) If $0 \leq$ $< \mathbb{E}_{\theta c}[U_B(\widetilde{q}_B,\theta)]$ *then the entrant in its best contract attracts the seller ($F_S^E \leq 0$) and sets $q^E = \widetilde{q}_S$. The incumbent distorts the quantity downward to $q^I = \widetilde{q}_B$, and earns* $^{I} =$.

[11] This condition is equivalent to condition (6) in Spulber (1988), which is a modification of Myerson-Satterthwaite condition for continuous q. Notice that unlike Spulber's model, here this is not a necessary condition for a monopoly incumbent to implement the efficient level of trade, because we assume that the two sides are initially uninformed about their types.

(iii) *If* $\mathbb{E}_{\theta c}[U_B(\widetilde{q}_B,\theta)] \leq \Delta \leq \mathbb{E}_{\theta c}[U_B(q^*,\theta)]$, *then the entrant in its best contract is indifferent between attracting the buyer or the seller. The incumbent distorts the quantity downward to* $q^I = \widetilde{q}_\Delta$, *where* $\widetilde{q}_\Delta$ *is an increasing function of* Δ *with values* $\widetilde{q}_\Delta \in [\widetilde{q}_B, q^*]$. *Moreover, the incumbent earns*

$$\Pi^I = \mathbb{E}_{\theta c}\left[V(\widetilde{q}_\Delta,\theta) - C(\widetilde{q}_\Delta,c)\right] - \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) - C(\widetilde{q}_B,c) - U_B(\widetilde{q}_B,\theta)\right].$$

The case where $\Delta < 0$ *is similar, with the buyer replacing seller (see Figure 1 for a full characterization of the equilibrium).*[12]

Proof. See Appendix, page 44.

Proposition 1 offers several interesting observations. The first observation concerns the equilibrium level of trade set by the dominant platform, the incumbent. If the difference in the degree of ex-post asymmetric information between the sides, Δ, is large such that $\Delta > \mathbb{E}_{\theta c}[U_B(q^*,\theta)]$, then the incumbent sets the welfare-maximizing quantity as in the monopoly case. However, if the difference is small, even though the incumbent benefits from favorable beliefs, the incumbent distorts the trade downward. For $\mathbb{E}_{\theta c}[U_B(\widetilde{q}_B,\theta)] \leq \Delta \leq \mathbb{E}_{\theta c}[U_B(q^*,\theta)]$, this distortion becomes stronger the smaller Δ is. This result is surprising as it shows that competition actually reduces social welfare in comparison with a monopoly. More precisely, the presence of competitive threat (even if not an active competitor) increases the customer surplus for some customers, while creating a dead-weight loss.

The intuition for these results is the following. Suppose that $\Delta > 0$, such that the information rents on the seller's side are higher than on the buyer's side. Consider first the optimal strategy for the incumbent. As the incumbent benefits from favorable beliefs, the incumbent finds it optimal to charge high access fees to the seller's side to fully extract, ex-ante, the high ex-post information rents. The incumbent competes with the entrant by charging negative access fees from the buyer. That is: $F^I_S \lessapprox \mathbb{E}_{\theta c}U_S(q^I)$ and $F^I_B < 0$. The incumbent then chooses F^I_B and q^I based on the way the entrant can respond to these strategies, and to make sure that the entrant cannot make a positive profit from dominating the market.

[12] The proposition describes subgame perfect equilibrium in sequential game. In a simultaneous game, the unique Nash equilibrium is the same as the subgame perfect equilibrium in sequential game when $\Delta > \mathbb{E}_{\theta c}[U_B(q^*,\theta)]$. However, for $\Delta \leq \mathbb{E}_{\theta c}[U_B(q^*,\theta)]$, there does not exist a pure strategy Nash equilibrium with favorable beliefs in the simultaneous move game (see Proposition 4 in Appendix A).

Both platforms attract the buyer.
The incumbent sets $q^I = q^*$.

$\mathbb{E}_{\theta c}[U_B(q^*, \theta)]$

The incumbents attracts the buyer, and the entrant is indifferent between attracting the seller or the buyer.
The incumbent sets $q^I = \tilde{\tilde{q}}_\Delta < q^*$.

$\mathbb{E}_{\theta c}[U_B(\widetilde{q}_B, \theta)]$

The incumbent attracts the buyer while the entrant attracts the seller.
The incumbent sets $q^I = \widetilde{q}_B < q^*$.

0

The incumbent attracts the seller while the entrant attracts the buyer.
The incumbent sets $q^I = \widetilde{q}_S < q^*$.

$\mathbb{E}_{\theta c}[U_S(\widetilde{q}_S, \theta)]$

The incumbents attracts the seller, and the entrant is indifferent between attracting the seller or the buyer.
The incumbent sets $q^I = \tilde{\tilde{q}}_\Delta < q^*$.

$\mathbb{E}_{\theta c}[U_S(q^*, \theta)]$

Both platforms attract the seller.
The incumbent sets $q^I = q^*$.

Figure 1: Properties of the equilibrium in sequential game, depending on the value of .

Turning to the entrant, in the attempt to win the market the entrant chooses between two \divide-and-conquer" strategies. First, charging a negative access fee (\divide") to the buyer such that the buyer prefers joining the entrant even when the seller joins the incumbent, and then charging a high access fee (\conquer") to the seller to extract the seller's information rents. That is: $F_B^E \gtrapprox F_B^I + \mathbb{E}_{\theta c} U_B(q^I)$, and $F_S^E \lessapprox \mathbb{E}_{\theta c} U_S(q^E)$. In this case, both platforms compete for the buyer and since beliefs are favorable towards the incumbent, the buyer expects to receive the information rent from the incumbent, but not from the entrant. This allows the incumbent to charge a higher access fee to the buyer (or to provide lower subsidy), to satisfy $F_B^I \gtrapprox \mathbb{E}_{\theta c} U_B(q^I) + F_B^E$. That is, the incumbent can ex-ante collect the buyer's expected information rent. Thus, the incumbent has no incentive to distort downward this information rent. In this option, the incumbent can therefore internalize the information rents of both sides and sets the rst-best level of trade, while the entrant internalizes only the seller's information rents and therefore distorts the quantity downwards.

The second option for the entrant is to \divide" the seller by o ering a slightly negative access fee such that the seller prefers to join the entrant given the beliefs that the buyer joins the incumbent, and then \conquer" the buyer by charging a high access fee from the buyer to capture the buyer's information rents. That is: $F_S^E \lessapprox 0$ and: $F_B^E + \mathbb{E}_{\theta c} U_B(q^E) \gtrapprox F_B^I$. In this case, favorable beliefs imply that the seller decides which platform to join expecting to get the information rent from the incumbent, but not from the entrant. But since the buyer observes that the entrant o ers subsidy to the seller, the buyer expects to get information rent from the entrant, not from the incumbent. Hence, the incumbent cannot ex-ante collect the buyer's expected information rents, and sets $F_B^I \gtrapprox \mathbb{E}_{\theta c} U_B(q^E) + F_B^E$. Consequently, the incumbent does not internalize the buyer's information rents while the entrant does not internalize the sellers' information rents, and both platforms distort their quantities downwards.

From the entrant's viewpoint, the bene t from the rst option is that given that the incumbent fully extracts the seller's information rents with the high access fees, it is easy for the entrant to attract the seller by o ering slightly negative access fees. In other words, the seller is the \weak link" that is easier to \conquer". The disadvantage is that now the entrant loses the seller's information rents, which are higher than that of the buyer's. Thus, if the seller's information rents are signi cantly higher than that of the buyer, such that is high, then the disadvantage of the second option is stronger than its advantage, and the entrant will prefer the rst option. If the gap is small, then the entrant prefers the second

option. For intermediate values of , the entrant is indifferent between the two options.

As the incumbent correctly anticipates the entrant's behavior, the incumbent will set the first-best level of trade if is high, but will distort it downward otherwise. Notice that the incumbent distorts the quantity downward even for the intermediate values of , because the entrant's second option is still binding on the incumbent.

The second observation related to Proposition 1 concerns with the difference between the incumbent's and the entrant's equilibrium level of trade. Consider the case where is small: $< \mathbb{E}_{\theta c}[U_B(\widetilde{q}_B, \theta)]$. In this case, while both platforms distort their quantities below the first-best level of trade, the features of this distortion is different. The incumbent sets $q^I = \widetilde{q}_B$ in order to reduce the buyer's information rents. Therefore $\widetilde{q}_B$ is increasing with θ and $\widetilde{q}_B(\theta_1, c) = q^*(\theta_1, c)$ for all c. In contrast, the entrant sets $q^E = \widetilde{q}_S$ in order to reduce the seller's information rents. Therefore, $\widetilde{q}_S(\theta, c_0) = q^*(\theta, c_0)$ for all θ, and $\widetilde{q}_S$ is decreasing with c. It is thus possible that the incumbent distorts the quantity more or less than the entrant. The same argument applies for the comparison between a monopoly platform that suffers from pessimistic beliefs and the entrant under competition. While a monopoly platform that faces unfavorable beliefs attracts the buyer and therefore distorts the quantity to $\widetilde{q}_B$, under competition, a platform that faces unfavorable beliefs distorts the quantity to $\widetilde{q}_S$. As $\widetilde{q}_B$ can be higher or lower than $\widetilde{q}_S$, it can be that a platform facing unfavorable beliefs sets a higher or lower quantity under competition than as monopoly. We demonstrate this point with the following example:

Example 2 ($\widetilde{q}_B$ and $\widetilde{q}_S$ compared) *Suppose that the buyer has linear demand and the seller has linear costs such that $V(q, \theta) = \theta q - \frac{q^2}{2}$ and $C(q, c) = cq$. Also, suppose that θ and c are distributed uniformly along the intervals $[\mu_\theta - \sigma_\theta, \mu_\theta + \sigma_\theta]$ and $[\mu_c - \sigma_c, \mu_c + \sigma_c]$. Then, the incumbent sets a higher quantity than the entrant, i.e., $\widetilde{q}_B > \widetilde{q}_S$, if and only if*

$$\theta + c > \mu_\theta + \mu_c + \sigma_\theta - \sigma_c\,,$$

and sets a lower quantity than the entrant otherwise. Also, a monopoly with pessimistic beliefs sets a higher quantity than the entrant if the above condition holds, and a lower quantity otherwise.

Moreover, the condition for $\widetilde{q}_B > \widetilde{q}_S$ always holds for the highest values of θ and c, i.e., $\theta = \mu_\theta + \sigma_\theta$ and $c = \mu_c + \sigma_c$. And the opposite condition holds for the lowest values of θ and c, i.e., $\theta = \mu_\theta - \sigma_\theta$ and $c = \mu_c - \sigma_c$.

Example 2 shows that for high realizations of θ and c, the incumbent sets a higher quantity than the entrant, but the opposite is true for low realizations of θ and c. This result implies that even though the incumbent benefits from favorable beliefs and wins the market, the incumbent may still motivate the two sides to trade at a higher or lower quantity than the entrant would. This result also implies that the entrant may increase or decrease its quantity, when facing competition with the incumbent, in comparison to the case where the entrant is a monopoly. Intuitively, the incumbent distorts the quantity downwards to reduce the buyer's incentive to understate θ. Therefore, the lower is the θ that the buyer reports, the stronger is the quantity distortion. The entrant, however, distorts the quantity to reduce the seller's incentive to overstate c. Therefore, the higher is c, the stronger is the quantity distortion. We therefore find that for a high θ and c there is a stronger incentive for the entrant to distort the quantity, while for a low θ and c, there is a stronger incentive for the incumbent to distort the quantity. The same intuition applies for the comparison between the quantity of the entrant and the quantity of a monopoly platform that suffers from pessimistic beliefs.

The third observation related to Proposition 1 concerns the incumbent's equilibrium profit. If the difference in the degree of ex-post asymmetric information is large such that $> \mathbb{E}_{\theta c}[U_B(q^*, \theta)]$, then the incumbent earns the difference between the P_o's and the P_p's profits under monopoly. Notice that this difference is higher the higher are the information rents that the entrant cannot extract from the buyer: $\mathbb{E}_{\theta c} U_B(\widetilde{q}_B, \theta)$. Hence, the incumbent's profit approaches zero at the limit as $\mathbb{E}_{\theta c} U_B(\widetilde{q}_B, \theta) \to 0$. This result implies that the incumbent gains more competitive advantage the larger is the informational problem on the buyer's side. Intuitively, recall that in this case the incumbent internalizes the information rents of both sides while the entrant internalizes only the seller's information rents. Therefore, the incumbent's competitive advantage is the result of the presence of information rents in the buyer side that the entrant does not internalize.

If is sufficiently small (i.e., $0 < \quad < \mathbb{E}_{\theta c}[U_B(\widetilde{q}_B, \theta)]$), the incumbent gains a higher profit the higher is the difference in the ex-post asymmetric information problem of the two sides, , and the incumbent's profit approaches zero at the limit as $\to 0$. Intuitively, recall that in this case the incumbent does not internalize the buyer's information rents while the entrant does not internalize the seller's information rents. Since the seller's rents are higher than the buyer's, the incumbent wins, and its competitive advantage is determined according to the gap between the seller's and the buyer's information rents.

For intermediate values of Δ (i.e., $\mathbb{E}_{\theta c}[U_B(\widetilde{q}_B,\theta)] < \Delta < \mathbb{E}_{\theta c}[U_B(q^*,\theta)]$), both forces described above coexist. Hence, as case (iii) of Proposition 1 reveals, the incumbent's profits increase with both $\mathbb{E}_{\theta c}[U_B(\widetilde{q}_B,\theta)]$ and Δ.[13] Intuitively, in case (iii) the entrant is indifferent between attracting the buyer or the seller. Therefore, the incumbent's competitive advantage comes from two elements: Δ and $\mathbb{E}_{\theta c}[U_B(\widetilde{q}_B,\theta)]$.

Notice that the special case of $\Delta = 0$ may occur even if the distributions of types, $K(\theta)$ and $G(c)$, are not degenerate, i.e., there is uncertainty and ex-post asymmetric information. In the assumptions of Example 1, this will occur if $\sigma_c = \sigma_\theta$ even though σ_c and σ_θ might be significantly large. When this is the case, both platforms distort their quantities downward: the incumbent to $\widetilde{q}_B$ and the entrant to $\widetilde{q}_S$. And since $\Delta = 0$, both platforms earn no profit.

However, when the type distribution is degenerate on (at least) one side of the market, both platforms set the trade-maximizing q^* and earn zero profits. Therefore, without uncertainty on both sides, the market behaves as in Caillaud and Jullien (2001 and 2003).

Corollary 1 *Suppose that there is no adverse selection on the buyer side, i.e.,* $(1 - K(\theta))/k(\theta) = 0$ *for all* θ*. Then, for* $\Delta \geq 0$, $q^I = q^E = q^*$ *and both platforms earn zero profits. The same market outcome occurs for* $\Delta \leq 0$*, if there is no adverse selection on the seller side, i.e.,* $G(c)/g(c) = 0$*.*

Proof. See Appendix, page 49.

The result of our Proposition 1 differs from Proposition 2 in Caillaud and Jullien (2001) and Proposition 1 in Caillaud and Jullien (2003). The propositions in Caillaud and Jullien papers show that undifferentiated platforms competing with both access fees and transaction fees make zero profit. In these papers, with no differentiation, the two platforms set the highest possible transaction fees and then compete in access fees (as in Bertrand competition), resulting in zero profits. Since Caillaud and Jullien do not assume asymmetric information in their papers, Corollary 1 is consistent with their results. The result of our Proposition 1 contributes to the above papers by showing that ex-post asymmetric information restores the incumbent's competitive advantage and enables the incumbent to earn positive payoff even without product differentiation.

[13] To see why, notice that Proposition 1 shows that $\tilde{\tilde{q}}_\Delta < q^*$ and $\tilde{\tilde{q}}_\Delta$ is increasing with Δ. Therefore, $\mathbb{E}_{\theta c}\left[V(\tilde{\tilde{q}}_\Delta,\theta) - C(\tilde{\tilde{q}}_\Delta,c)\right]$ is increasing with Δ.

In our model, we have focused on the coordination problem under ex-post asymmetric information, and we abstracted from additional constraints that the platforms may face. In some environments even a monopoly facing favorable beliefs may set an ine cient level of trade due to reasons other than coordination problem. In some of those cases it may be that the monopoly sets less e cient level of trade than the incumbent in a competitive market. In Appendix C, we analyze one such situation: The buyer is the subject of budget constraint on how large of an access fee he can pay up front (limited liability). The limited liability may drive a monopoly to set ine cient level of trade, despite optimistic beliefs it faces in the market. However, the level of trade that the incumbent sets in a competitive situation depends on the relative degree of asymmetric information. It is straightforward to nd condition where the e ect of limited liability is stronger than the e ect of asymmetric information. Then, the monopoly sets ine cient level of trade while the incumbent in competitive environment sets the e cient level.

4 Multi-homing and Exclusive Dealing

Until now, we have assumed that both the seller and the buyer are restricted to single-homing, i.e., they were allowed to join only one platform at a time. In this section, we extend the competition model of Section 3 by allowing one of the sides to \multi-home" by joining both platforms. This raises the question of whether a platform may want to restrict the agent's ability to join the competing platform by imposing exclusive dealing. This question has important implications for antitrust policy toward such exclusive arrangements.

As we show in this section, the equilibrium under multi-homing di ers from single-homing only for some cases. For those cases, the multi-homing equilibrium yields e cient levels of trade (welfare-maximizing q^*), while in the single-homing equilibrium the trade levels are distorted downward. Moreover, in those cases, the incumbent prefers the multi-homing equilibrium. However, if the incumbent plays as in the multi-homing equilibrium, the entrant's best response is to impose exclusive dealing. This, in e ect, leads to the single-homing equilibrium.

Suppose that it is the seller who can join more than one platform.[14] A third-party video

[14]The situation where only buyer multi-homes is symmetric. Our analysis, where only the seller multi-homes, is conducted for all values of Δ. If the buyer multi-homes under $\Delta > 0$, it equivalent to seller multi-homing under $\Delta < 0$.

game developer, for example, can choose to write a video game for more than one console. A smartphone application developer can choose to write an application compatible with more than one operating system. We focus on multi-homing coming from only one side of the market. Smartphone users, for example, may find it cumbersome to carry more than one smartphone with them. Likewise, gamers may find it difficult to store more than one videogame console with all the relevant accessories.[15]

As before, we assume that the incumbent announces its contract to both sides slightly earlier than the entrant, and the two sides simultaneously decide to which platform to join after observing contracts offered by both platforms. If the seller indeed joins both platforms, the buyer may join either the incumbent or the entrant. If both these situations constitute an equilibrium, then the equilibrium where the buyer joins the incumbent is played, since the incumbent enjoys favorable beliefs.

To be successful in the market, the entrant needs to attract (by subsidizing) one of the sides. It has two options: to attract the buyer, or to attract the seller. The entrant can attract the buyer by charging

$$F_B^E \gtrapprox \mathbb{E}_{\theta c} U_B(q^I, \theta) - F_B^I \implies F_B^E = F_B^I - \mathbb{E}_{\theta c} U_B(q^I, \theta) .$$

This condition is identical to the single-homing case because by assumption a buyer cannot multi-home. Given that the buyer joins the entrant, the entrant can charge the seller

$$F_S^E + \mathbb{E}_{\theta c} U_S(q^E, c) \gtrapprox 0 \implies F_S^E = \mathbb{E}_{\theta c} U_S(q^E, c) .$$

Notice that now F_S^E differs from the case of single-homing in that the incumbent's offer to the seller does not affect the seller's decision to join the entrant, because the seller can multi-home and therefore it joins the entrant whenever doing so provides positive payoff. The entrant's profit function when attracting the buyer is

$$\Pi^E(\text{attracting } B | q^E) = \mathbb{E}_{\theta c} \left[V(q^E, \theta) - C(q^E, c) - U_B(q^E, \theta) \right] + F_B^I - \mathbb{E}_{\theta c} U_B(q^I, \theta) ,$$

maximized by $q^E = \widetilde{q}_B$.

Next, suppose that the entrant chooses to attract the seller. Given unfavorable beliefs against the entrant, the entrant needs to make it worthwhile for the seller to join even if the

[15] Indeed, in the above examples even users can, and sometimes do, join more than one platform. We view our assumption as a simplification of a case where for exogenous reasons, most (though not all) agents on one side of the market do not consider the possibility to multi-home.

buyer would not join. That is, the entrant needs to set $-F_S^E \gtrapprox 0$, which we approximate by $F_S^E = 0$. Given $F_S^E = 0$, the buyer now expects the seller to join both platforms, and therefore will agree to join the entrant only if it offers him a larger surplus. Hence,

$$\mathbb{E}_{\theta c} U_B(q^E, \theta) - F_B^E \gtrapprox \mathbb{E}_{\theta c} U_B(q^I, \theta) - F_B^I \implies F_B^E = \mathbb{E}_{\theta c} U_B(q^E, \theta) - \mathbb{E}_{\theta c} U_B(q^I, \theta) + F_B^I.$$

This condition differs from the single-homing case, because given that the entrant sets $-F_S^E \gtrapprox 0$, now the seller can multi-home so the buyer expects to gain positive information rents for both the incumbent and the entrant. The entrant's profit is maximized for $q^E = \widetilde{q}_S$, and yields

$$\Pi^E(\text{attracting } S | \widetilde{q}_S(\theta, c)) = \mathbb{E}_{\theta c} \left[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c) \right] + F_B^I - \mathbb{E}_{\theta c} U_B(q^I, \theta) \, .$$

A direct comparison of the entrant's profits under the two scenarios reveals that the entrant attracts the buyer when $\Delta > 0$, and attracts the seller when $\Delta < 0$, independently of the incumbent's strategy.[16]

The incumbent's objective is to maximize its profit, under the constraints that winning the market is not profitable for the entrant, and both the buyer and the seller prefer to join the incumbent than to stay out of the market.[17]

Proposition 2 *Suppose that the seller can multihome by joining both platforms. Then, in the equilibrium of the sequential game:*

(i) If $\Delta > 0$, *then the incumbent sets* $q^I = q^*$, $F_B^I = -\mathbb{E}_{\theta c} \left[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta) \right] + \mathbb{E}_{\theta c} U_B(q^*, \theta)$, $F_S^I = \mathbb{E}_{\theta c} U_S(q^*, c)$ *and earns*

$$\Pi^I(q^*) = \mathbb{E}_{\theta c} \left[V(q^*, \theta) - C(q^*, c) \right] - \mathbb{E}_{\theta c} \left[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta) \right] \, .$$

(ii) If $\Delta < 0$, *then the incumbent sets* $q^I = q^*$, $F_B^I = -\mathbb{E}_{\theta c} \left[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c) \right] + \mathbb{E}_{\theta c} U_B(q^*, \theta)$, $F_S^I = \mathbb{E}_{\theta c} U_S(q^*, c)$ *and earns*

$$\Pi^I(q^*) = \mathbb{E}_{\theta c} \left[V(q^*, \theta) - C(q^*, c) \right] - \mathbb{E}_{\theta c} \left[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c) \right] \, .$$

Proof. See Appendix, page 50.

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[16] For $\Delta = 0$, the entrant is indifferent between attracting the buyer or the seller.

[17] This optimization problem is formally stated in the proof of Proposition 2.

Comparing Proposition 2 with Proposition 1 reveals that with multi-homing, the incumbent always wins the whole market, and o ers the welfare-maximizing quantity regardless of , thus the market is always e cient. Intuitively, if the entrant chooses to attract the seller but the seller can multi-home, then the buyer still gains the payo $\mathbb{E}_{\theta c} U_B(q^I, \theta)$ F_B^I

turn means that it is not optimal for the incumbent to set the multi-homing strategies to begin with. The intuition for this result is as follows: Multi-homing provides the entrant with an advantage and a disadvantage over single-homing. In comparison with single-homing, it is easier for the entrant to attract the seller under multi-homing because the seller can join both platforms, and therefore joins the entrant as long as the seller gains non-negative payoff. At the same time, it is more difficult for the entrant to attract the buyer under multi-homing for the same reason: If the buyer expects the seller to join both platforms, the entrant needs to leave the buyer with higher payoff to motivate the buyer to choose the entrant over the incumbent. In the multi-homing equilibrium, the incumbent eliminates the former, positive effect of multi-homing on the entrant by providing the seller with zero payoff. In such a case, the seller's incentive to join the entrant becomes the same under single- and multi-homing. Then, the incumbent can amplify the latter, negative effect of multi-homing by offering a low, possibly negative access fees to the buyer. As the incumbent turns the multi-homing effects against the entrant, the entrant would like to correct this by imposing exclusive dealing.

Next, we establish that in equilibrium, the two platforms indeed play their single-homing strategies and at least one of them imposes exclusive dealing.

Proposition 3 *Suppose that* $E_{\theta c}[U_S(\widetilde{q}_S, c)] < \quad < E_{\theta c}[U_B(\widetilde{q}_B, \theta)]$ *and that platforms can impose exclusive dealing. Then, in equilibrium,*

(i) If $0 \quad < E_{\theta c}[U_B(\widetilde{q}_B, \theta)]$*, then the incumbent sets the single-homing strategy but does not need to impose exclusive dealing. Given the incumbent's strategy, the entrant earns zero profit if it imposes exclusive dealing, and negative profit otherwise.*

(ii) If $E_{\theta c}[U_S(\widetilde{q}_S, c)] < \quad 0$*, then the incumbent sets the single-homing strategy and imposes exclusive dealing. The entrant then plays its single-homing strategy and earns zero profit.*

Proof. See Appendix, page 53.

Proposition 3 reveals that if the ex-post informational problem is more significant on the seller's side ($0 \quad < E_{\theta c}[U_B(\widetilde{q}_B, \theta)]$), then the incumbent does not directly impose exclusive dealing, though the entrant's ability to impose exclusivity forces the incumbent to set the single-homing strategies. If however the informational problem is more significant on the buyer's side $E_{\theta c}[U_S(\widetilde{q}_S, c)] < \quad 0$), then the incumbent will also need to impose

exclusive dealing. Intuitively, in the later case, under single-homing, the incumbent attracts the seller while the entrant attracts the buyer and earns zero profit. If the incumbent would not impose exclusivity in this case, then the entrant finds it optimal to also attract the seller, and win the market. To prevent this, the incumbent imposes exclusive dealing in equilibrium.

Next, consider the effect of exclusive dealing on welfare. Recall that if $E_{\theta c}[U_S(\widetilde{q}_S, c)] < \quad < E_{\theta c}[U_B(\widetilde{q}_B, \theta)]$, then Proposition 2 reveals that the single-homing strategies involve a downward distortion in the quantity, while Proposition 3 reveals that under multi-homing the incumbent always sets the welfare-maximizing quantity. Since the platforms' ability to impose exclusive dealing forces them to play the single-homing strategies, it also forces the incumbent to distort the quantity downward. Following Corollary 2 summarizes this finding.

Corollary 2 *Suppose that* $E_{\theta c}[U_S(\widetilde{q}_S, c)] < \quad < E_{\theta c}[U_B(\widetilde{q}_B, \theta)]$. *Then, the platforms' ability to impose exclusive dealing reduces social welfare.*

For antitrust policy, this result supports a restrictive approach by antitrust authorities against exclusive dealing.

We conclude this section by highlighting the role that ex-post asymmetric information plays in the analysis. Notice that without any asymmetric information, both platforms earn zero profits under both single- and multi-homing. Therefore, the incumbent loses all the advantages of multi-homing, while the entrant has nothing to gain by imposing exclusive dealing. Since the equilibria under multi- and single-homing are the same, no platform has incentive to impose exclusivity or seek multi-homing.

5 Conclusion

This paper considers platform competition in a two-sided market when agents do not know their valuations from joining the platform and they privately learn this information only after they join. The paper shows that this informational problem significantly affects pricing, profits, and market efficiency.

In our main result we show that the dominant platform may distort the level of trade (measured by quantity or quality) downward in comparison with the level of trade that maximizes social welfare. A monopoly facing the same informational problem does not distort the level of trade, and under competition with full information, there is no distortion

as well. Therefore, it is the *combination* of the informational problem and the presence of competition that creates the market inefficiency.

We extend our main result to the market with multi-homing. We find that the incumbent platform earns higher profit under multi-homing, and multi-homing eliminates the incumbent's need to distort the level of trade downward. However, if possible, the entrant prefers to prevent agents from multi-homing by imposing exclusive dealing or making the technologies of the two platforms incompatible. In the context of this model, exclusive dealing decreases social welfare because it forces the incumbent to distort the level of trade.

Our paper is derived under some simplifying assumptions that are worth mentioning. First, we assume that the platform can fully regulate the trade between the two sides in that the contract specifies the quantity and prices. This assumption might be suitable in some cases. Operating systems and manufacturers of videogames for example, sometimes regulate the quality of independent developers. In other cases, however, a platform's contracting possibilities might be more limited. Assuming a platform that can fully regulate the trade enables us to generate clean results and highlight the net effect of asymmetric information on the market's outcome and efficiency. It also allows us to separate the efficiency resulting from asymmetric information from inefficiency that may result from other contract structures. In accompanying research, we investigate platform competition with limited contracting possibilities.

Second, our paper focuses on ex-post asymmetric information. This informational problem is different from Damiano and Li (2008), Ambrus and Argenziano (2009), Peitz, Rady and Trepper (2010), Weyl (2010), and White and Weyl (2011) that focused on ex-ante asymmetric information. We believe that such ex-post asymmetric information is present in many markets for platforms, especially those involving a new and untested technology (i.e., a new smartphone's operating system or a new videogame console), such that agents on both sides of the markets can privately learn their valuations from the new technology only after they try it. At the same time, it is clearly natural to think of many scenarios where agents have ex-ante asymmetric information. In fact, real-life scenarios in some markets include both types of asymmetry, though certain markets can be characterized by having more ex-post asymmetric information than ex-ante while others having more ex-ante than ex-post. Our model then applies to the first type of markets.

The interplay between the ex-ante and ex-post asymmetric information leaves two important questions for future research. First, does the informational problem provide incumbents

with competitive advantage over entrants? From Damiano and Li (2008), we know that if agents' ex-ante information is significantly diffused, then there is a stable pure-strategy equilibrium with two active platforms. Our model shows that ex-post asymmetric information has a somewhat different effect, in that ex-post asymmetric information increases the profit of the incumbent in a dominant equilibrium. We can therefore speculate that incumbents that benefit from favorable beliefs gain stronger competitive advantage from the presence of asymmetric information in markets in which asymmetric information is stronger ex-post than ex-ante. However, the opposite case may be true for markets where asymmetric information is stronger ex-ante than ex-post. The second question is whether the quantity distortion that our paper identifies results also in a model with both ex-ante and ex-post asymmetric information. With ex-ante asymmetric information, platforms will need to leave agents with ex-ante information rents (in our model, there are only ex-post information rents as all agents are initially uninformed). This, in turn, may create even a stronger incentive for platforms to reduce the level of trade, in order to reduce the ex-ante information rents.

Third, we assume that only one buyer and one seller are matched to trade at a time. They can decide not to trade, but they cannot go to a different trading partner. Given our focus on ex-post asymmetric information, the results should follow for more than one agent on each side as long as there is no negative externalities within each group and as long as the valuations of the agents in the same side are independently drown (that is, θ and c are not correlated among different buyers and sellers, respectively). Indeed, in Appendix D we show that our results hold when there is a continuum of buyers and sellers, and platforms can match agents according to their types. Introducing negative externalities within each side (for example, because of competition between sellers), might change our results if it may make it easier for the entrant to gain market share. Likewise, allowing for correlation in agents' valuations may affect the result as it may make it easier for the platform to extract private information from agents. We leave these potential extensions of our model for future research.

Appendix

A Competition under Simultaneous Move Game

In Section 3 we have analyzed a game of competition between the incumbent and the entrant platform, where the incumbent announced its contract slightly earlier than the entrant. In this section, we consider a version of the competition game, where the incumbent and the entrant announce their contracts simultaneously. In such a game we look for pure strategy Nash equilibria. We show that for such that $\mathbb{E}_{\theta c} U_S(q^*, c) < \quad < \mathbb{E}_{\theta c} U_B(q^*, \theta)$, there does not exist a pure strategy Nash equilibrium. And otherwise there always exists a unique pure strategy Nash equilibrium.

Just as in the monopoly case and in the sequential move game, the entrant needs to subsidize one side of the market to attract the agents. The entrant either subsidizes the buyer or the seller. Suppose first, that the entrant subsidizes the buyer. By similar reasoning as in Section 3, we find that the entrant's best response to the incumbent's contract involves

$$F_B^E \gtrapprox \mathbb{E}_{\theta c} U_B(q^I, \theta) - F_B^I$$
$$F_S^E + \mathbb{E}_{\theta c} U_S(q^E, c) \gtrapprox 0 \,.$$

Then the entrant's profit function becomes $\mathbb{E}_{\theta c}\big[V(q^E, \theta) - C(q^E, c) - U_B(q^E, \theta)\big] + F_B^I - \mathbb{E}_{\theta c} U_B(q^I, \theta) + \min\{F_S^I, 0\}$, which is maximized by $q^E = \widetilde{q}_B$.

At the same time, the incumbent's best response to entrant's strategy of attracting the buyer involves

$$F_B^I + \mathbb{E}_{\theta c} U_B(q^I, \theta) \gtrapprox -F_B^E$$
$$F_S^I + \mathbb{E}_{\theta c} U_S(q^I, c) \gtrapprox 0 \,.$$

Then the incumbent's profit function becomes $\mathbb{E}_{\theta c}\big[V(q^I, \theta) - C(q^I, c)\big] + F_B^E$, which is maximized by $q^I = q^*$. Moreover, $F_S^I = \mathbb{E}_{\theta c} U_S(q^*)$. The incumbent sets F_B^I low enough to deter the entrant from the market (but not lower, because it would decrease the incumbent's profit), i.e., to set the entrant's profit to 0. The incumbent achieves this by setting

$$F_B^I = \mathbb{E}_{\theta c} U_B(q^*, \theta) - \mathbb{E}_{\theta c}\big[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta)\big] \,.$$

Then the incumbent achieves the profit of $\mathbb{E}_{\theta c}\big[V(q^*, \theta) - C(q^*, c)\big] - \big[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta)\big] > 0$.

Now suppose that the entrant subsidizes the seller. Then its best response to the incumbent's strategy involves

$$F_S^E \gtrapprox \mathbb{E}_{\theta c} U_S(q^I, c) \quad F_S^I$$
$$F_B^E + \mathbb{E}_{\theta c} U_B(q^E, \theta) \gtrapprox \quad \min f F_B^I, 0 g \, .$$

And the entrant's pro t $\mathbb{E}_{\theta c}\big[V(q^E, \theta) \quad C(q^E, c) \quad U_S(q^E, c)\big] + F_S^I \quad \mathbb{E}_{\theta c} U_S(q^I, c) + \min f F_B^I, 0 g$ is maximized by $q^E = \widetilde{q}_S$.

The incumbent's best response when the entrant subsidizes the seller involves

$$F_S^I + \mathbb{E}_{\theta c} U_S(q^I, c) \gtrapprox \quad F_S^E$$
$$F_B^I + \mathbb{E}_{\theta c} U_B(q^I, \theta) \gtrapprox 0 \, .$$

The incumbent's pro t of $\mathbb{E}_{\theta c}\big[V(q^I, \theta) \quad C(q^I, c)\big] + F_S^E$ is maximized by $q^I = q^*$. Moreover, $F_B^I = \mathbb{E}_{\theta c} U_B(q^*, \theta)$ and the incumbent sets $F_S^I = \mathbb{E}_{\theta c} U_S(q^*, c) \quad \mathbb{E}_{\theta c}\big[V(\widetilde{q}_S, \theta) \quad C(\widetilde{q}_S, c)$ $U_S(\widetilde{q}_S, c)\big]$ to induce zero pro t for the entrant.

However, in the simultaneous move game, the incumbent does not know a priori whether the entrant will o er subsidizing for the buyer or the seller.

Suppose that the incumbent believes that the entrant subsidizes the buyer, and sets $q^I = q^*$, $F_S^I = \mathbb{E}_{\theta c} U_S(q^*, c)$ and $F_B^I = \mathbb{E}_{\theta c} U_B(q^*, \theta) \quad \mathbb{E}_{\theta c}\big[V(\widetilde{q}_B, \theta) \quad C(\widetilde{q}_B, c) \quad U_B(\widetilde{q}_B, \theta)\big]$. If the entrant responds by subsidizing the buyer, it gets zero pro t. If, however, the entrant responds by subsidizing the seller, its pro t is

$$\mathbb{E}_{\theta c}\big[[V(\widetilde{q}_S, \theta) \quad C(\widetilde{q}_S, c) \quad U_S(\widetilde{q}_S, c)\big] + \min f F_B^I, 0 g \, .$$

If this pro t is larger than zero, the entrant prefers to respond with subsidizing the seller. This happens when

$$\mathbb{E}_{\theta c}\big[[V(\widetilde{q}_S, \theta) \;\; C(\widetilde{q}_S, c) \;\; U_S(\widetilde{q}_S, c)\big] > \mathbb{E}_{\theta c} U_B(q^*, \theta) \;\; \mathbb{E}_{\theta c}\big[V(\widetilde{q}_B, \theta) \;\; C(\widetilde{q}_B, c) \;\; U_B(\widetilde{q}_B, \theta)\big] \quad (\;)$$
$$(\;) \qquad < \mathbb{E}_{\theta c} U_B(q^*, \theta) \, .$$

Therefore, if $\quad < \mathbb{E}_{\theta c} U_B(q^*, \theta)$ then the entrant has incentive do deviate away from subsidizing the buyer. Conversely, if $\qquad \mathbb{E}_{\theta c} U_B(q^*, \theta)$ there exists a pure strategy equilibrium where the entrant subsidizes the buyer, and the incumbent responds optimally.

Suppose now that the incumbent believes that the entrant subsidizes the seller, and sets its strategy optimally under this belief. By similar reasoning we can show that if

$> \quad \mathbb{E}_{\theta c}U_S(q^*, c)$, then the entrant has incentive to deviate away from subsidizing the seller. And if $\quad \mathbb{E}_{\theta c}U_S(q^*, c)$, then there exists a pure strategy equilibrium where the entrant subsidizes the seller, and the incumbent responds optimally.

Notice that for such that $\mathbb{E}_{\theta c}U_S(q^*, c) < \quad < \mathbb{E}_{\theta c}U_B(q^*, \theta)$ there does not exist a pure strategy equilibrium. If the incumbent believes that the entrant subsidizes the buyers, the entrant's best response is to subsidize the sellers and vice versa. That is, there does not exists a pure strategy for the entrant which ful lls the incumbent's expectations. Therefore, a pure strategy Nash equilibrium does not exist.

The discussion above directly leads to Proposition 4.

Proposition 4 *Suppose that the incumbent and the entrant compete in a simultaneous move game. Then*

1. *For* $\quad \mathbb{E}_{\theta c}U_B(q^*, \theta)$ *there exists a unique pure strategy Nash equilibrium, where the entrant subsidizes the buyer.*

2. *For* $\quad \mathbb{E}_{\theta c}U_S(q^*, c)$ *there exists a unique pure strategy Nash equilibrium, where the entrant subsidizes the seller.*

3. *For* $\mathbb{E}_{\theta c}U_S(q^*, c) < \quad < \mathbb{E}_{\theta c}U_B(q^*, \theta)$ *there does not exist a pure strategy Nash equilibrium.*

B Competition under Sequential-Move Game where the Entrant Plays First

In Section 3 we considered the case where the incumbent sets the contract slightly before the entrant. In this section, we consider a version of the competition game, in which the entrant moves before the incumbent. We show that there are multiple equilibria. In all of them the incumbent dominates the market and sets $q^I = q^*$, regardless of . Therefore, unlike the opposite case where the incumbent moves rst, here the incumbent never distorts the quantity. Moreover, we provide a minimal boundary on the incumbent's pro t, and show that the incumbent can earn at least as much as it earns in the competition game under simultaneous move game or the sequential move game when the incumbent moves rst, for the case where is su ciently high.

To this end, suppose that the entrant offers a contract $\{F_B^E, F_S^E, t_B^E(\theta,c), t_S^E(\theta,c), q^E(\theta,c)\}$, and consider first the incumbent's best response to the entrant's contract. As the incumbent only needs to ensure that there is an equilibrium in which both sides join the incumbent, the incumbent will charge

$$\begin{aligned} F_B^I + \mathbb{E}_{\theta c} U_B(q^I,\theta) &\gtrapprox -\min\{F_B^E, 0\}, \\ F_S^I + \mathbb{E}_{\theta c} U_S(q^I,c) &\gtrapprox -\min\{F_S^E, 0\}. \end{aligned}$$

Hence the incumbent earns

$$\Pi^I(q^I) = \mathbb{E}_{\theta c}\big[V(q^I,\theta) - C(q^I,c)\big] + \min\{F_S^E, 0\} + \min\{F_B^E, 0\}.$$

Maximizing the incumbent's profit with respect to q^I yields that the incumbent sets $q^I = q^*$. Consequently, regardless of the entrant's first-stage strategies, the incumbent sets the welfare-maximizing quantity.

Next we turn to showing that there is no equilibrium in which the entrant dominates the market. To dominate the market, the entrant has to ensure that the incumbent earns non-positive payoff from the above strategies. Moreover, as the entrant suffers from unfavorable beliefs, the entrant has to set negative access fees for at least one side. Suppose first that in entrant sets $F_B^E < 0$. To ensure that the incumbent earns negative profit, the entrant sets

$$F_B^E = -\mathbb{E}_{\theta c}\big[V(q^*,\theta) - C(q^*,c)\big] - \min\{F_S^E, 0\}.$$

Hence, the entrant earns

$$\begin{aligned} \Pi^E(\text{attracting } B|q^E) = {} & \mathbb{E}_{\theta c}\big[V(q^E,\theta) - C(q^E,c) - U_B(q^E,\theta) - U_S(q^E,c)\big] \\ & + F_S^E - \min\{F_S^E, 0\} - \mathbb{E}_{\theta c}\big[V(q^*,\theta) - C(q^*,c)\big]. \end{aligned}$$

Notice that for $F_S^E < 0$, the entrant's profit is independent of F_S^E, while for $F_S^E > 0$ the entrant's profit is increasing in F_S^E. Therefore, the entrant sets the highest F_S^E possible: $F_S^E = \mathbb{E}_{\theta c} U_S(q^E,c)$, implying that the entrant sets $F_B^E = -\mathbb{E}_{\theta c}\big[V(q^*,\theta) - C(q^*,c)\big]$ and earns

$$\Pi^E(\text{attracting } B|q^E) = \mathbb{E}_{\theta c}\big[V(q^E,\theta) - C(q^E,c) - U_B(q^E,\theta)\big] - \mathbb{E}_{\theta c}\big[V(q^*,\theta) - C(q^*,c)\big].$$

The entrant's profit is maximized at $q^E = \widetilde{q}_B$, and the entrant earns

$$\Pi^E(\text{attracting } B|\widetilde{q}_B) = \mathbb{E}_{\theta c}\big[V(\widetilde{q}_B,\theta) - C(\widetilde{q}_B,c) - U_B(\widetilde{q}_B,\theta)\big] - \mathbb{E}_{\theta c}\big[V(q^*,\theta) - C(q^*,c)\big] < 0.$$

Following the same argument, if the entrant sets $F_S^E < 0$, the entrant's maximal profit is

$$\Pi^E(\text{attracting } S|\widetilde{q}_S) = \mathbb{E}_{\theta c}\big[V(\widetilde{q}_S,\theta) - C(\widetilde{q}_S,c) - U_S(\widetilde{q}_S,c)\big] - \mathbb{E}_{\theta c}\big[V(q^*,\theta) - C(q^*,c)\big] < 0.$$

Therefore, the entrant cannot earn positive profit, implying that there are multiple equilibria in which the incumbent dominates the market. Next we provide a minimum boundary on the incumbent's equilibrium profit. We focus on the more realistic case where the entrant does not set prices that inflict negative profit for the entrant, should both sides choose to join the entrant given these prices. Without this restriction, the entrant could dissipate the entire incumbent's profit. To this end, notice that if the entrant sets $F_B^E < 0$, then the above discussion indicates that the entrant sets $F_S^E = \mathbb{E}_{\theta c}U_S(\widetilde{q}_B,c)$ and earns

$$\Pi^E(attractingB|\widetilde{q}_B) = \mathbb{E}_{\theta c}\big[V(\widetilde{q}_B,\theta) - C(\widetilde{q}_B,c) - U_B(\widetilde{q}_B,\theta)\big] + F_B^E.$$

Therefore the lowest F_B^E that the entrant can set is $F_B^E = -\mathbb{E}_{\theta c}\big[V(\widetilde{q}_B,\theta) - C(\widetilde{q}_B,c) - U_B(\widetilde{q}_B,\theta)\big]$ and the incumbent earns

$$\Pi^I = \mathbb{E}_{\theta c}\big[V(q^*,\theta) - C(q^*,c)\big] - \mathbb{E}_{\theta c}\big[V(\widetilde{q}_B,\theta) - C(\widetilde{q}_B,c) - U_B(\widetilde{q}_B,\theta)\big].$$

Likewise, if the entrant sets $F_S^E < 0$, the incumbent earns

$$\Pi^I = \mathbb{E}_{\theta c}\big[V(q^*,\theta) - C(q^*,c)\big] - \mathbb{E}_{\theta c}\big[V(\widetilde{q}_S,\theta) - C(\widetilde{q}_S,c) - U_S(\widetilde{q}_S,c)\big].$$

Therefore, the incumbent's minimum equilibrium profit is

$$\begin{aligned}\Pi^I = {} & \mathbb{E}_{\theta c}\big[V(q^*,\theta) - C(q^*,c)\big] \\ & - \max\{\mathbb{E}_{\theta c}\big[V(\widetilde{q}_B,\theta) - C(\widetilde{q}_B,c) - U_B(\widetilde{q}_B,\theta)\big], \mathbb{E}_{\theta c}\big[V(\widetilde{q}_S,\theta) - C(\widetilde{q}_S,c) - U_S(\widetilde{q}_S,c)\big]\}.\end{aligned}$$

We summarize these results in the following proposition:

Proposition 5 *Suppose that the entrant moves slightly before the incumbent. Then, there are multiple equilibria. In all equilibria, the incumbent dominates the market and sets the welfare-maximizing quantity, q^*. Moreover, the incumbent earns at least as much as in the simultaneous move game or the opposite sequential move game for the case where is high.*

C Ex-ante Limited Liability on the Buyer's Side

Suppose that the buyer is unwilling or unable to pay more than K upfront. For example, the buyer's attitude for risk may deter the buyer from paying a higher access fee before observing θ and before observing that the seller indeed joined the platform. Alternatively, the buyer might be ex-ante financially constrained.

In this environment, consider a monopoly platform that benefits from optimistic beliefs. The monopoly's solution is similar to that in Section 2, but now there is an additional restriction that the platform does not charge a higher access fee to the buyer than K, i.e., $F_B^O < \min\{K, \mathbb{E}_{\theta c}[U_B(q^O, \theta)]\}$. The proposition below characterizes the optimal contract.

Proposition 6 *Suppose that the buyer cannot pay more than K upfront, and that the monopoly benefits from optimistic beliefs. Then,*

(i) If $K > \mathbb{E}_{\theta c}[U_B(q^*, \theta)]$, then the monopoly sets $F_B^O = \mathbb{E}_{\theta c}[U_B(q^*, \theta)]$ and $q^O = q^*$.

(ii) If $\mathbb{E}_{\theta c}[U_B(q^*, \theta)] > K > \mathbb{E}_{\theta c}[U_B(\widetilde{q}_B, \theta)]$, then the monopoly sets $F_B^O = K = \mathbb{E}_{\theta c}[U_B(\widetilde{\widetilde{q}}_K, \theta)]$ and $q^O = \widetilde{\widetilde{q}}_K$, where $\widetilde{\widetilde{q}}_K$ is an increasing function of K with values $\widetilde{\widetilde{q}}_K \in [\widetilde{q}_B, q^*]$.

(iii) If $\mathbb{E}_{\theta c}[U_B(\widetilde{q}_B, \theta)] > K$, then the monopoly sets $F_B^O = K$ and $q^O = \widetilde{q}_B$.

Proof. If $K > \mathbb{E}_{\theta c}[U_B(q^*, \theta)]$, then K is not binding on the monopoly, and the monopoly sets $F_B^O = \mathbb{E}_{\theta c}[U_B(q^*, \theta)]$ and $q^O = q^*$. If $K < \mathbb{E}_{\theta c}[U_B(q^*, \theta)]$, then K is binding, and the monopoly will therefore set: $F_B^O = K$ and $F_S^O = \mathbb{E}_{\theta c}[U_S(q^O, c)]$. The monopoly then sets q^O to maximize: $\mathbb{E}_{\theta c}\big[V(q^O, \theta) - C(q^O, c) - U_B(q^O, c)\big]$. The optimal quantity is then: $q^O = \widetilde{q}_B$. If $\mathbb{E}_{\theta c}[U_B(\widetilde{q}_B, \theta)] > K$, then the constraint $F_B^O < \mathbb{E}_{\theta c}[U_B(\widetilde{q}_B, \theta)]$ is not binding and therefore $q^O = \widetilde{q}_B$ is the optimal solution. However, if $\mathbb{E}_{\theta c}[U_B(q^*, \theta)] > K > \mathbb{E}_{\theta c}[U_B(\widetilde{q}_B, \theta)]$, then the condition $F_B^O < \mathbb{E}_{\theta c}[U_B(q^O, \theta)]$ is violated. In this case, the binding constraint is: $F_B^O = K = \mathbb{E}_{\theta c}[U_B(q^O, \theta)]$. Therefore, the monopoly maximizes $\mathbb{E}_{\theta c}\big[V(q^O, \theta) - C(q^O, c) - U_B(q^O, c) - U_S(q^O, c)\big] + F_B^O + F_S^O$, subject to the constraints that $F_B^O = K = \mathbb{E}_{\theta c}[U_B(q^O, \theta)]$ and $F_S^O = \mathbb{E}_{\theta c}[U_S(q^O, c)]$. Substituting $F_B^O = \mathbb{E}_{\theta c}[U_B(q^O, \theta)]$ and $F_S^O = \mathbb{E}_{\theta c}[U_S(q^O, c)]$, the problem becomes to set q^O as to maximize

$$\Pi^O(q^O) = \mathbb{E}_{\theta c}\big[V(q^O, \theta) - C(q^O, c)\big]$$

s.t.

$$\mathbb{E}_{\theta c}[U_B(q^O, \theta)] = K$$

Given this constraint, the monopoly's profit can be expressed as

$$\Pi^O(q^O) = \mathbb{E}_{\theta c}\big[V(q^O,\theta) - C(q^O,c)\big] + \lambda[K - \mathbb{E}_{\theta c}U_B(q^O,\theta)]\,,$$

where λ is the Lagrange multiplier. Differentiating with respect to q^O and λ yields following conditions for the optimal $\tilde{\tilde{q}}_K$ and λ

$$\begin{aligned} V_q(\tilde{\tilde{q}}_K,\theta) - C_q(\tilde{\tilde{q}}_K,c) - \lambda\frac{1-F(\theta)}{f(\theta)}V_{\theta c}(\tilde{\tilde{q}}_K,\theta) &= 0\,, \\ K - \mathbb{E}_{\theta c}U_B(\tilde{\tilde{q}}_K,\theta) &= 0\,. \end{aligned}$$

Notice that for $K = \mathbb{E}_{\theta c}[U_B(q^*,\theta)]$, the solutions to the above equations is at $\lambda = 0$ and $\tilde{\tilde{q}}_K = q^*$. For $K = \mathbb{E}_{\theta c}[U_B(\tilde{q}_B,\theta)]$, the solutions to the above equations is at $\lambda = 1$ and $\tilde{\tilde{q}}_K = \tilde{q}_B$. For $\mathbb{E}_{\theta c}[U_B(q^*,\theta)] > K > \mathbb{E}_{\theta c}[U_B(\tilde{q}_B,\theta)]$, the solution satisfies $0 < \lambda < 1$ and $\tilde{q}_B < \tilde{\tilde{q}}_K < q^*$. Moreover, as K increases, λ decreases and $\tilde{\tilde{q}}_K$ increases. ■

Intuitively, if K is small then the monopoly cannot use F_B^O for capturing the buyer's information rents. This in turn derives the monopoly to distort the quantity downward, to $\tilde{\tilde{q}}_K$ between $\tilde{q}_B$ and q^*, depending on K.

Now, suppose that $K < \mathbb{E}_{\theta c}[U_B(q^*,\theta)]$, while $\quad > \mathbb{E}_{\theta c}[U_B(q^*,\theta)]$. Then, the monopoly sets an inefficient level of trade, while in the presence of the competitive threat from the entrant, the incumbent — facing optimistic beliefs — sets the optimal trade level, regardless of K, because the proof of Proposition 1 below reveals that the incumbent sets $F_B^I < 0$, implying that the constraint $F_B^I < K$ is not binding.

D Robustness to Matching Function Adopted by Platforms

The model in the main paper is presented for one buyer and one seller. The main model also holds for continuum of buyers and continuum of sellers who are matched at random to trade on the platform. In this appendix we extend the model to allow platforms to match agents depending on their types. We show that for any matching function, the platform may still set a level of trade below the level that maximizes the joint surplus of the two agents.

Consider an environment with continuum of buyers and continuum of sellers. Buyers' types, θ, are distributed according to pdf and cdf $k(\theta)$ and $K(\theta)$ on the support $[\theta_0, \theta_1]$. Similarly, sellers' types, c, are distributed according to $g(c)$ and $G(c)$ on the support $[c_0, c_1]$. For simplicity, we assume that the distributions and supports are such that there is the same mass of buyers and sellers; specifically, we assume mass one.

The platform uses a matching function. The matching function may be characterized by the probability that buyer θ is matched with a seller c, for any pair (θ, c). We denote this probability by $h(\theta, c)$. We assume that the platform matches all types of agents. That is, for all c and θ,

$$\int_{\theta_0}^{\theta_1} h(\theta, c) dk(\theta) = g(c), \qquad \int_{c_0}^{c_1} h(\theta, c) dg(c) = k(\theta) . \tag{13}$$

For any given θ, there is a distribution of matching c's. We denote the conditional probability that a buyer is matched with a seller of type c, conditional on the buyer's type, θ, and given a matching function h, as $g(c|\theta, h)$. Bayes rule requires that

$$g(c|\theta, h) = \frac{h(\theta, c)}{\int_{c_0}^{c_1} h(\theta, c) dg(c)} = \frac{h(\theta, c)}{k(\theta)} . \tag{14}$$

Similarly, the conditional probability facing a seller of type c is

$$k(\theta|c, h) = \frac{h(\theta, c)}{\int_{\theta_0}^{\theta_1} h(\theta, c) dk(\theta)} = \frac{h(\theta, c)}{g(c)} . \tag{15}$$

Given the matching rule, a platform now offers the contract $Cont = \{F_S,\ F_B,\ t_S(\theta, c),\ t_B(\theta, c),\ q(\theta, c)\}$.

In this environment, consider the problem of a monopolist platform with optimistic beliefs. For a buyer who after joining the platform learned his type θ, his ex-post expected information rent is

$$U_B(q, \theta) = \int_{\theta_0}^{\theta} \int_{c_0}^{c_1} V_\theta(q(\theta, c), \theta)\, dg(c|\theta, h) d\theta .$$

Similarly, the ex-post information rent for the seller of type c is

$$U_S(q, c) = \int_{c}^{c_1} \int_{\theta_0}^{\theta_1} C_c(q(\theta, c), c)\, dk(\theta|c, h) dc .$$

Notice that the definition of the agents' ex-post information rents is different from the case of one buyer and one seller. Here, each side derives the expected information rents based on the conditional probabilities, $g(c|\theta, h)$ and $k(\theta|c, h)$, instead of the distribution functions, $g(c)$ and $k(\theta)$ respectively.

The expected trade-payments in exchange for goods are

$$t_B(\theta) = \int_{c_0}^{c_1} V(q(\theta,c),\theta)dg(c|\theta,h) - U_B(q,\theta)\,, \qquad \text{and} \qquad t_S(c) = -\int_{\theta_0}^{\theta_1} C(q(\theta,c),c)dk(\theta|c,h) - U_S(q,c)\,.$$

Then, the maximum access fees that P_O can charge are $F_B = \mathbb{E}_\theta U_B(q,\theta)$, and $F_S = \mathbb{E}_c U_S(q,c)$.

P_O profit is given by

$$\Pi_O = F_B + F_S + \mathbb{E}_\theta t_B(\theta) + \mathbb{E}_c t_S(c) = \int_{\theta_0}^{\theta_1}\int_{c_0}^{c_1} V(q(\theta,c),\theta)dg(c|\theta,h)dk(\theta) - \int_{c_0}^{c_1}\int_{\theta_0}^{\theta_1} C(q(\theta,c),c)dk(\theta|c,h)dg(c) =$$

$$= \int_{\theta_0}^{\theta_1}\int_{c_0}^{c_1} \big[V(q(\theta,c),\theta) - C(q(\theta,c),c)\big]h(\theta,c)dc\,d\theta\,.$$

P_O's objective is to set $q(\theta,c)$ to maximize the profit, subject to the constraints (13). The first-order condition with respect to $q(\theta,c)$ is

$$V_q(q(\theta,c),\theta) = C_q(q(\theta,c),c))\,.$$

Therefore, for any matching function, P_O chooses the first-best level of trade, $q^*(\theta,c)$.

Consider now the monopolist facing pessimistic beliefs. As in the main paper, the platform needs to attract either the buyers or the sellers by charging them a zero access fee. Suppose that the entrant attracts the buyers, i.e., $F_B = 0$, and $F_S = \mathbb{E}_c U_S(q,c)$.

Then the platform's profit function is

$$\Pi_P = \int_{\theta_0}^{\theta_1}\int_{c_0}^{c_1} V(q(\theta,c),\theta)dg(c|\theta,h)dk(\theta) - \underbrace{\int_{\theta_0}^{\theta_1}\left(\int_{\theta_0}^{\theta}\int_{c_0}^{c_1} V_\theta(q(\theta,c),\theta)dg(c|\theta,h)\,d\theta\right)dk(\theta)}_{=\int_{\theta_0}^{\theta_1}\int_{c_0}^{c_1} V_\theta(q(\theta,c),\theta)\frac{1-K(\theta)}{k(\theta)}h(\theta,c)\,dc\,d\theta}$$

$$- \int_{c_0}^{c_1}\int_{\theta_0}^{\theta_1} C(q(\theta,c),c)dk(\theta|c,h)dg(c) =$$

$$= \int_{\theta_0}^{\theta_1}\int_{c_0}^{c_1}\left[V(q(\theta,c),\theta) - V_\theta(q(\theta,c),\theta)\frac{1-K(\theta)}{k(\theta)} - C(q(\theta,c),c)\right]h(\theta,c)\,dc\,d\theta\,. \tag{16}$$

We obtain the simplified form after integrating by parts and rearranging. The platform maximizes profit subject to constraints (13). The objective function (16) indicates that platform facing pessimistic beliefs does not internalize the buyers' information rents. Given a matching function, the first-order condition with respect to the quantity is

$$V_q(q(\theta,c),\theta) = C_q(q(\theta,c),c) + \frac{1-K(\theta)}{k(\theta)}V_{\theta q}(q(\theta,c),\theta)\,.$$

The optimal level of trade for P_P is therefore $\widetilde{q}_B$. Intuitively, for any matching function, where P_P matches a buyer of type θ with a seller of type c, P_P cannot capture the buyer's information rents and therefore distorts the level of trade below the level that maximizes their joint payoff.

Notice that a matching function with less uncertainty about the match reduces the buyers' ex-post uncertainty and therefore their information rents. In the extreme case of a deterministic matching, for example, P_P can completely eliminate the buyers' ex-post uncertainty concerning the type with whom they are matched. While doing so reduces the buyers' expected information rents, P_P cannot completely eliminate the information rents it needs to give to the buyers to induce them to reveal their true type, and therefore the platform needs to distort the level of trade. It is straightforward to show that the case where P_P attracts the sellers is symmetric, and leads to a quantity distortion to $\widetilde{q}_S$.

Moreover, the analysis of competition between the incumbent and the entrant follows the same logic. Because the platforms need to pay ex-post information rents to the buyers and sellers to reveal their types, if the platforms cannot appropriate those rents ex-ante, they will distort the level of trade downward. Of course, the entrant and the incumbent may use different matching functions. Let $h^I(\theta, c)$ represent the matching function for the incumbents, and $h^E(\theta, c)$ one for the entrant. It would be straightforward to set up a maximization problem for the incumbent as the one in Proposition 1 (cf. the proof in Appendix D). By solving the maximization problem in the same way as in the proof of Proposition 1, we find that for the case where both the entrant and the incumbent attract the buyer (i.e., for large enough gap between the information rents of buyers and sellers), the incumbent's profit is

$$\Pi^I(q^I) = \int_{\theta_0}^{\theta_1}\int_{c_0}^{c_1}\left[V(q^I,\theta) - C(q^I,c)\right]h^I(\theta,c)\,dc\,d\theta - \int_{\theta_0}^{\theta_1}\int_{c_0}^{c_1}\left[V(\widetilde{q}_B,\theta) - V_\theta(\widetilde{q}_B,\theta)\frac{1-K(\theta)}{k(\theta)} - C(\widetilde{q}_B,c)\right]h^E(\theta,c)\,dc\,d\theta\,,$$

where $\widetilde{q}_B$ satisfies

$$V_q(\widetilde{q}_B,\theta) = C_q(\widetilde{q}_B,c) + \frac{1-K(\theta)}{k(\theta)}V_{\theta q}(\widetilde{q}_B,\theta)\,.$$

Incumbent maximizes the profit by setting $q^I = q^*$. That is, for any θ and c matched together, the incumbent sets the quantity that maximizes the totals gains from the trade of the two agents.

Now, when the entrant attracts the seller while the incumbent attracts the buyer (which happens for small gap between the information rents of buyers and sellers) incumbent's profit is

$$\Pi^I(q^I) = \int_{\theta_0}^{\theta_1}\int_{c_0}^{c_1}\left[V(q^I,\theta) - C(q^I,c) - U_B(q^I,\theta)\right]h^I(\theta,c)\,dc\,d\theta - \int_{\theta_0}^{\theta_1}\int_{c_0}^{c_1}\left[V(\widetilde{q}_S,\theta) - C_c(\widetilde{q}_S,c)\frac{G(c)}{g(c)} - C(\widetilde{q}_S,c)\right]h^E(\theta,c)\,dc\,d\theta\,,$$

where $\widetilde{q}_S$ satisfies

$$V_q(\widetilde{q}_S, \theta) = C_q(\widetilde{q}_S, c) + \frac{G(c)}{g(c)} C_{cq}(\widetilde{q}_S, c)\,.$$

In this case, incumbent maximizes its profit by setting $q^I = \widetilde{q}_B < q^*$. That is, for any buyer θ and seller c matched on the platform, the incumbent's optimal strategy is to specify a quantity below the quantity that maximizes the joint gains from trade of this particular seller and buyer. Therefore, the outcome is inefficient. As in the main model, the presence of the entrant — for small difference between the information rents of buyers and sellers — induces the incumbent to impose inefficient levels of trade.

E Proofs

Proof of Proposition 1 (page 19)

Proof. With optimal t_B^I and t_S^I given by (3), the incumbent sets F_B^I, F_S^I, and $q^I(\theta, c)$ in $Cont^I$ to maximize

$$\Pi^I(q^I) = \mathbb{E}_{\theta c}\big[V(q^I, \theta) - C(q^I, c) - U_B(q^I, c) - U_S(q^I, c)\big] + F_B^I + F_S^I$$

s.t.

$$\mathbb{E}_{\theta c}\left[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta)\right] - \mathbb{E}_{\theta c} U_B(q^I, \theta) + F_B^I + \min\{F_S^I, 0\} \leq 0\,, \tag{17}$$

$$\mathbb{E}_{\theta c}\left[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)\right] - \mathbb{E}_{\theta c} U_S(q^I, c) + F_S^I + \min\{F_B^I, 0\} \leq 0\,, \tag{18}$$

$$\mathbb{E}_{\theta c} U_B(q^I, \theta) - F_B^I \geq 0\,, \tag{19}$$

$$\mathbb{E}_{\theta c} U_S(q^I, c) - F_S^I \geq 0\,. \tag{20}$$

The first two constraints assure that the entrant cannot profit from winning the market, in that $\Pi^E(\text{attracting } B|\widetilde{q}_B, Cont^I) \leq 0$ and $\Pi^E(\text{attracting } S|\widetilde{q}_S, Cont^I) \leq 0$ respectively. The third and forth constraints assure that the two sides indeed agree to join the incumbent over the option of staying out of the market.

The plan of the proof is the following. We first establish that at least (17) or (18) has to bind. Then, we show that there is no equilibrium with both $F_B^I > 0$ and $F_S^I > 0$. Then, we characterize the incumbent's optimal pricing given that the incumbent sets $F_B^I \leq 0$. The solution for the case where $F_S^I \leq 0$ is symmetric with the seller replacing the buyer.

Starting with the first part of the proof, suppose that (17) and (18) are slack. Then, it is optimal for the incumbent to set $F_B^I = \mathbb{E}_{\theta c} U_B(q^I, \theta) > 0$ and $F_S^I = \mathbb{E}_{\theta c} U_S(q^I, c) > 0$. But then constraints (17) and (18) lead to $\mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta)] < 0$ and $\mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)] < 0$, which is a contradiction. We therefore have that at least (17) or (18) has to bind.

Next, we show that there is no equilibrium with both $F_B^I > 0$ and $F_S^I > 0$. Suppose that both $F_B^I > 0$ and $F_S^I > 0$ and suppose, without loss of generality, that $\mathbb{E}_{\theta c} U_B(q^*, \theta) < \mathbb{E}_{\theta c} U_S(q^*, c)$. Substituting $F_B^I > 0$ and $F_S^I > 0$ into (17) and (18) yields:

$$F_B^I \leq -\mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta)] + \mathbb{E}_{\theta c} U_B(q^I, \theta), \tag{21}$$

$$F_S^I \leq -\mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)] + \mathbb{E}_{\theta c} U_S(q^I, c). \tag{22}$$

Since the RHS of (21) and (22) is lower than $\mathbb{E}_{\theta c} U_B(q^I, \theta)$ and $\mathbb{E}_{\theta c} U_S(q^I, c)$ respectively, the incumbent will set F_B^I and F_S^I such that (21) and (22) hold with equality. The incumbent earns

$$\begin{aligned}
\Pi^I(q^I) &= \mathbb{E}_{\theta c}\left[V(q^I, \theta) - C(q^I, c) - U_B(q^I, c) - U_S(q^I, c)\right] + F_B^I + F_S^I \\
&= \mathbb{E}_{\theta c}\left[V(q^I, \theta) - C(q^I, c)\right] - \mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta)] \\
&\quad - \mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)].
\end{aligned}$$

Therefore, the incumbent sets $q^I = q^*$, but then

$$\begin{aligned}
F_B^I &= -\mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta)] + \mathbb{E}_{\theta c} U_B(q^*, \theta) \\
&< -\mathbb{E}_{\theta c}[V(q^*, \theta) - C(q^*, c) - U_B(q^*, \theta)] + \mathbb{E}_{\theta c} U_B(q^*, \theta) \\
&< -\mathbb{E}_{\theta c}[V(q^*, \theta) - C(q^*, c) - U_B(q^*, \theta) - U_S(q^*, c)] \\
&< 0,
\end{aligned}$$

where the first inequality follows from revealed preference, the second inequality follows because by assumption $\mathbb{E}_{\theta c} U_B(q^*, \theta) < \mathbb{E}_{\theta c} U_S(q^*, c)$ and the third inequality follows from condition (12). Therefore, it cannot be that the optimal solution involves both $F_B^I > 0$ and $F_S^I > 0$. Notice that if $\mathbb{E}_{\theta c} U_B(q^*, \theta) > \mathbb{E}_{\theta c} U_S(q^*, c)$ we can equivalently show that $F_S^I < 0$.

Next, we move to solve the case where the incumbent finds it optimal to set $F_B^I \geq 0$. Since either (17), (18) or both bind, it must be that one of the three cases occurs:

Case 1: $0 = \Pi^E(\text{attracting } B | \widetilde{q}_B, Cont^I) > \Pi^E(\text{attracting } S | \widetilde{q}_S, Cont^I)$;

Case 2: $0 =$ ^{E}(attracting Sj$\widetilde{q}_S, Cont^I) >$ ^{E}(attracting Bj$\widetilde{q}_B, Cont^I$);

Case 3: $0 =$ ^{E}(attracting Bj$\widetilde{q}_B, Cont^I$) = ^{E}(attracting Sj$\widetilde{q}_S, Cont^I$) .

The proof proceeds by considering those three cases in turn.

Case 1: 0 = ^{E}**(attracting** Bj$\widetilde{q}_B, Cont^I$**)** $>$ ^{E}**(attracting** Sj$\widetilde{q}_S, Cont^I$**)**

Suppose that ^{E}(attracting Bj$\widetilde{q}_B, Cont^I$) = 0. Then, the incumbent sets

$$F_B^I = \quad \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) \quad C(\widetilde{q}_B,c) \quad U_B(\widetilde{q}_B,\theta)\right] + \mathbb{E}_{\theta c}U_B(q^I,\theta) \quad \min f F_S^I, 0 g\,.$$

Substituting F_B^I into the incumbent's pro t function yields

$$\begin{aligned} {}^{I}(q^I) = \mathbb{E}_{\theta c}\big[V(q^I,\theta) \quad C(q^I,c) \quad U_B(q^I,\theta) \quad U_S(q^I,c)\big] + \\ \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) \quad C(\widetilde{q}_B,c) \quad U_B(\widetilde{q}_B,\theta)\right] + \mathbb{E}_{\theta c}U_B(q^I,\theta) \quad \min f F_S^I, 0 g + F_S^I. \end{aligned}$$

The pro t $^{I}(q^I)$ is independent of F_S^I for F_S^I 0 and $^{I}(q^I)$ is increasing with F_S^I for $F_S^I > 0$. Therefore, the incumbent sets the highest possible $F_S^I = \mathbb{E}_{\theta c}U_S(q^I,c)$. Substituting $F_S^I = \mathbb{E}_{\theta c}U_S(q^I,c)$ back into $^{I}(q^I)$ and rearranging yields

$${}^{I}(q^I) = \mathbb{E}_{\theta c}\big[V(q^I,\theta) \quad C(q^I,c)\big] \quad \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) \quad C(\widetilde{q}_B,c) \quad U_B(\widetilde{q}_B,\theta)\right].$$

To maximize the pro t, the incumbent will set $q^I = q^*$. The maximized pro t then is

$${}^{I}(q^*) = \mathbb{E}_{\theta c}\big[V(q^*,\theta) \quad C(q^*,c)\big] \quad \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) \quad C(\widetilde{q}_B,c) \quad U_B(\widetilde{q}_B,\theta)\right]. \tag{23}$$

Given the optimal values, and the condition that characterizes Case 1, we conclude that this solution is available to the incumbent when

$$\begin{aligned} \mathbb{E}_{\theta c}\left[V(\widetilde{q}_S,\theta) \quad C(\widetilde{q}_S,c) \quad U_S(\widetilde{q}_S,c)\right] \quad \mathbb{E}_{\theta c}U_S(q^I,c) + F_S^I + \min f F_B^I, 0 g < \\ < \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) \quad C(\widetilde{q}_B,c) \quad U_B(\widetilde{q}_B,\theta)\right] \quad \mathbb{E}_{\theta c}U_B(q^I,\theta) + F_B^I + \min f F_S^I, 0 g \end{aligned}$$

After substituting for F_B^I, F_S^I and q^I and rearranging the terms, this inequality is equivalent to

$$> \mathbb{E}_{\theta c}U_B(q^*,\theta).$$

Case 2: ^{E}**(attracting** Bj$\widetilde{q}_B, Cont^I$**)** $<$ ^{E}**(attracting** Sj$\widetilde{q}_S, Cont^I$**)** = 0

Suppose that $\quad {}^{E}$(attracting $Sj\widetilde{q}_S, Cont^I$)$=$0. Then, recalling that by assumption $F_B^I < 0$, the incumbent sets

$$F_B^I = \quad \mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) \quad C(\widetilde{q}_S, c) \quad U_S(\widetilde{q}_S, c)] + \mathbb{E}_{\theta c} U_S(q^I, c) \quad F_S^I.$$

Substituting this F_B^I into the incumbent's pro t function yields

$${}^{I}(q^I) = \mathbb{E}_{\theta c}\big[V(q^I, \theta) \quad C(q^I, c) \quad U_B(q^I, \theta)\big] \quad \mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) \quad C(\widetilde{q}_S, c) \quad U_S(\widetilde{q}_S, c)] \,.$$

Notice that $\quad {}^{I}(q^I)$ is independent of F_S^I for all F_S^I. To maximize its pro t, the incumbent sets $q^I = \widetilde{q}_B$. The maximized pro t then is

$${}^{I}(\widetilde{q}_B) = \mathbb{E}_{\theta c}\big[V(\widetilde{q}_B, \theta) \quad C(\widetilde{q}_B, c) \quad U_B(\widetilde{q}_B, \theta)\big] \quad \mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) \quad C(\widetilde{q}_S, c) \quad U_S(\widetilde{q}_S, c)] = \quad . \tag{24}$$

Substituting F_B^I and q^I into the inequality $\quad {}^{E}$(attracting $Bj\widetilde{q}_B, Cont^I$) $<$ $\quad {}^{E}$(attracting $Sj\widetilde{q}_S, Cont^I$), yields

$$\mathbb{E}_{\theta c} U_B(\widetilde{q}_B, \theta) < F_S^I \quad \mathbb{E}_{\theta c} U_S(\widetilde{q}_B, c) \quad \min f F_S^I, 0 g\,.$$

Notice that the LHS of this inequality is independent of F_S^I for $F_S^I < 0$, and increasing with F_S^I for $F_S^I > 0$. Therefore, to ensure the inequality the incumbent needs to set F_S^I as high as possible, implying that $F_S^I = \mathbb{E}_{\theta c} U_S(\widetilde{q}_B, c)$. Therefore, this solution is possible for any 0 $\quad < \mathbb{E}_{\theta c} U_B(\widetilde{q}_B, \theta)$.

Case 3: 0 $=$ $\quad {}^{E}$**(attracting** $Bj\widetilde{q}_B, Cont^I$) $=$ $\quad {}^{E}$**(attracting** $Sj\widetilde{q}_S, Cont^I$)

Notice that if the strategy that maximizes the incumbent's pro t exists when only one of the constraints (17) or (18) bind, it must yield a higher pro t than the most pro table strategy with both constraints assumed to be binding. Therefore, Case 3 is relevant only for parameters for which neither Case 1 or Case 2 solutions are available. Thus, we consider this case only for such $\quad$ where $\mathbb{E}_{\theta c} U_B(\widetilde{q}_B, \theta) \quad \quad \mathbb{E}_{\theta c} U_B(q^*, \theta)$.

To solve case 3, we follow the solution to case 1 in which

$$F_B^I = \quad \mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) \quad C(\widetilde{q}_B, c) \quad U_B(\widetilde{q}_B, \theta)] + \mathbb{E}_{\theta c} U_B(q^I, \theta)$$

and $F_S^I = \mathbb{E}_{\theta c} U_S(q^I, c)$, and add the Lagrangian multiplier to the additional constraint that ^{E}(attracting $Sj\widetilde{q}_S, Cont^I$) $\quad$ 0 (an equivalent way is to follow Case 2 and add the Lagrangian multiplier to the constraint that $\quad {}^{E}$(attracting $Bj\widetilde{q}_B, Cont^I$) $\quad$ 0). Substituting $F_B^I = \quad \mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) \quad C(\widetilde{q}_B, c) \quad U_B(\widetilde{q}_B, \theta)] + \mathbb{E}_{\theta c} U_B(q^I, \theta)$ and $F_S^I = \mathbb{E}_{\theta c} U_S(q^I, c)$ into

^{E}(attracting $Sj\widetilde{q}_S, Cont^I$) 0 requires that $\mathbb{E}_{\theta c}U_B(q^I,\theta)$ 0. Given this constraint, the incumbent pro t can be expressed as

$$ ^I(q^I) = \mathbb{E}_{\theta c}\big[V(q^I,\theta) \quad C(q^I,c)\big] \quad \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) \quad C(\widetilde{q}_B,c) \quad U_B(\widetilde{q}_B,\theta)\right] + \lambda[\quad \mathbb{E}_{\theta c}U_B(q^I,\theta)] ,$$

where λ is the Lagrange multiplier. Di erentiating with respect to q^I and λ yields following conditions for the optimal $\widetilde{\widetilde{q}}_\Delta$ and λ:

$$V_q(\widetilde{\widetilde{q}}_\Delta,\theta) \quad C_q(\widetilde{\widetilde{q}}_\Delta,c) \quad \lambda\frac{1 \quad F(\theta)}{f(\theta)}V_{\theta c}(\widetilde{\widetilde{q}}_\Delta,\theta) = 0\,, \tag{25}$$

$$\mathbb{E}_{\theta c}U_B(\widetilde{\widetilde{q}}_\Delta,\theta) = 0\,.$$

We turn to establishing that the optimal solution involves 0 λ 1 and q^* $\widetilde{\widetilde{q}}_\Delta$ $\widetilde{q}_B$. To see why, suppose rst that $= \mathbb{E}_{\theta c}U_B(q^*,\theta)$. Then, it is easy to see that the solution to the two equations above is at $\widetilde{\widetilde{q}}_\Delta = q^*$ and $\lambda = 0$. As decreases below $\mathbb{E}_{\theta c}U_B(q^*,\theta)$, the constraint $= \mathbb{E}_{\theta c}U_B(\widetilde{\widetilde{q}}_\Delta,\theta)$ requires that $\widetilde{\widetilde{q}}_\Delta$ decreases below q^*. This is because by assumption $V_{q\theta} > 0$, and therefore $\mathbb{E}_{\theta c}\left[U_B(q,\theta)\right]$ is increasing in q. At the same time, for $< \mathbb{E}_{\theta c}U_B(q^*,\theta)$ the condition (25) requires that λ increases above 0. This is because the LHS of (25) is decreasing with λ, and therefore the q that solves (25) is decreasing with λ.

For $= \mathbb{E}_{\theta c}U_B(\widetilde{q}_B,\theta)$, the constraint $= \mathbb{E}_{\theta c}U_B(\widetilde{\widetilde{q}}_\Delta,\theta)$ requires that $\widetilde{\widetilde{q}}_\Delta = \widetilde{q}_B$, while the condition (25) requires that $\lambda = 1$. This is because by de nition $q = \widetilde{q}_B$ is the solution to $V_q(q,\theta) \quad C_q(q,c) \quad 1 \quad \frac{1-F(\theta)}{f(\theta)}V_{\theta c}(q,\theta) = 0$. Therefore, it must be that 1 λ 0, q^* $\widetilde{\widetilde{q}}_\Delta$ $\widetilde{q}_B$, and $\widetilde{\widetilde{q}}_\Delta$ is decreasing with , while λ is decreasing with . Moreover, in the optimal solution (17), (18) and (20) bind only if $\mathbb{E}_{\theta c}U_B(\widetilde{q}_B,\theta)$ $\mathbb{E}_{\theta c}U_B(q^*,\theta)$. When this is the case, the incumbent earns

$$ ^I(\widetilde{\widetilde{q}}_\Delta) = \mathbb{E}_{\theta c}\big[V(\widetilde{\widetilde{q}}_\Delta,\theta) \quad C(\widetilde{\widetilde{q}}_\Delta,c)\big] \quad \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) \quad C(\widetilde{q}_B,c) \quad U_B(\widetilde{q}_B,\theta)\right] .$$

To sum up the three possible cases, we conclude that:

For $> \mathbb{E}_{\theta c}U_B(q^*,c)$ the optimal solution for the incumbent falls into Case 1. The incumbent sets $q^I = q^*$, $F_B^I =$ $\mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) \quad C(\widetilde{q}_B,c) \quad U_B(\widetilde{q}_B,\theta)\right] + \mathbb{E}_{\theta c}U_B(q^*,\theta) <$ 0, and $F_S^I = \mathbb{E}_{\theta c}U_S(q^*,c) > 0$, and induces the entrant to set $q^E = \widetilde{q}_B$ and to attract the buyer's side. The entrant earns zero pro ts, while the incumbent earns

$$ ^I(q^*) = \mathbb{E}_{\theta c}\big[V(q^*,\theta) \quad C(q^*,c)\big] \quad \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) \quad C(\widetilde{q}_B,c) \quad U_B(\widetilde{q}_B,\theta)\right] .$$

For 0 $< \mathbb{E}_{\theta c} U_B(\widetilde{q}_B, c)$ the optimal solution for the incumbent falls into Case 2. The incumbent sets $q^I = \widetilde{q}_B$, $F^I_B = \quad \mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) \quad C(\widetilde{q}_S, c) \quad U_S(\widetilde{q}_S, c)] < 0$, and $F^I_S = \mathbb{E}_{\theta c} U_S(\widetilde{q}_B, c) > 0$, and induces the entrant to set $q^E = \widetilde{q}_S$ and to attract the seller's side. The entrant earns zero pro ts, while the incumbent earns $^I(\widetilde{q}_B) =$.

For $\mathbb{E}_{\theta c} U_B(\widetilde{q}_B, \theta) \qquad \mathbb{E}_{\theta c} U_B(q^*, \theta)$ the only available solution is Case 3. The incumbent sets $q^I = \tilde{\tilde{q}}_\Delta$, $F^I_B = \quad \mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) \quad C(\widetilde{q}_B, c) \quad U_B(\widetilde{q}_B, \theta)] + \mathbb{E}_{\theta c} U_B(\tilde{\tilde{q}}_\Delta, \theta) <$ 0 and $F^I_S = \mathbb{E}_{\theta c} U_S(\widetilde{q}_B, c) > 0$ and the entrant is indi erent between setting $q^E = \widetilde{q}_B$ and attracting the buyer, or setting $q^E = \widetilde{q}_S$ and attracting the seller. The entrant earns zero and the incumbent earns

$$^I(\tilde{\tilde{q}}_\Delta) = \mathbb{E}_{\theta c}\left[V(\tilde{\tilde{q}}_\Delta, \theta) \quad C(\tilde{\tilde{q}}_\Delta, c)\right] \quad \mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) \quad C(\widetilde{q}_B, c) \quad U_B(\widetilde{q}_B, \theta)] .$$

This completes the proof of Proposition 1. ■

Proof of Corollary 1 (page 25)

Proof. Since $\mathbb{E}_\theta U_B(q, \theta) = 0$, then formula (7) becomes

$$\mathbb{E}_{\theta c}[V(q_B, \theta) \quad C(q_B, c) \quad U_B(q_B, c)] = \mathbb{E}_{\theta c}[V(q_B, \theta) \quad C(q_B, c)] ,$$

and it is maximized by $\widetilde{q}_B = q^*$.

For $\;> 0$, $\;> \mathbb{E}_\theta U_B(q, \theta)$, and case (i) of Proposition 1 applies. But since $\widetilde{q}_B = q^*$ and $\mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) \quad C(\widetilde{q}_B, c) \quad U_B(\widetilde{q}_B, c)] = \mathbb{E}_{\theta c}[V(q^*_B, \theta) \quad C(q^*_B, c)]$, then $q^I = q^E = q^*$ and both platforms' pro ts are 0.

For $\;= 0$, $\;= \mathbb{E}_\theta U_B(q, \theta)$, and the special case of (iii) in Proposition 1 applies. It yields the same result. ■

Proof of Proposition 2 (page 28)

Proof. The incumbent's objective is to maximize

$$^{I}(q^I) = \mathbb{E}_{\theta c}\big[V(q^I,\theta) \quad C(q^I,c) \quad U_B(q^I,\theta) \quad U_S(q^I,c)\big] + F_B^I + F_S^I$$

$$s.t.$$

$$\mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) \quad C(\widetilde{q}_B,c) \quad U_B(\widetilde{q}_B,\theta)\right] \quad \mathbb{E}_{\theta c}U_B(q^I,\theta) + F_B^I \quad 0, \tag{26}$$

$$\mathbb{E}_{\theta c}\left[V(\widetilde{q}_S,\theta) \quad C(\widetilde{q}_S,c) \quad U_S(\widetilde{q}_S,c)\right] \quad \mathbb{E}_{\theta c}U_B(q^I,\theta) + F_B^I \quad 0, \tag{27}$$

$$\mathbb{E}_{\theta c}U_B(q^I,\theta) \quad F_B^I \quad 0, \tag{28}$$

$$\mathbb{E}_{\theta c}U_S(q^I,c) \quad F_S^I \quad 0. \tag{29}$$

As follows from the entrant's decision which side to attract, regardless of the incumbent's strategy, if $\ > 0$, then constraint (26) is binding while (27) is slack. Likewise, if $\ < 0$, then constraint (27) is binding while (26) is slack. Moreover, in both cases the incumbent uses F_B^I for imposing zero profit on the entrant and therefore would like to set F_S^I as high as possible implying that (29) also binds while (28) is slack.

(i) Substituting (29) and (26) with equality for the case of $\ > 0$ into the incumbent's profit and solving leads us directly to the result in Proposition 2.

(ii) For the case of $\ < 0$, (29) and (27) are substituted with equality into the incumbent's profit.

This completes the proof of Proposition 2. ■

Proof of Lemma 2 (page 29)

Proof. We first show that the incumbent earns higher profit under multi-homing than under single-homing. Suppose first that $0 < \ < \mathbb{E}_{\theta c}\left[U_B(\widetilde{q}_B,\theta)\right]$. Under single-homing, the incumbent earns

$$
\begin{aligned}
&= \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) \quad C(\widetilde{q}_B,c) \quad U_B(\widetilde{q}_B,\theta)\right] \quad \mathbb{E}_{\theta c}\left[V(\widetilde{q}_S,\theta) \quad C(\widetilde{q}_S,c) \quad U_S(\widetilde{q}_S,c)\right] \\
&< \mathbb{E}_{\theta c}\left[U_B(\widetilde{q}_B,\theta)\right] \\
&\quad \mathbb{E}_{\theta c}\left[U_B(\widetilde{q}_B,\theta)\right] + \mathbb{E}_{\theta c}\left[V(q^*,\theta) \quad C(q^*,c)\right] \quad \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) \quad C(\widetilde{q}_B,c)\right] \\
&= \mathbb{E}_{\theta c}\left[V(q^*,\theta) \quad C(q^*,c)\right] \quad \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B,\theta) \quad C(\widetilde{q}_B,c) \quad U_B(\widetilde{q}_B,\theta)\right],
\end{aligned}
$$

where the first inequality follows because by assumption $< \mathbb{E}_{\theta c}[U_B(\widetilde{q}_B, \theta)]$ and the second inequality follows because by definition q^* maximizes $\mathbb{E}_{\theta c}[V(q, \theta) - C(q, c)]$ and the last term is the incumbent's profit from multi-homing. Next suppose that $\mathbb{E}_{\theta c}[U_S(\widetilde{q}_S, c)] < \quad < 0$. Under single-homing, the incumbent earns

$$
\begin{aligned}
&= \mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)] - \mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta)] \\
&< \mathbb{E}_{\theta c}[U_S(\widetilde{q}_S, c)] \\
&\quad \mathbb{E}_{\theta c}[U_S(\widetilde{q}_S, c)] + \mathbb{E}_{\theta c}[V(q^*, \theta) - C(q^*, c)] - \mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c)] \\
&= \mathbb{E}_{\theta c}[V(q^*, \theta) - C(q^*, c)] - \mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)],
\end{aligned}
$$

where again the first inequality follows because by assumption $< \mathbb{E}_{\theta c}[U_S(\widetilde{q}_S, c)]$ and the second inequality follows because by definition q^* maximizes $\mathbb{E}_{\theta c}[V(q, \theta) - C(q, c)]$ and the last term is the incumbent's profit from multi-homing.

Next, we show that given that the incumbent sets the multi-homing strategies, the entrant will impose exclusive dealing and dominate the market with a positive profit. Suppose first that $0 < \quad < \mathbb{E}_{\theta c}[U_B(\widetilde{q}_B, \theta)]$. Under multi-homing, the incumbent sets: $q^I = q^*$, $F_B^I = -\mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta)] + \mathbb{E}_{\theta c} U_B(q^*, \theta)$ and $F_S^I = \mathbb{E}_{\theta c} U_S(q^*, c)$. If the entrant does not impose exclusivity then the entrant earns zero profit. Suppose however that the entrant imposed exclusivity on the seller. Then, the entrant can attract the seller by charging:

$$F_S^E \gtrsim -F_S^I + \mathbb{E}_{\theta c} U_S(q^*, c) = 0 \Rightarrow F_S^E = 0.$$

Given that the seller now moves exclusively to the entrant, the entrant can charge the buyer

$$\mathbb{E}_{\theta c} U_B(q^E, \theta) - F_B^E \gtrsim \min\{-F_B^I, 0\} \Rightarrow F_B^E = \mathbb{E}_{\theta c} U_B(q^E, \theta) + \min\{F_B^I, 0\}.$$

The entrant earns

$$^{E}(\text{attracting } S|q^E) = \mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)] + \min\{F_B^I, 0\}.$$

If $F_B^I = -\mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta)] + \mathbb{E}_{\theta c} U_B(q^*, \theta) > 0$, then the entrant earns $\mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)] > 0$. If $F_B^I = -\mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta)] +$

$\mathbb{E}_{\theta c} U_B(q^*, \theta) < 0$, then the entrant earns:

$$\begin{aligned}
\Pi^E(\text{attracting } S|q^E) &= \mathbb{E}_{\theta c}\left[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)\right] + \min\{F_B^I, 0\} \\
&= \mathbb{E}_{\theta c}\left[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)\right] - \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_B(\widetilde{q}_B, \theta)\right] + \mathbb{E}_{\theta c} U_B(q^*, \theta) \\
&= \mathbb{E}_{\theta c}[U_B(q^*, \theta)] - \Delta \\
&> \mathbb{E}_{\theta c}\left[U_B(\widetilde{q}_B, \theta)\right] - \Delta \\
&> 0,
\end{aligned}$$

where the first inequality follows because $\mathbb{E}_{\theta c}[U_B(q^*, \theta)] > \mathbb{E}_{\theta c}\left[U_B(\widetilde{q}_B, \theta)\right]$ and the second inequality follows because by assumption $< \mathbb{E}_{\theta c}\left[U_B(\widetilde{q}_B, \theta)\right]$.

Next suppose that $\mathbb{E}_{\theta c}\left[U_S(\widetilde{q}_S, c)\right] < \quad < 0$. Under multihoming the incumbent sets: $q^I = q^*$, $F_B^I = -\mathbb{E}_{\theta c}\left[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)\right] + \mathbb{E}_{\theta c} U_B(q^*, \theta)$ and $F_S^I = \mathbb{E}_{\theta c} U_S(q^*, c)$. If the entrant does not impose exclusivity then the entrant earns zero profit. Suppose however that the entrant imposed exclusivity on the seller. Then, the entrant can attract the seller by charging

$$F_S^E \gtrapprox -F_S^I + \mathbb{E}_{\theta c} U_S(q^*, c) = 0 \implies F_S^E = 0.$$

Given that the seller now moves exclusively to the entrant, the entrant can charge the buyer

$$\mathbb{E}_{\theta c} U_B(q^E, \theta) - F_B^E \gtrapprox -\min\{-F_B^I, 0\} \implies F_B^E = \mathbb{E}_{\theta c} U_B(q^E, \theta) + \min\{F_B^I, 0\}.$$

The entrant earns

$$\Pi^E(\text{attracting } S|q^E) = \mathbb{E}_{\theta c}\left[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_S(\widetilde{q}_S, c)\right] + \min\{F_B^I, 0\}.$$

If $F_B^I = -\mathbb{E}_{\theta c}\left[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)\right] + \mathbb{E}_{\theta c} U_B(q^*, \theta) > 0$, then the entrant earns $\mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) - C(\widetilde{q}_B, c) - U_S(\widetilde{q}_S, c)] > 0$. If $F_B^I = -\mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)] + \mathbb{E}_{\theta c} U_B(q^*, \theta) < 0$, then the entrant earns

$$\begin{aligned}
\Pi^E(\text{attracting } S|q^E) &= \mathbb{E}_{\theta c}\left[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)\right] + \min\{F_B^I, 0\} \\
&= \mathbb{E}_{\theta c}\left[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)\right] - \mathbb{E}_{\theta c}\left[V(\widetilde{q}_S, \theta) - C(\widetilde{q}_S, c) - U_S(\widetilde{q}_S, c)\right] + \mathbb{E}_{\theta c} U_B(q^*, \theta) \\
&= \mathbb{E}_{\theta c}[U_B(q^*, \theta)] \\
&> 0.
\end{aligned}$$

This completes the proof of Lemma 2. ■

Proof of Proposition 3 (page 30)

Proof.

(i) Suppose that $0 < \quad < \mathbb{E}_{\theta c}[U_B(\widetilde{q}_B, \theta)]$. Given that the incumbent expects the entrant to impose exclusive dealing, the incumbent's optimal strategies is to set the single-homing strategies: $F_B^I = \quad \mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) \quad C(\widetilde{q}_S, c) \quad U_S(\widetilde{q}_S, c)]$, and $F_S^I = \mathbb{E}_{\theta c} U_S(\widetilde{q}_B, c)$. To show that given these strategies the entrant imposes exclusive dealing, substituting them into the entrant's multi-homing pro t yields

$$
\begin{aligned}
{}^E(\text{attracting } Bj\widetilde{q}_B) &= \mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) \quad C(\widetilde{q}_B, c) \quad U_B(\widetilde{q}_B, \theta)] + F_B^I \quad \mathbb{E}_{\theta c} U_B(\widetilde{q}_B, \theta) \\
&= \qquad \mathbb{E}_{\theta c} U_B(\widetilde{q}_B, \theta) \\
&< 0,
\end{aligned}
$$

where the last inequality follows from the assumption that $\quad < \mathbb{E}_{\theta c}[U_B(\widetilde{q}_B, \theta)]$. If the entrant imposes exclusive dealing, Proposition 2 implies that the entrant earns zero pro t. Between these two options, the entrant will therefore choose to impose exclusive dealing.

(ii) Next, suppose that $\quad \mathbb{E}_{\theta c}[U_S(\widetilde{q}_S, c)] < \quad < 0$. Given that the incumbent expects the entrant to impose exclusive dealing, the incumbent's optimal strategies is to set the single-homing strategies: $F_B^I = \mathbb{E}_{\theta c} U_B(\widetilde{q}_S, \theta)$ and $F_S^I = \quad \mathbb{E}_{\theta c}[V(\widetilde{q}_B, \theta) \quad C(\widetilde{q}_B, c) \quad U_B(\widetilde{q}_B, \theta)]$. To show that given these strategies the entrant does not impose exclusive dealing, substituting them into the entrant's multi-homing pro t yields

$$
\begin{aligned}
{}^E(\text{attracting } Sj\widetilde{q}_S) &= \mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) \quad C(\widetilde{q}_S, c) \quad U_S(\widetilde{q}_S, c)] + F_B^I \quad \mathbb{E}_{\theta c} U_B(\widetilde{q}_S, \theta) \\
&= \mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) \quad C(\widetilde{q}_S, c) \quad U_S(\widetilde{q}_S, c)] + \mathbb{E}_{\theta c} U_B(\widetilde{q}_S, \theta) \quad \mathbb{E}_{\theta c} U_B(\widetilde{q}_S, \theta) \\
&= \mathbb{E}_{\theta c}[V(\widetilde{q}_S, \theta) \quad C(\widetilde{q}_S, c) \quad U_S(\widetilde{q}_S, c)] > 0.
\end{aligned}
$$

Consequently, the entrant will not nd it optimal to impose exclusive dealing. This implies that in addition to setting the single-homing strategies, the incumbent will have to impose exclusivity.

This completes the proof of Proposition 3. ■

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