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DISCLOSURE-BASED PRICE DISCRIMINATION BY INFORMATION EXCHANGE PLATFORMS

PINGJING BO AND AGOSTINO MANDUCHI

ABSTRACT. Consumers often face a trade off when considering whether to share more information with firms - for example, by letting an app access their list of contacts, location or browsing history. More precise information can help the sellers to make more targeted offers, and can yield multiple relevant offers and lower prices. However, information disclosure can entail costs via identity theft, fraud, extortion etc. In this paper, we explore this trade-off in a model in which a monopoly platform can gather personal customer information, and offer it to other sellers. The consumers differ relatively to their aversion to information disclosure, and the platform can offer them menus with different disclosure levels. In equilibrium, options featuring greater disclosure levels command a premium, and information about the consumers choosing them is sold to the sellers at a lower price. If we compare scenarios with alternative menus, a greater number of options corresponds to a greater average disclosure level and a greater surplus. If the potential surplus from the induced exchanges is relatively large, equilibrium with a binary menu features levels of the platform's profit and the surplus close to those achieved with a continuum of offers.

Keywords: Information disclosure, Consumer privacy, Price discrimination

JEL classification codes: C72, D43, L13.

1. INTRODUCTION

1.1. Motivation and results. Consumers often face a trade off when considering whether to share information with firms - concerning for example their geographic location, gender, age, address and hobbies - when making purchases. Better information can help the sellers to make more targeted offers, and can yield offers from multiple firms and better prices. However, information disclosure can entail losses of different types. The mere awareness of information disclosure may cause discomfort, and giving details on purchases of embarrassing products or medical procedures may not only cause additional disutility but may have unintended consequences (Acquisti, 2010). Third parties may use sensitive information to identify vulnerable “trails,” either physical or virtual, and use them to carry out crimes, possibly in the form of identity theft (Anderson, Durbin and Salinger, 2008; IdentityTheft.com, 2013); these risks may be especially serious in the case of location-based services and other apps that broadcast very precise information about the user's physical location. Unsolicited recommendations may be “annoying” (Goldstein, Suri, McAfee, Ekstrand-Abueg and Diaz, 2014), and loading online advertisements and their trackers can slow down sites navigation. Both the costs and the risks faced and the opportunities to avoid them can depend on personal characteristics such as education, occupation, wealth, and tech-savviness (Liao, Liu and Chen, 2011; Tucker, 2012).

In this paper, we explore the trade-off between the benefits and the losses from information disclosure in a model in which a platform offering a product (or service) can obtain personal information about its customers, and sell it to other producers. More refined information is a

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more effective facilitator of further exchanges - and thus entails a social benefit, potentially - and boosts competition among the sellers using it. However, the consumers also face an idiosyncratic, privately known nuisance from disclosure whose size is positively related to the amount of information disclosed. The platform can use menus with different combinations of disclosure levels and prices. We consider alternative scenarios in which the consumers face menus with one option, two options and a continuum of options, and focus the incentives for the platform to offer menus with more options and on market distortions.

We find that menus with a greater number of options are associated with higher average disclosure levels and greater levels of the surplus generated by the exchanges, net of the disclosure losses. The surplus- and profit-losses with a two option-menu are however small, at least if the potential surplus is large - in line with the findings of the literature on “small menus” (Bergemann, Shen, Xu and Yeh , 2015; Wong , 2014) - and could be offset by the costs potentially associated with more complex contracts. The consumers choosing options with higher disclosure levels pay higher prices, whereas the sellers pay lower prices for the information gathered about them. If the platform can only partly appropriate the profits from the induced exchanges, the numerical results in Appendix A reveal that a lower proportional participation typically entails more differentiated disclosure levels, and that the average disclosure level can be non-monotonic.

The profit and surplus losses with fewer options are partly an expression of the Spence (1975) externality: As each option must exactly satisfy the participation constraint of the consumer choosing it who is most averse to disclosure, the equilibrium disclosure level or levels is/are typically too low. Moreover, greater disclosure levels boost the effects of the consumers’ dispersed nuisance parameters, and make it more difficult for the platform to appropriate the consumers’ gains from the induced exchanges. By contrast, lower disclosure levels can reduce competition and increase the profits of the sellers who purchase consumer information, which the platform can appropriate. Menus with a greater number of options improve the situation on both counts, by allowing the platform to offer better tailored options to different groups of consumers.

Our results reflect the fact that in the present model - unlike in the more traditional models of platforms linking *monopolist* sellers and consumers (Anderson and Gabszewicz , 2006) - a greater disutility for the consumers corresponds not only to a greater (expected) number of relevant offers, but also a greater probability of multiple, *competing* offers, with potentially unrestricted competition among the sellers. Hence, the model presented in the present paper can better account for cases in which fees, subscriptions or other forms of payment allow the consumers to obtain more qualified offers, rather than to avoid advertisements.

We relate our results to the contractual arrangements used by digital platforms which can gather information about their customers. Typically, these firms offer to the consumers multi-tier menus of service level and prices. In 2005, Amazon launched *Amazon Prime*, a premium service whose subscribers receive discounted offers on selected products, special delivery terms, and music and video streaming services. Since 2013, Google has offered *Google Express*, a premium shopping and delivery service mainly aimed at linking the consumers with local merchants. In both cases, service-specific apps are used as mobile interfaces. Google Express is viewed by many as a tool to solidify Google’s position in the search engines market, particularly in the case of searches related to products and services. In a 2014 speech, Google’s chairman Eric Schmidt explicitly stated that “our biggest search competitor is Amazon [...] if you are looking for something to buy, you are more often than not looking for it on Amazon” (Slate , 2014).

The information provided by the users’ activities can easily be parsed together with other personal information, and can be used by these platforms to provide more valuable search results. Organic results are typically the main driver of web-traffic (Search Engine Watch , 2014). High quality organic links can however make sponsored links less appealing, and platforms funded by advertising can therefore deliberately suggest socially sub-optimal

organic links ([Burguet, Caminal and Ellman , 2015](#)), also in the presence of competition between platforms ([Taylor , 2013](#)). Even the choice of the sponsored links proposed may be inefficient ([de Cornière , 2016](#); [Karle and Peitz , 2016](#)), possibly even if a fee is charged to the consumers ([Hagiu and Jullien , 2011](#)). The reputational incentive created by subscriptions can counter the effects leading to these distortions, and induce the platform to fully lever on the information available to recommend valuable organic links to their premium customers. As of 2016, Amazon Prime had over 66 million of US-based subscribers, corresponding to over half of the total number of users ([Recode , 2017](#); [Statista , 2016](#)). These numbers, together with a double digit-growth rate and a renewal rate greater than 90% ([Pymnts.com , 2016](#)), testify the popularity of this bundle of services, and can motivate future empirical research on the performance of informational platforms for different balances of various sources of revenues. A model of information provision with subscriptions does have a counterpart in more traditional settings. For example, many supermarket chains offer membership cards, which allow them to acquire information about their customers and to propose special offers. Also, the readers in many magazine segments are willing to pay a premium for informative advertisements ([Kaiser and Song , 2009](#)).

In the equilibrium of our model, the sellers actually pay a (low) positive price even for the information related the consumers who choose to disclose more information. Organic results could however be incorporated in the model with relative ease - and with no substantial effects on the results, within limits. The possibility of manipulative information provision by the platform, as in the papers on seller-funded platforms cited above, could be explored in future research. The use of pricing models designed to elicit a substantial fraction of the revenues from the consumers could be facilitated by a shared measure of the consumers' gains. The lack of a counterpart to measures such as the number of contacts established, providing the basis for the price charged to the sellers in the "pay per click" format, could therefore be an obstacle, and the platform's reputation could be especially important for the consumers. A further obstacle, in the case of digital platforms, could be represented by the consumers' reluctance to pay for online services - which however is not a significant factor for all groups of consumers.

Other platforms could charge their users for disclosure. Sports and performing arts agents, relocation agents and head-hunters could also be able to gather a greater number of offers by disclosing additional information about the parties represented, and to charge their clients accordingly.¹ In cases such as location-based services, the disclosure fees may be incorporated in the price of add-ons providing enhanced tracking opportunities, such as bracelets and dedicated apps.

If we relate the consumer disutility to the costs of processing advertisements, the insights of the paper can also be relevant in the case of advertisements presented to non-premium users - representing over 95% of the users of services such as *Dropbox*, *Evernote* and *Google Drive* ([Process.st , 2016](#)). The revenues from these advertisements are threatened by ad-blockers, which may force the platforms to increase the advertising exposure of the more tolerant users, and may thereby create a vicious circle ([Anderson and Gans , 2011](#); [Johnson , 2013](#)). In this situation, we seem to observe a trend toward a growing fraction of skippable advertisements - see for example [Search Engine Journal \(2017\)](#); [TechCrunch \(2017\)](#). Considering the conclusions of the present paper, displaying skippable advertisements by competing sellers, which would be especially appealing for the low nuisance-users, could help the platforms to profitably screen their users. Exposure to advertisements that are either non-skippable, or not followed by advertisements for competing products could then effectively be the "price" charged for the exposure to valuable advertisements. Under this interpretation, skippable advertisements could be expected to be more often related to competing product, and to be sold at lower prices.

¹We thank an anonymous referee for suggesting these examples.

1.2. Related literature. Casadesus-Masanell and Hervas-Drane (2015) consider a duopoly market whereby the consumers can disclose information allowing the sellers to offer them more valuable products. The duopolists can offer the information to other sellers, and thereby possibly harm the consumers. Unlike in the present paper, the valuations for the products - rather than the disclosure losses - are idiosyncratic, and the price of the information is exogenous. Their focus is on the implications of consumer privacy from the point of view of competition, whereas our focus is on price menus.

Hann, Hui, Lee and Png (2008) investigate a model in which some monopolists market their products through solicitations which entail a disutility for the consumers, and the consumers can resort to alternative forms of marketing avoidance. The parties interact directly, and prior commitments concerning the intensity of the marketing effort are not possible. Anderson and de Palma (2009, 2012) and Van Zandt (2004) investigate models in which the senders of messages compete for the receivers' limited attention, and consider alternative arrangements such as a tax on the messages sent, a gatekeeper and legal restrictions. Our sellers of generic products and our buyers could be viewed as the senders and the receivers of these models, respectively; however, the agents in our model face no cognitive limitations. Acquisti and Varian (2005) and Taylor (2004) investigate models in which each buyer's valuations for different products are positively correlated, and some prices may be set taking into account the information revealed by the buyers' decisions. They also consider cases in which the buyers are not aware of the informational consequences of their decisions.

Bergemann and Bonatti (2015) focus on the pricing strategies of a data-provider selling a given amount of personal information to other firms, and consider also bundling and non-linear prices. Ghosh and Roth (2015) characterize incentive-compatible auction mechanisms that can be used to purchase information from individuals facing privately known disclosure losses. Li and Raghunathan (2014) characterize an incentive-compatible mechanism that a data-provider could use to sell personal information, in the presence of a risk of inappropriate use. In the present paper, we consider the problems faced by the consumers, the sellers and the platform, and endogenize the intensity of competition in the product market.

1.3. Plan of the paper. The model is described in Section 2. Section 3 focuses on the equilibrium in the case in which the platform makes two offers to the consumers. Section 4 considers surplus maximization with two offers and the equilibria with one offer and with a continuum of offers. The results for the different scenarios are compared and discussed in Section 5. Section 6 contains some concluding remarks. Appendix A presents our numerical results for the case in which the platform's appropriation of the sellers' profits is only partial. All proofs are in Appendix B.

2. THE MODEL

The model features:

- (1) A continuum of *consumers* with finite measure, normalized to 1.
- (2) A *platform* which can obtain information about the consumers' preferences by selling a product (or service) to them.
- (3) A continuum of (*generic*) *sellers*, also with unit measure, who can use the consumers' personal information to market their products.

All agents are risk-neutral. The platform's product is produced in indivisible units at the constant unit cost of 0. Each consumer has unit demand for the product, and derives a payoff $v_M > 0$ from its consumption. We make the standard "covered market" assumption of a suitably large value of v_M , such that all consumers do purchase the product, in each scenario that we consider. The covered market assumption essentially allows us to by-pass the comparison between solutions with a fully and a partly covered market in Lemma 2 and in Propositions 2 and 3. In principle, a low value of v_M could make menus with a greater number of options, which soften this trade-off, more profitable and more efficient.

An offer ϕ is a pair (δ_ϕ, p_ϕ) , where $\delta_\phi \geq 0$ is the *disclosure level* and p_ϕ is the *price*. A larger value of δ_ϕ corresponds to more precise information made available to the sellers, which can in turn make it easier to identify both the products of interest and also the vulnerabilities of each consumer. The platform is committed to the terms announced; the price may be lower than the valuation v_M , and possibly negative, to strengthen the incentive to disclose information. We consider the cases of one offer, two offers and a continuum of offers. Variables referred to the single offer-case carry the subscript S . In the case of two offers, we use the subscripts H and L , and assign them in such a way that offer H features the higher disclosure level, namely $\delta_H \geq \delta_L$, with no loss of generality. In the continuum case, offers are directly indexed by the reported consumer type θ . We always use Φ to denote the set of the offers.

Each generic seller offers indivisible units of a single product. As in the case of the platform, we assume unit demand and a cost of 0. The consumers' valuations are equal either to 0 or to $v_G > 0$. Ideally, we could think that the set of the sellers is partitioned into subsets of identical size, and that the sellers in each subset offer the product of choice of a set of consumers with the same size. Given the agents' risk-neutrality, increases in v_G may also be interpreted as increases in the number of products of interest for each consumer, under the given matching routine, if the valuations are independent across products.

Each seller can purchase information from the platform and use it to contact some consumers who have a positive valuation for her product. We postulate a random routine under which a consumer willing to disclose more refined information receives a greater number of offers, in expectation. In particular, we posit a Poisson distributional form: Each consumer choosing offer ϕ receives $k = 0, 1, 2, \dots$ offers for her product of choice with probability $\mu_k = \frac{e^{-\delta_\phi \eta} (\delta_\phi \eta)^k}{k!}$. The exogenous parameter $\eta > 0$ captures technical efficiency, and measures the expected number of sellers of a valuable product who contact the consumers, per unit of information disclosed. Thus, the market for generic products is competitive, at least potentially, and the sellers cannot co-ordinate their marketing activities so as to avoid overlaps.

The links between the sellers and the consumers can only be established through the information provided by the platform. If this information makes it possible to finalize a transaction, in the base model the platform captures the whole profit. In the extension studied in Appendix A, we allow for the platform to only capture a fraction ξ of the profit, where $0 < \xi \leq 1$. We assume - with no loss of generality, given risk-neutrality - that the price of the information is paid by the seller to the platform upon purchase, and is calculated on the basis of the expected profit.

The sellers set the prices of their products. The price charged to each consumer can be made conditional on how much information the consumer chose to disclose to the platform. As we shall see, the choice of the high disclosure-offer entails a lower expected transaction price, due both to the greater number of offers received and to the more aggressive pricing strategies used by the sellers. The former effect does not rely on price-discrimination, which is thus not critical for our results.

The platform can prevent each seller from sharing the information purchased with other sellers. To achieve this goal, the platform could disclose information in a seller-specific format - for example by indicating to each seller some specific consumers of interest, rather than by providing more general information. The platform cannot impose any price or range of prices at which the sellers' products should be offered to the consumers.

A consumer choosing offer ϕ bears a direct utility loss $\delta_\phi \theta$, where the *nuisance parameter* θ is uniformly distributed over the interval $[0, 1]$, and is independent of the consumers' preferences for generic products. This modelling strategy builds on [Anderson and Coate \(2005\)](#), and provides a tractable way to model the effect of different disclosure levels, ranked by taking into account the type of information that can be collected and the use that can be made of it. Technically, we consider the model in [Mussa and Rosen \(1988\)](#), where

consumers are differentiated along the “vertical” dimension. In the present case, the vertical differentiation parameter θ accounts for the importance of a source of *negative* utility, namely disclosure. Hence, the preference for higher quality should be understood in the sense that the higher types are willing to pay a higher price, and/or to surrender a greater amount of consumer surplus, to *avoid* any given level of disclosure.

The expected surplus that a consumer choosing offer ϕ in Φ realizes in the market for generic products, net of the price paid to the seller, is denoted by β_ϕ . The net expected payoff for a consumer of type θ who chooses an offer ϕ is

$$u_\theta(\phi) = v_M - p_\phi - \delta_\phi \theta + \beta_\phi. \quad (1)$$

A consumer who turns down all offers receives a reservation payoff of 0, regardless of her type. All agents can fully evaluate the payoff consequences of their decisions.

The timing is as follows:

- (1) The platform makes its offers to the consumers.
- (2) Each consumer decides whether to accept one of the offers, and to thereby purchase the platform’s product, or not.
- (3) The platform sells the information gathered to the sellers.
- (4) The transactions in the market for generic products are finalized.

The decisions made in each stage are common knowledge in the following stages.

The equilibrium concept is Perfect Bayesian Equilibrium. We thus require the platform and the sellers to evaluate the payoffs from their alternative strategies by considering the consumers’ optimal responses, both on and off the equilibrium path. Also, the consumers must take into account all gains and losses from information disclosure, given the platform’s and the sellers’ strategies. We focus on deterministic strategies used by the platform and the consumers, and denote by Φ^B the set of the options faced by each consumer, including both accepting one of the platform’s offers and turning down all offers. The best options faced by a consumer of type $\theta \in [0, 1]$ are the members of the set

$$S_\theta = \{\phi \in \Phi^B \mid u_\theta(\phi) \geq u_\theta(\phi') \text{ for every } \phi' \in \Phi^B\}. \quad (2)$$

The set of the types for which S_θ includes multiple options - empty or non-empty as it may be - has always measure 0. Hence, the choice of any specific tie-breaking rule has no effects on our results. We state the requirements for equilibrium in Definition 1; an asterisk used as a superscript indicates equilibrium variables.

Definition 1. *An equilibrium is:*

- (1) *A set of offers Φ^* , maximizing the platform’s profit.*
- (2) *A profit-maximizing strategy for each generic seller, consisting of a rule used to decide whether to purchase the information gathered by the platform under each offer, or not, and a pricing strategy allowing the seller to set one price for each offer.*
- (3) *An optimal shopping strategy $\chi_\theta^* \in S_\theta^*$, where S_θ^* is defined by using (2), for each consumer type $\theta \in [0, 1]$.*

The market for generic products admits (only) active equilibria in which the consumers face randomized prices. For any disclosure level δ_ϕ , the variables of interest, besides the consumer surplus β_ϕ , are the profit per seller ψ_ϕ and the total surplus τ_ϕ . Each seller’s profit is understood as inclusive of the platform’s participation, which is thus equal to $\xi\psi_\phi$. The values of these variables corresponding to the market equilibrium are stated in Lemma 1.

Lemma 1. *In the equilibrium of the market for generic products, the expected values of the surplus of a consumer who chooses offer ϕ , the gross profit per seller and the total surplus*

are

$$\beta_\phi = (1 - e^{-\delta_\phi \eta} - \delta_\phi \eta e^{-\delta_\phi \eta}) v_G, \quad (3a)$$

$$\psi_\phi = \delta_\phi \eta e^{-\delta_\phi \eta} v_G, \quad (3b)$$

$$\tau_\phi = (1 - e^{-\delta_\phi \eta}) v_G. \quad (3c)$$

Figure 1 illustrates the responses of the total surplus, the profit and the consumer surplus to changes in δ_ϕ . The total surplus τ_ϕ is monotonically increasing and concave in δ_ϕ . The profit ψ_ϕ is first increasing and then decreasing in δ_ϕ , due to the tension between the greater probability of an exchange and the greater number of potential competitors, and peaks at $\delta_\phi = \eta^{-1}$. The consumer surplus β_ϕ is monotonically increasing in δ_ϕ and approaches the total surplus τ_ϕ as $\delta_\phi \rightarrow \infty$, under the pressure of increasing competition among the sellers.

As the demand of each consumer who is contacted by at least one generic seller is certainly satisfied, the equilibrium of the market for generic products guarantees surplus maximization, conditional on the values of the disclosure parameters. We consider equations (3) as parts of each configuration that we investigate below.

FIGURE 1. The total surplus, the gross profit per seller and the consumer surplus in the market for generic products, plotted as functions of δ_ϕ .

3. EQUILIBRIUM WITH A TWO OFFER-MENU

The value of the nuisance parameter of a consumer who would be indifferent between the high- and the low-disclosure offer, if she were ideally forced to accept one of the two offers, is

$$\iota(\delta_H, \delta_L, p_H, p_L) = \frac{\beta_H - p_H - (\beta_L - p_L)}{\delta_H - \delta_L}. \quad (4)$$

The presence of the terms expressing the consumer surplus in the market for generic products, β_H and β_L , differentiates (4) from the corresponding expression in the standard model of vertical differentiation (Mussa and Rosen, 1988). The threshold in (4) also differs from the corresponding threshold separating the consumers who accept the two offers in the analysis of surplus maximisation - expressed by (B.10), in Appendix B - whereby the total surplus replaces the consumer surplus, and the prices p_H and p_L do not appear. Essentially, each consumer bases her decision on the prices and the surplus received from the induced transactions, whereas a planner would consider the total surplus from each offer.

The assumptions of a high value of v_M and bounded gains from disclosure guarantee full market coverage at the platform's optimum. Lemma 2 states that the offers must *exactly*

guarantee market coverage, and leave the consumer type $\theta = 1$ indifferent between accepting the best offer faced or rejecting it.

Lemma 2. *In equilibrium, (almost) all consumers accept either offer H or offer L . Moreover, the consumer type $\theta = 1$ is the only one facing a net expected surplus from market participation equal to 0; any optimal offer $\phi' \in S_1$ faced by this type is therefore such that*

$$v_M - p_{\phi'} - \delta_{\phi'} + \beta_{\phi'} = 0. \quad (5)$$

A further observation that allows us to dispense with unnecessary notational complications, formally stated as Lemma 3, is that the platform always uses both offers to cover the market.

Lemma 3. *At the optimum, offers H and L feature different disclosure levels, and each offer is chosen by a set of consumers with positive measure.*

Lemma 3 relies on the observation that if all consumers chose the same offer, the platform could certainly increase its profit by targeting the consumers with the lower values of the nuisance parameter with an offer featuring a relatively high disclosure level. A corresponding result does hold in the other cases with multiple offers that we consider below. An immediate corollary of Lemma 3 is that the optimized profit is strictly greater than v_M , which can be realized with a single no-disclosure offer.

Motivated by Lemma 2 and Lemma 3, we restrict attention to the set of the platform's strategies such that both offers are chosen by sets of consumers with positive measure and the market is exactly covered, denoted by B :

$$B = \left\{ (\delta_H, \delta_L, p_H, p_L) \in \mathbb{R}_+^2 \times \mathbb{R}^2 \mid \begin{aligned} & \iota(\delta_H, \delta_L, p_H, p_L) \in (0, 1) \text{ and (5) holds} \end{aligned} \right\}. \quad (6)$$

The demand functions for the two offers can then be written as

$$D_H(\delta_H, \delta_L, p_H, p_L) = \iota(\delta_H, \delta_L, p_H, p_L), \quad (7a)$$

$$D_L(\delta_H, \delta_L, p_H, p_L) = 1 - \iota(\delta_H, \delta_L, p_H, p_L). \quad (7b)$$

and the platform's profit and maximization problem are

$$\pi(\delta_H, \delta_L, p_H, p_L) = (p_H + \xi\psi_H) D_H(\delta_H, \delta_L, p_H, p_L) + (p_L + \xi\psi_L) D_L(\delta_H, \delta_L, p_H, p_L), \quad (8)$$

$$\max_{(\delta_H, \delta_L, p_H, p_L) \in B} \left\{ \pi(\delta_H, \delta_L, p_H, p_L) \right\}. \quad (9)$$

Lemma 4 characterizes the prices that the platform would charge to the consumers, for values of the disclosure variables compatible with an optimum.

Lemma 4. *In any quadruple $(\delta_H, \delta_L, p_H, p_L) \in B$ that solves the platform's problem (9), the prices are equal to $p_H = p_H^*(\delta_H, \delta_L)$ and to $p_L = p_L^*(\delta_H, \delta_L)$, where*

$$p_H^*(\delta_H, \delta_L) = v_M - \delta_L \quad (10a)$$

$$+ \left(1 - \frac{(1 + \eta(1 + \xi)\delta_H) e^{-\delta_H\eta} + (1 + \eta(1 - \xi)\delta_L) e^{-\delta_L\eta}}{2} \right) v_G,$$

$$p_L^*(\delta_H, \delta_L) = v_M - \delta_L + (1 - e^{-\delta_L\eta} (\delta_L\eta + 1)) v_G. \quad (10b)$$

Although the equations in (10) do not rule out the possibility of a greater price being charged in the low disclosure-offer, we have not encountered any equilibria in which this situation does occur in our analysis.

Proposition 1 characterizes the equilibrium of the case in which the platform fully appropriates the profits from the induced exchanges; the case of incomplete appropriation is numerically investigated in Appendix A.

Proposition 1. *If $\xi = 1$, then the equilibrium values of the disclosure variable and the threshold value of the nuisance parameter are*

$$(\delta_H^*, \delta_L^*) = \begin{cases} (\underline{\delta}_H, 0), & \text{if } \eta v_G \leq \mathcal{T} + 1, \\ \left(\frac{1}{\eta} \log \left(\frac{\eta v_G}{\mathcal{T}} \right), \frac{1}{\eta} \log \left(\frac{\eta v_G}{\mathcal{T} + 1} \right) \right), & \text{if } \eta v_G > \mathcal{T} + 1, \end{cases} \quad (11)$$

and

$$i^* = \begin{cases} \eta v_G e^{-\underline{\delta}_H \eta} & \text{if } \eta v_G \leq \mathcal{T} + 1, \\ \mathcal{T}, & \text{if } \eta v_G > \mathcal{T} + 1. \end{cases} \quad (12)$$

where $\underline{\delta}_H$ is the unique positive value of δ_H that solves

$$e^{\delta_H \eta} - 2\delta_H \eta - 1 = 0, \quad (13)$$

and $\mathcal{T}$, approximately equal to 0.4, is the unique real value of θ that solves

$$\theta \log \left(\frac{\theta + 1}{\theta} \right) = \frac{1}{2}. \quad (14)$$

4. PERFORMANCE BENCHMARKS

4.1. Surplus maximization with two offers. In this Subsection, we characterize the disclosure levels and the matching between the offers and the consumers that would maximize the net surplus generated by the exchanges, in the case of two offers. The solution could ideally be implemented through a suitable system of conditional payments made to the consumers - see Figure 2a in Subsection 5.1 below for an example. Considering (1) and the assumption of a large value of v_M , the consumers with values of the nuisance parameter θ smaller and greater than a threshold value Θ should respectively choose offer H and offer L . The planner's objective function and problem can then be written as

$$\begin{aligned} w(\delta_H, \delta_L, \Theta) &= v_M + \int_0^\Theta (\tau_H - \delta_H \theta) d\theta + \int_\Theta^1 (\tau_L - \delta_L \theta) d\theta \\ &= v_M + \Theta \tau_H + (1 - \Theta) \tau_L - \frac{\Theta^2}{2} \delta_H - \frac{1 - \Theta^2}{2} \delta_L, \end{aligned} \quad (15)$$

and as

$$\max_{(\delta_H, \delta_L, \Theta)} \{w(\delta_H, \delta_L, \Theta)\}. \quad (16)$$

respectively. The results concerning surplus maximization are stated in Proposition 2.

Proposition 2. *The values of the disclosure parameters and the threshold value of the nuisance parameter that solve the planner's problem in (16), if $\xi = 1$, are*

$$(\delta_H^W, \delta_L^W) = \begin{cases} (\underline{\delta}_H, 0), & \text{if } \eta v_G < \frac{\mathcal{T} + 1}{2}, \\ \left(\frac{1}{\eta} \log \left(\frac{2\eta v_G}{\mathcal{T}} \right), \frac{1}{\eta} \log \left(\frac{2\eta v_G}{\mathcal{T} + 1} \right) \right), & \text{if } \eta v_G \geq \frac{\mathcal{T} + 1}{2}, \end{cases} \quad (17)$$

and

$$\Theta^W = \begin{cases} 2\eta v_G e^{-\underline{\delta}_H \eta}, & \text{if } \eta v_G < \frac{\mathcal{T} + 1}{2}, \\ \mathcal{T}, & \text{if } \eta v_G \geq \frac{\mathcal{T} + 1}{2}, \end{cases} \quad (18)$$

where $\underline{\delta}_H$ and $\mathcal{T}$ respectively solve (13) and (14).

4.2. Equilibrium with a single offer. In the present Subsection, we characterize the equilibrium of the version of the model in which the platform makes a single offer to the consumers. Both here and in Subsection 4.3, as in Proposition 1, we focus on the case of full appropriation of the sellers' profits by the platform.

The assumption of a large value of v_M implies that the offer (δ_S, p_S) that solves the platform's problem features full market coverage. A result corresponding to Lemma 2 also holds with a single offer: The optimal price must leave the consumer type $\theta = 1$ with a net surplus of 0, and is therefore equal to $p_S^*(\delta_S) = v_M + \beta_S - \delta_S$. The profit is then $\pi_S(\delta_S) = p_S^*(\delta_S) + \xi\psi_S$, and the platform's problem is

$$\max_{\delta_S} \{ \pi_S(\delta_S) \}. \quad (19)$$

Proposition 3 characterizes the equilibrium disclosure level.

Proposition 3. *If the platform makes a single offer and $\xi = 1$, then the equilibrium disclosure level is*

$$\delta_S^* = \begin{cases} 0, & \text{if } \eta v_G \leq 1, \\ \frac{1}{\eta} \log(\eta v_G), & \text{if } \eta v_G > 1. \end{cases} \quad (20)$$

4.3. Equilibrium with a continuum of offers. The characterization of the case of a continuum of offers relies on the analysis of the problem of regulating a firm with a privately known cost function in [Baron and Myerson \(1982\)](#). We conveniently allow the platform to choose a set of offers of the form $(\delta_C(\hat{\theta}), \rho_C(\hat{\theta}))$, where the index $\hat{\theta}$ takes values in $[0, 1]$ and is understood as the type reported by any consumer choosing the respective offer. The variables $\delta_C(\hat{\theta})$ and $\rho_C(\hat{\theta})$ denote the disclosure level and the reward associated with the respective offer. The reward is comprised of the product handed out by the platform, the consumer surplus from the induced exchanges and a monetary transfer, either positive or negative; the platform retains the profits of the generic sellers, plus/minus any monetary transfers received or paid out.

The platform's problem can be written as

$$\max_{\{(\delta_C(\hat{\theta}), \rho_C(\hat{\theta}))\}} \int_0^1 (\tau_{\hat{\theta}} - \rho_C(\hat{\theta})) d\theta,$$

and each consumer type θ chooses an offer $\hat{\theta} = t(\theta)$ that maximizes her expected payoff. The equilibrium features truthful reporting by the consumers, namely $t(\theta) = \theta$ for each type θ . As market participation is voluntary, the consumers must receive non-negative payoffs from the offers that they are designated to accept, namely we must have $\rho_C(\theta) - \theta\delta_C(\theta) \geq 0$. Proposition 4 characterizes the equilibrium.

Proposition 4. *The disclosure level and the reward for each consumer type θ with a continuum of offers, if $\xi = 1$, are*

$$\delta_C^*(\theta) = \max \left\{ \frac{1}{\eta} \log \left(\frac{\eta v_G}{2\theta} \right), 0 \right\} \quad (21)$$

and

$$\rho_C^*(\theta) = \begin{cases} v_M + \max \left\{ \frac{v_G}{2} - \frac{\theta}{\eta}, 0 \right\}, & \text{if } \frac{\eta v_G}{2} \leq 1, \\ v_M + \frac{1}{\eta} \left(\log \left(\frac{\eta v_G}{2} \right) + 1 - \theta \right), & \text{if } \frac{\eta v_G}{2} > 1. \end{cases} \quad (22)$$

5. COMPARISONS AND DISCUSSION

5.1. Equilibrium versus surplus maximization in the two offer-case. To compare the equilibrium and the planner's solution with a menu of two offers, notice that if $\eta v_G > \mathcal{T} + 1$, then the values of the disclosure parameters are all strictly positive, in both cases. It is also readily verified that the difference between the optimized and the equilibrium surplus is equal to $\frac{1-\log(2)}{2\eta}$. This gap occurs, firstly, because the equilibrium disclosure levels are too low; moreover, the equilibrium threshold value of the nuisance parameter $\theta^* = \mathcal{T}$ is half as large as the surplus maximizing threshold value conditional on δ_H^* and δ_L^* . If $\eta v_G \leq \frac{\mathcal{T}+1}{2}$, then the surplus maximizing and the equilibrium disclosure levels coincide, with $\delta_L^W = \delta_L^* = 0$. Comparison of (12) and (18) reveals however that also in this case, the threshold value of θ that maximizes surplus is twice as large as the equilibrium value, and too many consumers choose to disclose no information. For values of the product ηv_G between $\frac{\mathcal{T}+1}{2}$ and $\mathcal{T} + 1$, the planner's solution and the equilibrium respectively feature an interior and a boundary solution, with a smooth transition between the two regimes discussed above.

FIGURE 2. Incentive-compatible patterns of surplus-distribution under three alternative arrangements, in an example with $\eta = 2$ and $v_G = 1$.

Figure 2 illustrates some patterns of division of the surplus from the induced exchanges with a two offer-menu in a numerical example. Figures 2a and 2b respectively illustrate the surplus distribution corresponding to unconstrained surplus maximization and to the equilibrium. The values of the disclosure parameters, measuring the slope of the curves expressing the losses from disclosure, are lower in equilibrium than at the planner's solution. Hence, the (potential) consumer surplus from the induced exchanges and the sellers' profits are respectively smaller and larger in the former case. Figure 2c illustrates the configuration that would implement surplus maximization, *conditional* on the equilibrium values of the disclosure variables. The conditional surplus maximizing value of p_L is identical to the equilibrium value. However, the value of p_H that would make the conditional surplus maximizing threshold $2\mathcal{T}$ incentive-compatible is unprofitably low for the platform, as it reflects a large subsidy paid to the consumers with higher valuations.

It is readily verified that $p_H^* > p_L^*$ holds if $\eta v_G > \mathcal{T} + 1$; otherwise, both prices are equal to v_M . Thus, with an efficient matching routine and/or valuable products, the consumers choosing offer H do pay a premium to the platform, in equilibrium. The premium is justified by the greater expected number of offers and by the sellers' more aggressive pricing strategies, which translate into a large surplus from the induced exchanges. Conversely, the consumers choosing offer L may effectively be subsidized, as $p_L^* < v_M$ certainly holds for values of the product ηv_G in a right-neighborhood of $\mathcal{T} + 1$.

These patterns reflect two distinct effects, which also shape the features of the equilibrium with a single offer. One effect is the [Spence \(1975\)](#) externality. Our monopoly platform chooses the “quality” of the product - namely the level of disclosure in each offer - taking into account the largest value of the nuisance parameter among those of the customers choosing that offer. The equilibrium disclosure level is therefore too low for the other consumers choosing the same offer, except possibly in boundary cases. The covered market assumption does not play a critical role in this regard. The second effect follows from the fact that high disclosure levels boost the effects of consumer heterogeneity, and thereby reduce the platform's ability to appropriate the surplus that the consumers can realize in the market for generic products. By contrast, low disclosure levels stymie competition and have a positive effect on the sellers' profits, which the platform can appropriate. Both effects also influence the matching between the consumers and the offers, play themselves out in full with a single offer, and are mitigated by a two offer-menu.

The surplus gap is generally a decreasing function of the arrival parameter η , and vanishes as η approaches infinity, but is independent of the valuation v_G . Essentially, with large values of η , (11) and (17) reveal that a given potential gain from the induced exchanges can be and is eventually pursued with a smaller and smaller sacrifice in terms of information disclosure. By contrast, exploiting larger values of v_G requires larger disclosure levels, whose implementation always entails a significant distortion. This tendency holds more generally, as shown by Figures 3e and 3f in 5.2 below. The *relative* performance gaps do nevertheless decrease in both cases; even with increases in v_G , any given sacrifice from disclosure does in fact yield a greater gain in terms of the value of the products exchanged.

FIGURE 3. The levels of the total surplus and the platform's profit in the market for generic products and the average disclosure levels under alternative menus of offers. The variables are plotted for different values of η and of v_G , with v_G and of η held fixed to 1 and to 2, respectively.

5.2. Equilibria with different menus of offers. Figure 3 illustrates the equilibrium surplus and profit levels and the average disclosure levels under our alternative menus, for different values of the parameters η and v_G . Both in the surplus and in the profit case, the gap between the levels with a continuum of offers and with two offers initially increases and then decreases in size as the value of either parameter increases. The comparison between the continuum and the one offer-case reveals a similar pattern. In each case, the gap peaks at the threshold value of the product ηv_G above which all consumers accept a positive disclosure

level; essentially, leaving some gains from disclosure completely unexploited becomes increasingly penalizing as the potential surplus grows. With a single offer, the gaps remains fairly sizeable even for large values of η and v_G .

Figure 4 illustrates the equilibrium disclosure levels chosen by the different consumer types, for different parameter values. Figures 4a and Figure 4b focus on different combinations of η and v_G that yield the same surplus, with a continuum of offers; Figure 4c focuses on a further combination that yields a higher surplus. The curve representing the continuously matched disclosure levels in Figure 4c descends more gently than the corresponding curves in the two other Figures. Hence, in the high surplus-case, the step functions identifying the equilibrium disclosure levels with one and two offers can better approximate the ideal disclosure levels, and a more effective exploitation of the exchange opportunities is possible.

FIGURE 4. Disclosure levels for different values of the parameters η and v_G , under alternative menus.

Comparison of Figures 3a and 3b also suggests that the variables plotted are relatively more responsive to changes in η than to changes in v_G , in the lower part of the respective range. With a continuum of offers, the platform would assign a positive disclosure level to a greater fraction of the buyers in the case of relatively large values of η , compared to the case of large values of v_G - witness Figures 4a and 4b. This pattern is accounted for by the same effect noted in 5.1: As Figures 3e and 3f show, large values of η - unlike large values of v_G - eventually make the disclosure levels necessary to implement the optimal allocation small, and reduce the impact of the distortions, in equilibrium.

The surplus and profit gaps with a one offer-menu are relatively persistent in the face of increases in the potential surplus. This pattern follows from the relatively large weight that the two effects noted in 5.1 - the Spence (1975) “marginal buyer” effect and the dispersive

effect of large values of the disclosure parameter - have with a single offer. The gap is more persistent in the case of the profit than in the case of the surplus, and in the case of increases in v_G . Thus, improvements in the informational technologies are relatively more likely to make menus with more than two offers less appealing, both from the social point of view and the point of view of the platform. Also, in the presence of complexity costs associated with larger menus, the platform might then find the two offer-menu unduly appealing, from the point of view of surplus maximization.

6. CONCLUDING REMARKS

We have explored the trade-off between the benefits and the costs of information disclosure in a model in which a monopoly platform can gather personal information about its customers and offer it to other sellers. Disclosure may reveal further possible exchanges, but entails idiosyncratic losses for the consumers. We considered both scenarios in which the platform can make a single offer, and scenarios in which the platform offers menus with different combinations of the disclosure level and the price, each targeting a different subset of the consumer population. With multiple offers, the platform charges higher prices to the consumers who choose higher disclosure levels, and sells the respective information to the sellers at a lower price. This effect emerges because under our matching routine, a higher disclosure level implies not only a higher probability of receiving relevant offers, but also a greater probability to receive multiple competing offers, for each consumer.

The average disclosure level increases with the number of offers, and a binary menu can make both the platform's profit and the total surplus generated by the induced exchanges close to those achieved with a continuum of offers, provided the potential surplus is relatively large. A lower fractional participation of the platform in the sellers' profits typically induces more differentiated disclosure levels; the response of the average disclosure level may be non-monotonic.

Relatively simple menus of offers made to the consumers can thus allow the platform to effectively reconcile the exploitation of exchange opportunities and the consumers' aversion to information disclosure. Platforms deriving their revenues from advertisements may sacrifice the quality of the organic links suggested (Burguet, Caminal and Ellman, 2015; Taylor, 2013), and possibly even suggest inefficient sponsored links (de Cornière, 2016; Hagiu and Jullien, 2011; Karle and Peitz, 2016); consumer payments can limit the relevance of these problems, at least for the consumers who choose options with larger disclosure levels. Amazon, which is currently a popular search engine and offers a premium service providing additional information about the subscribers' transaction history such as Amazon Prime, is in a position to exploit the advantages of the pricing menus considered in the paper. Location-based services are other natural candidates in this sense, also considering the additional tracking opportunities provided by specific devices such as dedicated apps and bracelets.

Future theoretical research could focus on:

- (1) The empirical analysis of the effects of the balance of different sources of revenues on the performance of informational platforms, drawing on the results of both the present paper and the related papers mentioned in the previous paragraph.
- (2) The analysis of models in which information disclosure is only *one* of the dimensions along which the product packages provided under alternative offers are differentiated, rather than as the only dimension. The analysis could also consider the disclosure of information to sellers facing different degrees of potential competition in their respective markets.
- (3) The analysis of the incentives faced by the information providers to improve the quality of the services offered - possibly in settings featuring different level of competition intensity, along the lines of the empirical research of Arora, Forman, Nandkumar and Telang (2010).

APPENDIX A. EQUILIBRIUM WITH TWO OFFERS AND PARTIAL PROFIT APPROPRIATION

In the present Appendix, we summarize the main results of our numerical analysis of the case in which the platform makes two offers and can only appropriate a part of the profits generated by the induced exchanges. Figures A.1a, A.1b and A.1c are referred to a set of examples which share $\eta = 2$ and $v_G = 1$ with the example in Figure 2. In the case of Figure A.1d, we have instead $\eta = 2$ and $v_G = 2$.

FIGURE A.1. Some results for the case of partial participation of the platform in the sellers' profits.

Figures A.1a and A.1d show the surplus maximizing and the equilibrium disclosure levels. If $\eta v_G > \mathcal{T} + 1$, as in the cases considered, then there is a threshold value of ξ , denoted by ξ_t , such that $\delta_L^* = 0$ and $\delta_L^* > 0$ respectively hold if $\xi \leq \xi_t$ and if $\xi > \xi_t$. The figures also report the average value of the disclosure parameter across all consumers. For relatively small values of η and v_G , as in the case of Figure A.1a, δ_H^* decreases strictly with ξ , and δ_L^* increases strictly with ξ if $\xi > \xi_t$. The average disclosure level respectively decreases and increases with ξ to the left and to the right of ξ_t , and falls systematically short of the level corresponding to the surplus maximizing solution, approximately equal to 0.78.

For large values of η and/or v_G , the transition at ξ_t is discontinuous, with an upward jump of δ_H^*, δ_L^* and the average disclosure level - witness Figure A.1d. δ_H^* is generally decreasing,

except for this jump; δ_L^* is increasing to the immediate right of ξ_t , but may be decreasing for higher values of ξ , as in the case of Figure A.1d. The average disclosure level is decreasing, as in the case of low values of η and v_G , if $\xi \leq \xi_t$, but is either decreasing (as in the Figure) or non-monotonic if $\xi > \xi_t$.

Figure A.1b shows the threshold value of θ , both at the equilibrium and at the surplus maximizing configuration conditional on δ_H^* and δ_L^* . The platform generally serves an excessively large number of consumers through the low disclosure-offer. Both threshold levels are increasing if $\xi \leq \xi_t$ and decreasing if $\xi > \xi_t$. This qualitative pattern is independent of the values of η and v_G ; if η and/or v_G are large, conditional surplus maximization may require all consumers to choose offer H , for values of ξ slightly smaller than ξ_t . The price p_H^* is positive and strictly decreasing; p_L^* is equal to v_M if $\xi \leq \xi_t$, and is strictly decreasing - and thus negative - if $\xi > \xi_t$.

Figure A.1c illustrates the general tendency of the surplus to increase with ξ , as the platform internalizes an increasing part of the benefits from disclosure. For large values of η and/or v_G , the surplus actually decreases mildly if $\xi > \xi_t$. This pattern is observed for example in the case of $\eta = 2$ and $v_G = 2$ - for which a specific figure is not reported - and is due to the pressure toward large values of δ_H and δ_L that emerges for intermediate values of ξ . This effect also lies behind the steep ascent of the equilibrium surplus in Figure A.1c, to the immediate right of ξ_t .

The responses to changes in ξ largely reflects the platform's use of the disclosure variables to control the intensity of competition, and to ultimately achieve a profitable distribution of the surplus from the induced exchanges. The sellers' profits are generally larger under offer L , and large values of δ_L , making low values of p_L necessary to guarantee market participation of the consumers who are more exposed to losses, are only justified if the platform's participation in the profits is correspondingly large. On the opposite side of the preference spectrum, the more intense competition fostered by offer H allows the respective consumers to realize a larger fraction of the gross surplus, and the platform responds to lower values of ξ by increasing both δ_H and p_H .

As to the abrupt regime switch observed for large values of η and/or v_G , a large potential surplus from the induced transactions makes disclosure potentially profitable even for relatively low values of ξ . However, if ξ is low, the platform is unwilling to cut p_L to induce the consumers featuring high values of θ to accept a small positive value of δ_L , as most of the surplus would take the form of profits of which she only receives a small part. Thus, the positive values of δ_L^* are bounded away from 0, and leave the consumers with a relatively large surplus.

APPENDIX B. PROOFS

B.1. Proof of Lemma 1. We build on the standard argument used to establish existence of equilibria with randomized pricing strategies (Baye, Kovenock and de Vries, 1992). For any given disclosure level $\delta > 0$, let $Y(q)$ and Q denote the cumulative distribution of the lowest price charged by the competitors of any given seller and its support. We first observe that Q must be a subset of some interval of the form $[\underline{q}, v_G]$. Prices above v_G are ruled out by the voluntary nature of trade. The lower bound $\underline{q}$ must be strictly positive as each seller makes the only offer faced by any consumer contacted with probability $e^{-\delta\eta}$, and can therefore certainly realize an expected profit no smaller than $e^{-\delta\eta}q > 0$ from the respective transaction by charging a price $q \in (0, v_G)$.

Secondly, the cumulative distribution $Y(q)$ must be continuous - and Q must have positive measure in $\mathbb{R}$. If some price $\hat{q}$ were a mass point of $Y(q)$, any seller choosing it could in fact increase both her probability of trading and her expected profit by a discrete amount by charging a price $\hat{q} - \epsilon$, for a small positive ϵ .

Thirdly, Q must be an interval, and v_G must be its least upper bound. If two hypothetical prices q' and q'' in Q existed identifying a gap (q', q'') which is not a subset of Q , then the probabilities of trade at q' and at q'' would be identical, namely we would have $Y(q') = Y(q'')$, and the expected profit would necessarily be greater at q'' . Similarly, if Q had an upper bound $\bar{q} < v_G$, then each seller would have identical probabilities of trade at $\bar{q}$ and at any price $\check{q} \in (\bar{q}, v_G)$, and the choice of $\check{q}$ would dominate that of $\bar{q}$. The expected profit at any price in Q must then be equal to $e^{-\delta\eta}v_G$, and using $q(1 - (1 - e^{-\delta\eta})Y(q)) = e^{-\delta\eta}v_G$, we obtain $Q = [e^{-\delta\eta}v_G, v_G]$ and

$$Y(q) = \frac{1}{1 - e^{-\delta\eta}} \left(1 - \frac{e^{-\delta\eta}v_G}{q} \right). \quad (\text{B.1})$$

Using $Y(q) = \sum_{k=1}^{\infty} e^{-\delta\eta} (\delta\eta(1 - F(q)))^k / k!$, we can verify that (B.1) obtains, for example, if the cumulative distribution of each seller's price over Q is

$$F(q) = 1 - \frac{1}{\delta\eta} \log \left(\frac{v_G}{q} \right).$$

As to (3b), let σ_k denote the profit that each seller can ideally expect, if k sellers contacted a consumer, and set $\sigma_0 = 0$. As the profit per seller at any price in Q is an expectation taken over all strictly positive numbers of sellers, we must have

$$e^{-\delta\eta}v_G = \frac{\sum_{k=1}^{\infty} \mu_k k \sigma_k}{\sum_{k=1}^{\infty} \mu_k k}. \quad (\text{B.2})$$

The *ex-ante* expected profit flow referred to our continua of sellers and consumers, both of which have unit size, can be expressed in terms of the probability of receiving one of k “tickets” granting a probability of selling the product to each consumer, with at most one ticket assigned to each seller. As the expected payoff for the holder of each ticket is equal to σ_k , we have

$$\begin{aligned} \psi &= \sum_{k=0}^{\infty} \mu_k k \sigma_k && (\text{by definition}) \\ &= \sum_{k=1}^{\infty} \mu_k k \sigma_k && (\text{as } \mu_0 \times 0 \times \sigma_0 = 0) \\ &= \sum_{i=1}^{\infty} \mu_i k \times \frac{\sum_{k=1}^{\infty} \mu_k k \sigma_k}{\sum_{i=1}^{\infty} \mu_i k} && (\text{we multiply and divide by } \sum_{i=1}^{\infty} \mu_i k) \\ &= \sum_{k=0}^{\infty} \mu_k k \times e^{-\delta\eta}v_G && (\text{by (B.2) and } \mu_0 \times 0 = 0) \\ &= \delta\eta e^{-\delta\eta}v_G && (\text{as the matches follow a Poisson distribution}). \end{aligned}$$

The total surplus in (3c) is obtained by noting that each consumer accepts the lowest price faced, if any, with probability 1, and that a surplus v_G is therefore generated, per consumer, if and only if at least one offer is received. Finally, the consumer surplus in (3a) is obtained by using the difference $\tau - \psi$.

B.2. Proof of Lemma 2. Notice first that the platform can certainly realize a positive profit by selling its product with no information disclosure. If any quadruple $(\delta_H, \delta_L, p_H, p_L)$ were such that all consumers' participation constraints were met even after that both prices were increased by the same amount $\omega > 0$, then the platform could replace p_H and p_L by $p_H + \omega$ and $p_L + \omega$ without affecting the threshold value of θ defined by (4), and thereby necessarily increase its profit.

Moreover, under the maintained assumptions of a large value of v_M and bounded gains from disclosure, if $\omega > 0$ were such that $p_H - \omega$ and $p_L - \omega$ are the greatest prices for which all participation constraints hold, the platform could certainly increase its profit by replacing p_H and p_L by $p_H - \omega$ and by $p_L - \omega$.

Hence, at the optimum, all participation constraints must hold, and at least one of them must hold as an equality. If ϕ' is a best offer faced by type 1, then we have $u_1(\phi') <$

$u_\theta(\phi') \leq u_\theta(\phi^\theta)$ for any type $\theta \neq 1$ and any offer ϕ^θ in the respective best offer set S_θ , and the most demanding constraint must therefore pertain to type $\theta = 1$.

B.3. Proof of Lemma 3. To show that the platform must use both offers, we consider a benchmark in which all consumers accept the same offer (δ', p') , which yields a non-negative profit. To show that this cannot possibly be an optimum, it is sufficient to find a further offer (δ'', p'') such that, if a prime or a double prime denotes variables associated with the respective offer, the following requirements are both satisfied:

- (1) There exists some $\bar{\theta} > 0$ such that the consumer types $\theta \in [0, \bar{\theta}]$ prefer (δ'', p'') to (δ', p') . By continuity of u_θ in (1) w.r.t. θ , this condition is verified if type $\theta = 0$ strictly prefers (δ'', p'') to (δ', p') , namely if $\beta' - p' < \beta'' - p''$.
- (2) The profit per consumer from offer (δ'', p'') is strictly greater than the profit from offer (δ', p') , namely $p' + \xi\delta'\eta\psi' < p'' + \xi\delta''\eta\psi''$.

By rearranging these requirements, we obtain

$$\xi\eta(\delta'\psi' - \delta''\psi'') < p'' - p' < \beta'' - \beta'. \quad (\text{B.3})$$

As $\lim_{\delta'' \rightarrow \infty} \{\beta''\} = v_G$, $\lim_{\delta'' \rightarrow \infty} \{\psi''\} = 0$ and $\xi\delta'\eta\psi' + \beta' \leq \tau' < v_G$, we have

$$\lim_{\delta'' \rightarrow \infty} \{\beta'' - \beta' - \xi\eta(\delta'\psi' - \delta''\psi'')\} = v_G - \beta' - \xi\delta'\eta\psi' > 0.$$

A suitably large value of δ'' can thus guarantee existence of values of the difference $p'' - p'$ satisfying (B.3), and of an offer (δ'', p'') satisfying requirements 1 and 2.

B.4. Proof of Lemma 4. It is readily verified that as each offer must be accepted by a positive fraction of the consumers, by Lemma 3, offer L must strictly dominate offer H for the consumer type $\theta = 1$. Equation (5) then yields the expression for $p_L^*(\delta_H, \delta_L)$ in (10b). The expression for $p_H^*(\delta_H, \delta_L)$ in (10a) is obtained from the first and second order-conditions for maximization of $\pi(\delta_H, \delta_L, p_H, p_L) \big|_{p_L=p_L^*(\delta_H, \delta_L)}$ w.r.t. p_H .

B.5. Proof of Proposition 1. By Lemmas 3 and 4, we can focus on the profit function

$$\pi^*(\delta_H, \delta_L) = \pi(\delta_H, \delta_L, p_H, p_L) \big|_{p_H=p_H^*(\delta_H, \delta_L), p_L=p_L^*(\delta_H, \delta_L)},$$

where the functions on the right hand-side are defined in (8) and in (10), and on interior values of the threshold value of the nuisance parameter in (4), expressed by

$$t^*(\delta_H, \delta_L) = \frac{(e^{-\delta_L\eta} - e^{-\delta_H\eta})v_G}{2(\delta_H - \delta_L)}, \quad (\text{B.4})$$

Under our assumptions on the exchange technology, $\pi^*(\delta_H, \delta_L)$ is necessarily smaller than v_M outside a closed, bounded subset of the feasible disclosure levels that includes $(0, 0)$. Continuity and differentiability of $\pi^*(\delta_H, \delta_L)$ then ensure existence of an optimum at which the first order-conditions are verified, taking into due account the possibility of $\delta_L = 0$.

As to the first order-conditions, given $\delta_H > \delta_L$, $\frac{\partial \pi^*(\delta_H, \delta_L)}{\partial \delta_H} = 0$ requires

$$e^{-\delta_L\eta} - e^{-\delta_H\eta} - 2\eta e^{-\delta_H\eta}(\delta_H - \delta_L) = 0, \quad (\text{B.5})$$

and $\frac{\partial \pi^*(\delta_H, \delta_L)}{\partial \delta_L} = 0$ requires at least one of the two equations in (B.6),

$$(e^{-\delta_L\eta} - e^{-\delta_H\eta})v_G - 2(\delta_H - \delta_L) = 0, \quad (\text{B.6a})$$

$$(e^{-\delta_L\eta} - e^{-\delta_H\eta})v_G - 2(\eta e^{-\delta_L\eta}v_G - 1)(\delta_H - \delta_L) = 0. \quad (\text{B.6b})$$

(B.6a), together with (B.4), implies $\iota^*(\delta_H, \delta_L) = 1$, which is ruled out by Lemma 4, and can thus be immediately discarded. On the other hand, by rearranging (B.5) and (B.6b), we obtain

$$\eta e^{-\delta_H \eta} v_G = \frac{(e^{-\delta_L \eta} - e^{-\delta_H \eta}) v_G}{2(\delta_H - \delta_L)} = \eta e^{-\delta_L \eta} v_G - 1, \quad (\text{B.7})$$

and therefore $(e^{-\delta_L \eta} - e^{-\delta_H \eta}) v_G = \frac{1}{\eta}$ and, using (B.4),

$$\eta e^{-\delta_H \eta} v_G = \check{\theta} = \eta e^{-\delta_L \eta} v_G - 1, \quad (\text{B.8})$$

where

$$\check{\theta} = \frac{1}{2\eta(\delta_H - \delta_L)} \quad (\text{B.9})$$

is the optimal value of the threshold. (B.8) then implies

$$(\delta_H, \delta_L) = \left(\frac{1}{\eta} \log \left(\frac{\eta v_G}{\check{\theta}} \right), \frac{1}{\eta} \log \left(\frac{\eta v_G}{\check{\theta} + 1} \right) \right),$$

and a further reference to (B.9) yields $\check{\theta} = \mathcal{T}$, where $\mathcal{T}$ is the unique solution to (14), and the expressions for δ_H^*, δ_L^* and ι^* in (11) and in (12) if $\eta v_G > \mathcal{T} + 1$.

If $\eta v_G \leq \mathcal{T} + 1$, then at least the value of δ_L in (11) is non-positive and Lemma 4 leaves us with (B.5), which yields (13) if we set $\delta_L = \delta_L^* = 0$. The value of δ_H^* in (11) for the respective case is the unique solution to (13), and the leftmost equality in (B.7) yields the optimal threshold value of θ in (12).

B.6. Proof of Proposition 2. An argument similar to that used in the proof of Lemma 3, in the case of profit maximization, allows us to show that maximization of the surplus $w(\delta_H, \delta_L, \Theta)$ in (15) also requires different disclosure levels across offers. The optimal levels of δ_L and δ_H must then be compatible with an interior optimal value of the threshold Θ , which is readily found to be equal to

$$\Theta_W(\delta_H, \delta_L) = \frac{(e^{-\delta_L \eta} - e^{-\delta_H \eta}) v_G}{\delta_H - \delta_L}, \quad (\text{B.10})$$

We can then focus on the conditional optimal surplus

$$v(\delta_H, \delta_L) = w(\delta_H, \delta_L, \Theta) \Big|_{\Theta = \Theta_W(\delta_H, \delta_L)},$$

and follow a procedure similar to that used in the proof of Proposition 1. $\frac{\partial v(\delta_H, \delta_L)}{\partial \delta_H} = 0$ requires

$$2\eta e^{-\delta_H \eta} (\delta_H - \delta_L) - e^{-\delta_L \eta} + e^{-\delta_H \eta} = 0 \quad (\text{B.11})$$

whereas $\frac{\partial v(\delta_H, \delta_L)}{\partial \delta_L} = 0$ requires at least one of the two equations in (B.12),

$$\delta_H - \delta_L - (e^{-\delta_L \eta} - e^{-\delta_H \eta}) v_G = 0, \quad (\text{B.12a})$$

$$(2\eta v_G e^{-\delta_L \eta} - 1)(\delta_H - \delta_L) - (e^{-\delta_L \eta} - e^{-\delta_H \eta}) v_G = 0. \quad (\text{B.12b})$$

(B.12a), together with (B.10), implies $\Theta_W(\delta_H, \delta_L) = 1$, and is therefore inconsistent with surplus maximization. Moreover, by rearranging (B.11) and (B.12b), we obtain

$$2\eta v_G e^{-\delta_H \eta} = \frac{(e^{-\delta_L \eta} - e^{-\delta_H \eta}) v_G}{\delta_H - \delta_L} = 2\eta v_G e^{-\delta_L \eta} - 1, \quad (\text{B.13})$$

and therefore $2\eta v_G e^{-\delta_L \eta} - 2\eta v_G e^{-\delta_H \eta} = 1$. Using (B.10), we can then write

$$2\eta v_G e^{-\delta_H \eta} = \check{\theta} = 2\eta v_G e^{-\delta_L \eta} - 1, \quad (\text{B.14})$$

where $\check{\theta}$ is defined by (B.9). We can then use the first and the second equality in (B.14) to express δ_H and δ_L as functions of $\check{\theta}$, refer again to (B.9) to conclude that $\check{\theta} = \mathcal{T}$, and obtain the expressions in (17) and in (18) for the case of $\eta v_G > \frac{\mathcal{T}+1}{2}$.

If $\eta v_G \leq \frac{\mathcal{T}+1}{2}$, we have a boundary solution, and the requirement of differentiated disclosure levels leaves us with (B.11), which turns into (13) if $\delta_L = 0$. The only positive value of δ_H that solves (13) then completes the characterization of the disclosure levels in (17), and the optimal threshold value of θ is found by using the leftmost equation in (B.13) and the expression for $\Theta_W(\delta_H, \delta_L)$ in (B.10).

B.7. Proof of Proposition 3. The disclosure level in (20) is immediately obtained from the first and second order-conditions for a solution to the platform's problem in (19), taking into due account the assumption of a large value of v_M and the possibility of solutions with no information disclosure.

B.8. Proof of Proposition 4. The proof relies on Baron and Myerson (1982); we provide a synthesis focused on the results of interest, and refer the reader to the original paper for the details. Given differentiability and concavity in δ of the total surplus from the induced exchanges, the platform chooses the positive levels of disclosure, under truthful reporting by the respective types, by equalizing the marginal product $\eta e^{-\delta\eta} v_G$ and the type-specific virtual cost. Using $F(\theta)$ and $f(\theta)$ to denote the cumulative distribution and the density function of the types, the virtual cost is expressed by $\theta + \frac{F(\theta)}{f(\theta)}$, and (21) follows from $\eta e^{-\delta\eta} v_G = 2\theta$.

The first order condition for the choice of a value of $\hat{\theta}$ at which the transfer function $\rho_C(\hat{\theta})$ is differentiable, for a consumer of type θ , is

$$\frac{d(\rho_C(\hat{\theta}) - \theta\delta_C(\hat{\theta}))}{d\hat{\theta}} = \frac{d\rho_C(\hat{\theta})}{d\hat{\theta}} + \frac{\theta}{\eta\hat{\theta}} = 0.$$

By invoking again truthful reporting, we obtain the differential equation $\frac{d\rho_C(\theta)}{d\theta} = -\frac{1}{\eta}$, whose general solution is

$$\rho_C(\theta) = \gamma - \frac{\theta}{\eta}.$$

The parameter γ is identified by imposing the boundary condition of a net surplus of 0 for type $\theta = \min\left\{\frac{\eta v_G}{2}, 1\right\}$, which features the lowest positive level of disclosure, and the information rents guarantee satisfaction of the participation constraints of the lower types. If $\frac{\eta v_G}{2} < 1$, the derivation of (22) is completed by imposing a net surplus of 0 for the non-disclosing types as well.

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