Online shopping and platform design with ex ante registration requirements[*]

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Abstract

We study platform design in online markets in which buying involves a (non-monetary) cost for consumers caused by privacy and security concerns. Firms decide whether to require registration at their website before consumers learn relevant product information. We derive conditions under which a monopoly seller benefits from ex ante registration requirements and demonstrate that the profitability of registration requirements is increased when taking into account the prospect of future purchases or an informational value of consumer registration to the firm. Moreover, we consider the effectiveness of discounts (store credit) as a means to influence the consumers' registration decision. Finally, we confirm the profitability of ex ante registration requirements in the presence of price competition.

Keywords: E-commerce; Privacy concerns; Security concerns; Registration cost; Platform design; Monopoly; Price competition; Information; Digital Transformation

JEL Codes: D42; D43; D82; D83; L81

1   Introduction

In online markets, the interactions between firms and consumers exhibit many new characteristics which are not present in traditional shopping at brick and mortar stores. This raises new questions concerning firms' platform design. In particular, while traditional shopping typically does not require consumers to reveal personal information, shopping online often requires creating a user account and entering detailed contact and payment information. Therefore, shopping online can involve costs caused by privacy and security concerns which are less important in traditional markets.[1]

This paper considers firms' platform choices when buying involves a non-monetary cost for consumers which we call a 'cost of registration.' In our model, a firm selling a product online faces a mass of consumers who are ex ante uncertain about the price and characteristics of the product. The firm can credibly reveal this information to the consumers (for instance by providing a preview of a song or book, or by releasing various product photos and details). The platform choice we are interested in is whether to make the information accessible to consumers upon visiting the online shop, or to require the consumers to set up an account before they can learn all relevant product details and, hence, their valuation. In other words, the firm decides whether to require ex ante registration, in which case each consumer who registers incurs a non-monetary registration cost (independently of buying), or to require registration only ex post (only if the consumer actually wants to buy). Moreover, the firm can offer the option of guest checkout, in which case the consumers need to provide less personal information.

There are many examples in which firms require some kind of 'registration' before consumers obtain all relevant information. Shopping at iTunes, for instance, requires the download and installation of the software, together with the setup of a user account.[2] The same is true for many music and video streaming services such as Spotify or Netflix for which consumers can only browse the catalog of available titles when having created a user account and, in some cases, installed a software or app; here, consumers are often offered a free trial

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[1]Privacy concerns include concerns about the collection and use of personal information by firms and advertisers, but also by governments. They are often closely related to security concerns such as the fear of the misuse of information (personal information as well as password and credit card information, for instance) and concerns about the security of communication channels. In their survey on identity theft, Anderson et al. (2008, p.181) state: "Concerns about maintaining the security of personal data may lead consumers to avoid online transactions, make them less willing to shop around for credit, or otherwise cause them to spend resources to protect their personal records." For a review on the collection and use of personal information by companies and data brokers see also Alice E. Marwick, "How your data are being deeply mined," available at: http://www.nybooks.com/articles/archives/2014/jan/09/how-your-data-are-being-deeply-mined/.

[2]In older versions of iTunes, setting up a user account also required the provision of credit card or other valid payment information.

period in which they can learn their valuation before deciding whether to buy (that is, not to terminate their subscription). Moreover, directing consumers on mobile devices to the respective app stores and making them install the app on their device and set up an account has become increasingly popular.[3] Other online stores offer certain features of their website only after registration and for users signed in to the website.[4] Sometimes, detailed delivery information and services and total costs (including shipping fees and/or credit card fees) are only disclosed after signing in and at the very end of the checkout process.[5]

The non-monetary registration costs may deter consumers from buying. We show in a baseline model (Section 3) that it can be profitable for firms to detach the registration costs from the actual buying decision and shift it forward in the shopping process. Thereby the registration costs are already sunk at the point in time where the consumer decides whether to buy, and do not matter for the purchase decision anymore. Thus, with an ex ante registration policy, the firm can sell its product to a larger share of consumers and at a higher price, compared to the case without ex ante registration requirement where all information is released immediately and the cost of registration is only incurred by consumers who finally buy.

In Sections 4 to 6 we consider further specific features of online shopping and analyze how they affect the profitability of registration requirements. Section 4 shows that the prospect of future purchases strengthens both the consumers' willingness to set up an account, and the firm's advantage of registration requirements; it also demonstrates interesting trade-offs when allowing the option of guest checkout.[6] Section 5 takes into account that firms may value the information that consumers provide when setting up an account and making their buying decision.[7] In this case, equilibrium prices are reduced (consumers "pay" with their information) and the relative profitability of registration requirements is increased; we also address the welfare consequences of registration requirements. Section 6 considers discount policies as a means to increase consumers' incentives to register.[8] For example,

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[3]According to the Economist's Special Report on Advertising and Technology (Sep. 13th 2014), "Ads that encourage people to download apps account for a large proportion of mobile-ad spending."

[4]For instance, the 'search inside books' at amazon.com is only available to registered customers.

[5]In addition, online shops often keep uncertainty about the 'registration cost' by not making transparent ex ante which information is required when setting up an account. High registration cost and privacy and security concerns are also considered a reason for why consumers may not complete an online transaction but abandon their shopping cart before the final purchase stage (see, e.g., Cho et al. 2006).

[6]On repeat purchases and customer loyalty as determinants of the success of online sellers see Reichheld and Schefter (2000) for seminal insights and Toufaily et al. (2013) for a review of the literature.

[7]Brokering consumer information is an important source of revenue for online sellers (see, e.g., Lambrecht et al. 2014). Moreover, one reason for consumers' privacy concerns is the sellers' economic incentive to use the information revealed by the customer, either by selling it to third parties, or by targeting ads or personalizing offers.

[8]Discounts, promotional codes or (digital) coupons are a widely used instrument, in particular in e-

Google recently offered a \$25 Google Play credit for its Play Store to consumers "who have, or add, a valid form of payment to your Google Wallet account." Such a discount increases a consumer's surplus from registration as long as it is not offered to all registered consumers (otherwise, the equilibrium price increases by the discount, which consumers anticipate). We show that even though discounts distort the firm's pricing decision, discount policies can make ex ante registration requirements more profitable for the firm. Finally, the online appendix studies optimal platform design under competition, assuming that each firm has loyal consumers who only consider buying at this particular firm.[9] The mass of loyal consumers can be arbitrarily small. We show that in any equilibrium where firms do not randomize their registration requirements, all firms, except possibly one, require ex ante registration. Intuitively, ex ante registration requirements are a means to avoid fierce price competition and yield higher profits at least from selling to the loyal consumers (due to the same 'sunk cost' advantage as in the benchmark model).

2 Related literature

Our paper contributes to the literature on internet markets surveyed by Bakos (2001), Ellison and Ellison (2005), and Levin (2013). Privacy and security concerns have, so far, received only little attention in the literature on market structures and platform design. Lambrecht et al. (2014) emphasize the value of user information in their discussion of different business strategies in the context of digital goods. Our analysis of how the value of user information affects registration policies (in Section 5) is closely related to Akçura and Srinivasan (2005). While we focus on registration policies, they analyze price-setting decisions of a monopolist who sells a good to consumers and, in addition, the consumers' information to a third party. Casadeus-Masanell and Hervas-Drane (2015) study competition between sellers in a setting related to Akçura and Srinivasan (2005). Bergemann and Bonatti (2013) consider the demand for information and pricing decisions of data providers (who collect data, for instance, via third-party cookies). Chellappa and Shivendu (2010) analyze the economics of personalization for free goods and services when consumers have privacy concerns.

Goldfarb and Tucker (2012) empirically investigate consumers' privacy concerns and document an increasing trend to refuse the revelation of information as well as clear differences

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commerce where they can be specifically targeted to certain groups of consumers, and are a way to induce consumers to reveal personal information (compare Shapiro and Varian 1999 and OFT 2010).

[9] As argued by Smith and Brynjolfsson (2001) for online shopping, "brand is an important determinant of consumer choice," possibly out of concerns for non-contractible service quality such as shipping reliability, or cognitive lock in. In the context of music streaming services, brand loyalty to the recently launched *Apple Music*, for instance, need not be a pure preference of consumers for a certain brand but can also emerge due to complementarities with other products (iPhones) which consumers already own.

between age cohorts. According to surveys by the Pew Research Center (2013, 2014), 91% of American adults agree that consumers have lost control over the collection and use of private information; at the same time, 61% say that they would like to do more to protect their privacy.[10] Moreover, 21% of internet users reported that they had an e-mail or social networking account compromised or taken over and 11% had important information stolen (such as Social Security Number or credit card information).[11] For recent reviews of the economics of privacy see Acquisti et al. (2015) and Acquisti et al. (2016).

Methodologically, the registration costs considered in our model share some similarities with other purchase-related costs, such as transportation costs, search costs, and set-up or switching costs. It is well known that even arbitrarily small search costs can lead to equilibrium prices that drastically differ from the marginal cost pricing obtained under perfect competition (Diamond 1971). We derive a related result in the presence of arbitrarily small registration costs, but the logic differs in subtle respects, as our result also requires the presence of an arbitrarily small mass of loyal customers (see Section B of the online appendix).[12]

Moreover, in our baseline model, ex ante registration requirements can be seen as a light form of 'bait-and-switch' strategies which are used to increase the share of consumers who visit the store and who, once they are there, are more willing to buy (Gerstner and Hess 1990; Lazear 1995). Anderson and Renault (2006, 2013) analyze a related effect in a search cost model in which a monopoly firm can advertise price and/or match information before the consumer decides whether to visit the store. Koessler and Renault (2012) derive conditions for full disclosure of product and match information for the case of a monopoly firm which can commit to an observable price. Moreover, a recent literature considers firms' incentives to use 'obfuscation strategies' to make it more difficult to compare products and prices (Ellison and Ellison 2009; Carlin 2009; Wilson 2010; Ellison and Wolitzky 2012). Such obfuscation may be particularly relevant in online markets where search costs are low and the price elasticity of demand is high. The literature on switching costs as another prominent type of purchase-related costs has been surveyed by Chen and Hitt (2006) and Farrell and Klemperer (2007). While the effect of registration requirements in our baseline model shares

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[10] Around 90% of the respondents have taken steps at least once to keep anonymity online and to avoid being tracked (see Pew Research Center 2013, 2014 for further details). According to the surveys conducted by Milne et al. (2004), around two third of respondents had decided not to purchase at a website due to uncertainty about the use of personal information.

[11] See also the survey by Anderson et al. (2008) on costs and implications of identity theft.

[12] When consumers are aware of the quality (their valuation) of a product but have to incur a cost to learn its price, a hold-up problem emerges, which may even result in a complete market breakdown (Stiglitz 1989, Section 2). The literature on informative advertising (surveyed by Bagwell 2007 and Renault 2016) has studied several ways to deal with this hold-up problem. In our setting, there is no market breakdown unless registration costs are prohibitively high, since consumers are unaware of some product characteristics of the good prior to registration and need to 'inspect' the product in order to learn their valuation.

some similarities with effects identified in the literature on purchase-related costs, there are also fundamental differences to other types of purchase-related costs, which become most visible when we extend the baseline model as to analyze the interactions of registration requirements with specific features of online markets.[13]

3   The logic of ex ante registration requirements

In this section we demonstrate why firms can benefit from making their customers register early: Ex ante registration requirements detach any (non-monetary) cost of registration/buying from the actual buying decision; this increases a firm's profit whenever some information about product characteristics and prices is only revealed during the process of shopping. We first show this 'sunk cost' effect in a baseline one-period model in which any other motivations for requiring ex ante registration are absent.

Suppose there is one firm and a mass of consumers of size one. The firm offers a product to the consumers; without loss of generality we assume the marginal production cost to be zero. Each consumer has single unit demand. Denote a consumer's valuation of the good by θ. It is commonly known that the valuations are independent draws from a cumulative distribution function F with support $[0, \infty)$; we assume that F is twice differentiable.

Initially, consumers do not know their valuation; they can inspect the product and learn their θ prior to the purchase decision. In order to purchase the product, a buyer needs to provide personal information such as payment and address details, which causes a non-monetary cost $k > 0$. This cost comprises the opportunity cost of the time needed to set up an account and the disutility due to privacy and security concerns; it depends on the firm's registration requirements, as explained next.

The firm makes a platform choice consisting of a decision $r \in \{ExA, ExP, G\}$ on the registration requirement, and chooses a price p (per unit of the product).[14] If the firm requires ex ante registration ($r = ExA$) then in order to learn his valuation and to observe the price, a consumer has to register and incur a registration cost $k_R > 0$. If the firm requires registration only ex post ($r = ExP$) then consumers learn their valuation and the price without having to

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[13]For instance, registration costs also apply in situations in which consumers know all product and price details, while search costs are irrelevant in this case. Moreover, in the multi-period model, consumers can buy repeatedly with the same account and, hence, only need to incur the registration costs once, while incurring transportation or search costs once does not typically lower the transportation or search costs for future purchases.

[14]We do not consider upfront payments made upon registration and independent of eventual purchase, such as up-front subsidies or registration fees. These may be misused, and are rarely found in practice at online shops. A feasible and profitable form of subsidies are discounts or store credits that can be cashed in upon purchase, which we discuss in Section 6.

register. Consumers who want to buy have to set up an account at the firm; hence, the cost k_R is incurred if and only if a consumer decides to buy. As an additional option, the firm can allow guest checkout: If $r = G$, consumers learn their valuation and the price without having to register. If a consumer wants to buy, he can either set up an account (at cost k_R) or use the option of guest checkout, which causes a non-monetary cost k_G, where $0 < k_G < k_R$. The non-monetary cost k_G of using guest checkout is strictly lower than the registration cost k_R, because consumers have to provide less information and privacy concerns are less important. But k_G is strictly positive: Even the use of guest checkout requires the provision of some personal information such as shipping and payment details as well as an e-mail address, and does not completely eliminate all security concerns. We will see that since $k_G < k_R$, offering guest checkout dominates requiring ex post registration in the benchmark model of this section. Ex post registration requirements can become optimal, however, when considering dynamic aspects (Section 4) or an informational value of consumer registration (Section 5), and interesting trade-offs between allowing guest checkout and requiring registration ex post arise in these settings.

The timing of the game is as follows. At the beginning of stage 1, nature draws each consumer's valuation θ independently from the distribution F (neither consumers nor the firm observe these draws of θ). Then, the firm decides on the registration requirement and this platform choice becomes common knowledge. In stage 2, the firm chooses a price $p \geq 0$. The sequence of events in stage 3 depends on whether or not the firm has chosen to require ex ante registration. If $r = ExA$ then, in stage 3, each buyer decides whether to register at cost $k_R > 0$. Registered consumers can observe the price p and their valuation θ and decide if they want to buy one unit of the good; non-registered consumers cannot buy. If $r \neq ExA$, all consumers observe p and their θ and then decide whether or not to buy. If $r = ExP$, a consumer who wants to buy has to set up an account at cost $k_R > 0$; if $r = G$, consumers can choose between setting up an account (at cost k_R) and buying as a guest (at cost k_G). The firm's profit is equal to the share of consumers who buy, multiplied by the price p. A buyer's utility is equal to (i) $-k_R$ if he registers but does not buy, (ii) $\theta - p - k_R$ if he buys with an account, (iii) $\theta - p - k_G$ if he buys as guest, and (iv) zero otherwise. We assume the tie-breaking rules that indifferent consumers set up an account, and buy when indifferent between buying and not buying. Moreover, unless explicitly noted otherwise, we break ties between $r = ExA$ and $r \neq ExA$ in favor of $r = ExA$, and ties between $r = ExP$ and $r = G$ in favor of $r = ExP$. The equilibrium concept is perfect Bayesian equilibrium.

Before turning to the equilibrium of the game, we pause to discuss the informational aspects, and an alternative interpretation of the setup. The model assumes that with an ex ante registration requirement, consumers cannot learn their valuation without setting up

an account. In reality, for some types of products it may be difficult for firms to "hide" the relevant product characteristics. For example, the consumer may learn about the *search qualities* (Nelson 1974) of the product from reviews or discussion boards. We point out, however, that the information obtained in this way will typically not be complete. In particular, in order to find out how much he values the *experience qualities* of the good, a consumer will have to inspect the product (or a sample thereof) himself, and no other channels can reliably transmit all of the relevant information. Our model applies whenever some information provision remains under the control of the seller (for example, Netflix and Spotify control when to divulge lists of movies and songs, respectively). Formally, the cumulative distribution function F captures the residual uncertainty. Moreover, obtaining information from other sources than the seller is not costless for the consumers; we determine a consumer's maximum willingness to pay for such information below.

Apart from unit demand for one product, the model reflects markets such as music or video streaming services with a continuum of goods. The price p can be interpreted as the price for a subscription, and θ as a measure for the share of goods a consumers likes where he derives a utility of one if he likes the good and zero utility otherwise; hence, θ is equal to the expected utility from subscribing.

No ex ante registration Suppose that the firm does not require ex ante registration. Then, in stage 3, each buyer learns the price p and his valuation θ. For a non-monetary cost of buying k (where $k \in \{k_G, k_R\}$), the share of consumers who buy is equal to

$$\Pr\left(\theta \geq p + k\right) = 1 - F\left(p + k\right).$$

In stage 2, the firm anticipates the consumers' buying decisions and chooses a price p as the solution to

$$\max_{p}\left(1 - F\left(p + k\right)\right)p.$$

Define $p\left(k\right)$ as the solution to[15]

$$p\left(k\right) = \frac{1 - F\left(p\left(k\right) + k\right)}{F'\left(p\left(k\right) + k\right)} \tag{1}$$

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[15]To simplify the notation, we assume here that there is a unique solution to the firm's maximization problem given by the first-order condition, which can be guaranteed under additional assumptions on F. For example, Assumption 1 introduced below is sufficient for the profit-maximizing price to be unique and given by (1).

and the corresponding profit $\pi(k)$ as

$$\pi(k) := (1 - F(p(k) + k)) p(k). \tag{2}$$

Then, if the firm chooses $r = G$ and a price p, all consumers who want to buy will use the guest checkout (due to $k_G < k_R$). Hence, the firm's optimal price is $p(k_G)$, with a corresponding profit of $\pi(k_G)$. If instead $r = ExP$ then all consumers who want to buy have to register at cost k_R, which yields an optimal price of $p(k_R)$ and a corresponding profit of $\pi(k_R)$. With

$$\bar{u}(k) := \int_{p(k)+k}^{\infty} (\theta - p(k) - k) \, dF(\theta), \tag{3}$$

expected consumer surplus is equal to $\bar{u}(k_G)$ if $r = G$ and equal to $\bar{u}(k_R)$ if $r = ExP$.

Ex ante registration   Suppose that the firm requires ex ante registration. Then, in stage 3, only registered consumers learn p and their θ. A (registered) consumer buys if and only if $\theta \geq p$.

If a buyer knew the price p (but not yet his valuation θ), he would register if and only if his expected utility from registration is sufficient to cover the registration cost, that is,

$$\int_p^{\infty} (\theta - p) \, dF(\theta) \geq k_R. \tag{4}$$

The buyers, however, do not know the price when deciding on registration. They therefore have to form beliefs about the price set by the firm. In a perfect Bayesian equilibrium, these beliefs must be consistent with the firm's price setting behavior and derived from Bayes rule wherever possible.

Consider the firm's pricing decision. Suppose that the firm believes that all buyers register. Then, the firm chooses a price as the solution to

$$\max_p (1 - F(p)) p.$$

This yields an optimal price equal to $p(0)$ and a corresponding profit of $\pi(0)$ (where $p(k)$ and $\pi(k)$ are defined in (1) and (2), respectively). Anticipating this price, a buyer registers if and only if $k_R \leq \bar{u}(0)$ where

$$\bar{u}(0) = \int_{p(0)}^{\infty} (\theta - p(0)) \, dF(\theta). \tag{5}$$

Therefore, if $k_R \leq \bar{u}(0)$, the continuation game has an equilibrium in which the firm

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chooses $p = p(0)$; all buyers register, and they buy if and only if $\theta \geq p(0)$.[16] If instead $k_R > \bar{u}(0)$ then in the equilibrium of the continuation game no buyer registers. To see why, suppose that, in stage 3, a buyer registers with some probability $\mu \in (0, 1]$. Anticipating this registration decision, the firm will choose the price $p(0)$.[17] But if a buyer's beliefs about the price p are consistent with this choice, it is optimal for the buyer not to register in case of $k_R > \bar{u}(0)$: Anticipating the firm's choice of the price, the expected surplus from registration is too low. Comparing the firm's expected profits under the different registration requirements yields our first main result.

Proposition 1 *In equilibrium, a monopoly firm requires ex ante registration if and only if $k_R \leq \bar{u}(0)$ (where $\bar{u}(0)$ is given in (5)). Otherwise, the firm chooses $r = G$ and offers the option of guest checkout.*

Proof. Suppose that $k_R \leq \bar{u}(0)$. If the firm requires ex ante registration, it chooses the price $p(0)$. Since all consumers register, the firm's expected profit is

$$\pi(0) = (1 - F(p(0))) p(0),$$

which is (weakly) larger than $(1 - F(p)) p$ for all $p \neq p(0)$. In particular, for any $k > 0$,

$$\pi(0) \geq (1 - F(p(k) + k)) (p(k) + k) > (1 - F(p(k) + k)) p(k) = \pi(k).$$

Hence, the firm's profit under $r = ExA$ is strictly higher than (i) its profit under $r = ExP$ (which is $\pi(k_R)$) and (ii) its profit under $r = G$ (which is $\pi(k_G)$).

If $k_R > \bar{u}(0)$, the firm makes zero profits if it requires ex ante registration but strictly positive profits if it does not require ex ante registration. Under $r = G$, it chooses $p = p(k_G)$ and must be (weakly) better off than when choosing $p' = p(k_R) + k_R - k_G$, thus,

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\begin{aligned}
\pi(k_G) &\geq (1 - F((p(k_R) + k_R - k_G) + k_G)) (p(k_R) + k_R - k_G) \\
&> (1 - F(p(k_R) + k_R)) p(k_R) = \pi(k_R).
\end{aligned}
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The intuition for Proposition 1 is straightforward. If the consumers' costs of registration are sufficiently small $(k_R \leq \bar{u}(0))$, consumers are willing to register ex ante. In this case,

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[16] There is an additional set of equilibria in which the firm sets a (high) price at which (4) is violated and all buyers believe that the firm sets this high price and hence do not register. In the following, we ignore these equilibria which can be eliminated by an appropriate equilibrium refinement.

[17] Since buyers do not know their valuation when registering and are symmetric ex ante, the distribution of types that the firm faces in stage 3 is still described by the distribution F, leading to a price choice that is independent of μ (as long as $\mu > 0$).

requiring ex ante registration is optimal for the firm. With ex ante registration, the registration costs k_R are sunk when a consumer decides whether to purchase; ex ante registration detaches the registration costs from the purchase decision. Consequently, with ex ante registration, the firm can choose a higher price and still sell to a larger share of consumers. If, however, the consumers' registration costs are high relative to the expected consumer surplus, no one would be willing to register ex ante; therefore the firm does not require it. In the latter case, the firm prefers $r = G$ over $r = ExP$ since, for any given price, more consumers buy if less personal information is required (formally, this follows from $k_G < k_R$).

To gain a better understanding of pricing decisions and consumer surplus, we make the following assumption on the probability distribution F.

Assumption 1 *F has a strictly monotone hazard rate:*

$$\frac{d}{d\theta} \frac{F'(\theta)}{1 - F(\theta)} > 0.$$

Assumption 1 implies the following ranking of the candidate equilibrium prices:[18]

$$p(k_R) < p(k_G) < p(0) < p(k_G) + k_G < p(k_R) + k_R.$$

The higher the consumers' registration costs k, the lower is the price $p(k)$ that the firm charges. But the sum of the price and the registration cost, $p(k) + k$, is increasing in k, which implies that higher registration costs reduce the equilibrium probability of trade. Therefore, if the firm requires ex ante registration, its equilibrium price is higher ($p(0) > p(k)$ for all $k > 0$); nevertheless, its demand goes up ($1 - F(p(0)) > 1 - F(p(k) + k)$ for all $k > 0$). Each of these two effects makes the firm benefit from shifting the registration cost to the ex ante stage. The effect of ex ante registration on consumer surplus is, however, exactly the opposite. With ex ante registration, the consumers pay a higher price; in addition, they pay k_R independently of whether they buy. Both effects reduce consumer surplus compared to the case of no ex ante registration and cause consumer surplus to be highest when the firm offers the option of guest checkout ($r = G$).

Defining welfare as the sum of the firm's expected profits and the consumers' expected utility, the effect of an ex ante registration requirement on welfare can be separated into two effects: (i) changes in the surplus from trade caused by changes in the equilibrium price, and (ii) changes in the total expected non-monetary cost of registration. The second effect

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[18] Assumption 1 guarantees that the pass-through rate of the registration costs takes an interior value between 0% and 100%; compare also Bulow and Pfleiderer (1983) and Weyl and Fabinger (2013). Related questions on pass-through rates arise in the literature on tax incidence (see Fullerton and Metcalf 2002 for a survey).

is always welfare-reducing since $k_R > k_G$ and since under ex ante registration requirements the cost of registration is incurred independently of whether a consumer actually buys. The first effect can, however, be positive: If Assumption 1 holds, there is more trade with ex ante registration requirements, which is welfare improving since there is inefficiently low trade in equilibrium.[19] If F is a uniform distribution, for instance, the total welfare effect of ex ante registration requirements is negative even when $k_R \to k_G$ (the second, negative effect outweighs the first, positive effect). But there are also examples for distributions F for which welfare is higher with than without ex ante registration.[20]

To conclude this section we discuss the informational assumptions of the model, effects of price competition, and a possible heterogeneity in consumers' privacy concerns.

Registration requirements, information provision, and consumer search As discussed above, with an ex ante registration requirement, consumers may try to obtain relevant information through other channels such as product reviews or discussion forums. Searching for information is likely to be time-consuming or costly in other ways, however. If $k_R \leq \bar{u}(0)$ and $r = ExA$, a consumer is willing to invest search effort up to

$$\int_{p(0)+k_R}^{\infty} (\theta - p(0) - k_R)\, dF(\theta) - (\bar{u}(0) - k_R)$$

$$= F(p(0))\, k_R + \int_{p(0)}^{p(0)+k_R} (p(0) + k_R - \theta)\, dF(\theta) \tag{6}$$

to learn θ and p. This amount is strictly positive because the information acquisition allows the consumer to avoid (i) the registration costs when not buying (the first term in (6)) and (ii) buying at a total (monetary and registration) cost higher than θ (the second term). The firm can keep using ex ante registration requirements whenever the consumers' costs of learning the information through other channels are larger than the amount in (6).

Search costs are likely to be high for experience and inspection goods where learning one's valuation essentially requires trying out the good or a sample of it, and for specialized goods and services for which only a few other buyers exist from whom one could gather relevant information. On the other hand, for highly standardized mass products with mainly search characteristics which can easily be communicated by other customers, search costs are likely to be low, and hence ex ante registration policies may be undermined by consumers' search behavior. In this case, the firm would be willing to pay up to its profit increase under ex

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[19]Since marginal production costs are assumed to be zero, all consumers with $\theta > k_G$ should buy in the welfare optimum, but in case of $r = G$, for instance, consumers buy only if $\theta > p(k_G) + k_G$.

[20]This can most easily be shown by using discrete distribution functions F; however, smooth examples can also be constructed. Details are available upon request.

ante registration, $\pi(0) - \pi(k_G)$, in order to implement 'obfuscation strategies' that raise the consumers' search costs above the amount in (6).[21]

Our model also abstracted away from any direct costs of the firm to provide information to consumers such as offering product samples or designing the website accordingly. Moreover, registration often includes installing some software or app, in which case providing product information to non-registered consumers may be more costly for the firm. A lower cost of information provision to registered as compared to non-registered consumers would make ex ante registration requirements relatively more profitable.

A related issue is the credibility of the information provided by the firm. For experience qualities, the main uncertainty is about the match between the product and the consumer's idiosyncratic tastes; the firm may be unable to directly communicate anything about the match but needs to let the consumers inspect or try out the product, for instance, through book previews, song samples or free trial memberships. Here, credibility is less an issue because providing information means letting consumers test (aspects of) the product itself. Conversely, credibility may be more of a concern with respect to search qualities. Any issue of credibility of the firm's information provision will arise in all types of registration policies discussed above and is therefore orthogonal to our main research objective.

Finally, the analysis above assumes that in case of an ex ante registration requirement, the price is only revealed upon registration. This assumption is most restrictive for making ex ante registration profitable since a firm that requires ex ante registration cannot commit to a lower price but will always choose $p = p(0)$ in equilibrium, which the consumers anticipate. If $k_R \leq \bar{u}(0)$, this assumption is inconsequential since with price commitment the firm chooses the same price $p(0)$ such that our results are unaffected. If $k_R > \bar{u}(0)$, however, ex ante registration requirements are infeasible without price commitment. In contrast, when the firm can commit to a price, ex ante registration requirements can still be profitable.

To formalize this argument suppose that the consumers learn the price set by the firm prior to registration, even if the firm requires ex ante registration. Moreover, suppose that the price chosen by the firm is a binding commitment and cannot be changed once consumers have registered. Arguably, this fits some of the examples mentioned in the introduction. For example, the prices of the streaming services of Netflix and Spotify can be found on their

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[21]For instance, consumers can find a list of movies available on Netflix and other competing sellers on www.justwatch.com (accessed on June 11, 2016). It is doubtful, however, how much scrolling through such a list will improve the accuracy of a consumer's estimate of his valuation of a subscription, as viewing the complete list is likely to be prohibitively time consuming; moreover, the catalog will typically change within the period of subscription. Nevertheless, in the presence of such information the firms would need to keep the costs of registration sufficiently low in order not to deter consumers from registering, and may want to provide services such as personalized recommendation systems which are difficult for consumers to judge ex ante and without inspecting the product.

websites, and reputational concerns may make costly for firms to deviate from these prices.

Remark 1 *With price commitment, a monopoly firm requires ex ante registration if and only if $k_R \leq \hat{k}_R$, where $\bar{u}(0) < \hat{k}_R < E(\theta)$. Otherwise, the firm chooses $r = G$ and offers the option of guest checkout.*

The proofs of Remark 1 and subsequent results are relegated to the appendix. Comparing Remark 1 with Proposition 1 shows that the possibility of price commitment enlarges the range of parameters where the firm requires ex ante registration. For $k_R \leq \bar{u}(0)$, the optimal price and expected profits are the same with and without the possibility of price commitment. But if k_R is in some environment above $\bar{u}(0)$ then, by committing to a price slightly below $p(0)$, the firm can guarantee that the consumers register ex ante. Therefore, if k_R is in the (non-empty) interval $(\bar{u}(0), \hat{k}_R)$, the optimal registration choice is $r = ExA$ in the case with price commitment, while it is $r = G$ in the case without ex ante observability of prices. Another way of enlarging the range of registration costs for which consumers register is the use of discounts (store credit); in Section 6 we demonstrate the effectiveness of such discounts when commitment on prices is not possible.

Competition The benchmark model above assumed a monopoly seller, and this naturally raises the question of how robust the results are with respect to competition. Indeed, under Assumption 1 consumer surplus is lowest in case of an ex ante registration requirement; hence, the consumers may prefer to shop at a firm that does not require ex ante registration. Therefore, we also study price competition between $N \geq 2$ firms (see Section B of the online appendix), assuming that each firm may have a share $\beta \geq 0$ of 'loyal' consumers who only consider to buy at this particular firm, while the remaining share $1 - \beta N$ of 'non-committed' consumers can buy at either firm.[22] We show that ex ante registration requirements are prevalent: whenever $\beta > 0$, all firms, except possibly one, will require ex ante registration and charge prices equal to $p(0)$, in any equilibrium where firms do not randomize their platform choices. Even though a firm i with $r_i \neq ExA$ attracts the non-committed consumers, the threat of price competition prevents a second firm j from choosing $r_j \neq ExA$. In the latter case j may get (some of) the non-committed consumers but realizes a lower profit from

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[22] For early papers on price competition with brand loyalty see Rosenthal (1980) and Narasimhan (1988). A similar structure emerges when a share of consumers is uninformed about the existence of other firms (Varian 1980, Baye et al.1992). Brand loyalty can be explained by switching cost, more specifically, for instance, by costly learning how to use new products, complementarities to other purchased products and network effects; for an overview of reasons for brand loyalty see Klemperer (1995). In Baye and Morgan (2001) loyalty emerges from local segregation of markets and can be broken down by creating a virtual marketplace on the internet. See also Baye and Morgan (2009) for a model of price competition when consumer loyalty is endogenous and affected by advertising.

selling to its loyal consumers; such a deviation turns out to be never profitable, even for arbitrarily small β. By a similar argument, if the share of loyal consumers is sufficiently high, all firm require ex ante registration in equilibrium and charge prices equal to the monopoly price.

The high prices chosen in equilibrium are reminiscent of the Diamond (1971) paradox that arbitrarily small search costs can yield prices equal to the monopoly price. Our assumption that prices are unobservable contributes to a related finding: If all firms choose $r_i = ExA$, the non-committed consumers expect all firms to choose $p = p(0)$; thus, with arbitrarily small registration costs k_R, they register at one random firm. In turn, the firms have no incentive to lower their prices. If, instead, the firms can commit to prices ex ante (compare the discussion above), this leads to prices below the monopoly price even in case all firms choose $r_i = ExA$. However, the result that all firms, except possibly one, require ex ante registration in equilibrium continues to hold in case of observable prices (details are in Section D of the online appendix). The sunk cost advantage of ex ante registration requirements is sufficiently strong to make $r_i = ExA$ attractive even in the absence of 'price obfuscation.' Moreover, just as in the monopoly case, the ability to commit to prices enlarges the range of registration costs k_R for which ex ante registration requirements are profitable.

Heterogeneity in registration costs While the profitability of ex ante registration requirements is most visible in the case where all consumers face the same registration cost k_R, it carries over to situations in which there is heterogeneity in the consumers' registration costs. We briefly discuss how the main proposition of this section changes if consumers differ in their cost of registration, for instance, because some consumers care more about privacy than others. For this purpose, suppose that a consumer's costs of registration k_R and k_G are drawn from two probability distributions $H_R(k_R)$ and $H_G(k_G)$, respectively, with support $[0, \infty)$. The cost parameters k_R and k_G can be correlated (H_R and H_G should be interpreted as the marginal distributions of the joint distribution of (k_R, k_G)). We assume that $k_R \geq k_G$ for each consumer, with strict inequality for a positive mass of consumers. Moreover, we assume k_R and k_G to be independent of the valuation θ so that under $r = ExA$ a consumer's choice to register does not convey information about his valuation θ. Each consumer privately knows his registration costs k_R and k_G.

Remark 2 *If the consumers' costs of registration k_R and k_G are distributed according to $H_R(k_R)$ and $H_G(k_G)$, respectively, the firm requires ex ante registration if and only if*

$$H_R(\bar{u}(0)) \geq \frac{\tilde{\pi}_G}{\pi(0)} \in (0,1), \tag{7}$$

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where

$$\tilde{\pi}_G := \max_p \int_0^\infty \left(1 - F\left(p + k_G\right)\right) p \, dH_G\left(k_G\right).$$

Otherwise, the firm offers the option of guest checkout ($r = G$).

If the consumers differ in their costs of registration, the firm faces a trade-off when choosing its registration policy: In case of $r = ExA$, only the consumers with low k_R will register and possibly buy, whereas under $r = G$ demand may be increased. But the profit extracted from those consumers who register under $r = ExA$ is higher than under $r \neq ExA$ (as shown in Proposition 1). Therefore, if a sufficiently high share of consumers have registration costs k_R below $\bar{u}\left(0\right)$ and are willing to register, the firm requires ex ante registration, accepting that it will not sell to some consumers who have a high cost of registration. Here, the additional gain from selling to consumers who register (those with low k_R) outweighs the loss from not selling at all to some other consumers (those with high k_R). If, however, the share of consumers with high k_R is increased then the firm is better off by not requiring ex ante registration and offering the option of guest checkout.

Formally, the left-hand side of (7) determines the share of consumers who register under $r = ExA$, and the right-hand side of (7) relates the profits per registered consumer under $r = ExA$ (which still is $\pi\left(0\right)$) to the profit per consumer under $r = G$ (which now is $\tilde{\pi}_G < \pi\left(0\right)$). In case of identical registration costs k_R (as assumed in our baseline model) the left-hand side of (7) is equal to one if $k_R \leq \bar{u}\left(0\right)$ and zero otherwise; in this case, (7) holds if and only if $k_R \leq \bar{u}\left(0\right)$ (compare the condition in Proposition 1).

4   A dynamic perspective

This section analyzes how the monopoly firm's choice of its registration policy is affected by aspects of future purchases. We first show that consumers expect a higher future surplus in case they already have an account at the firm and do not need to register again when buying; this increases the range of registration costs for which ex ante registration requirements are optimal. Second, we consider the firm's decision whether to offer the option of guest checkout in situations in which ex ante registration requirements are not feasible, either because the consumers' cost of registration is high or because the consumers can learn their valuation through other channels at comparably low cost (compare the discussion in Section 3). Here, we show that the firm may prefer to require registration ex post (instead of offering guest checkout). This result is again due to a sunk cost advantage when selling in future periods

to consumers who are already registered.[23]

Suppose that there are two periods, t and $t+1$. Each consumer has unit demand in each period; his valuations in the two periods are denoted by θ_t and θ_{t+1} and are independent draws from the probability distribution F.[24] The sequence of actions within period $\tau \in \{t, t+1\}$ is as in the baseline model. At the beginning of each period $\tau \in \{t, t+1\}$, the firm chooses its registration requirement r_τ as well as its price policy. The choice r_τ determines whether the consumers need a user account in order to observe θ_τ and the price in period τ.

As above, registration involves a cost k_R. Moreover, for each purchase using guest checkout consumers incur a cost k_G.[25] Consumers who have, in t, set up an account at the firm (at cost k_R) can, in $t+1$, use their existing account to inform themselves about the product and its price, and can also buy, without incurring additional registration costs. Registered consumers can also set up a new account (again at cost k_R) or use guest checkout if offered (at cost k_G), instead of buying with their existing account, but, as we will see, they have no incentive to do this since in equilibrium the total costs of buying (the price plus the costs of registration or guest checkout) turn out to be higher than when using the existing account.

We assume that the firm can charge different prices to registered and to non-registered consumers.[26] More precisely, the firm can condition its price offer in period $t+1$ on a consumer's registration decision in period t. This assumption simplifies the analysis considerably; it implies that a consumer's expected future gain from being registered does not depend on the other consumers' registration choices.[27] The assumption is also reasonable

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[23]Note that this section does not rely on a "switching cost" argument since we consider a monopoly firm. Effects of registration requirements in competitive environments are analyzed in the online appendix.

[24]To save on notation, we assume the valuations in the two periods to be identically distributed, but the results easily extend to the case where θ_t and θ_{t+1} are drawn independently from distribution functions F_t and F_{t+1}, respectively. For the same reason we also abstract from discounting of future profits/surplus. The assumption of independence of θ_t and θ_{t+1} rules out some forms of price discrimination; we discuss this issue further below.

[25]As in the baseline model k_R and k_G are assumed to be identical across consumers.

[26]Since θ_t and θ_{t+1} are independent, the firm cannot gain from discriminating between registered costumers based on their purchase behavior in t. This allows us to focus on the choice of registration policies and to abstract from many additional aspects discussed in the literature on behavior-based price discrimination; see, for instance, Hart and Tirole (1988) and Villas-Boas (2004) for the case of a monopoly seller, Villas-Boas (1999) and Fudenberg and Tirole (2000) for oligopolistic competition, and the surveys by Fudenberg and Villas-Boas (2006) and Stole (2007). Aspects of e-commerce and improved information technologies in this context are discussed, for instance, by Taylor (2004), Acquisti and Varian (2005) and in the survey by Fudenberg and Villas-Boas (2012). In our model, the use of behavior-based price discrimination would also be complicated by the possibility for consumers to set up new accounts or use guest checkout.

[27]If the firm charges the same price to all consumers, the price in period $t+1$ turns out to be an increasing function of the share of consumers who already have an account. But a higher price in $t+1$ reduces the consumers' incentive to register in period t since they expect a lower future benefit from already having an account. Therefore, the price in t affects the price in $t+1$ and the share of consumers who register, and vice-versa, and an individual consumer's period t choice depends on all other consumers' choices in t. This generates considerable technical complexities in the analysis, without affecting the main economic insights.

since the consumers identify themselves when visiting the website and deciding to sign in; thus, in order to pursue such a strategy, the firm does not need to know more about the consumers than they reveal themselves. Moreover, charging different prices for "existing" and "new" consumers is a widely established strategy in practice (Caillaud and De Nijs 2014). Finally, we assume in what follows that Assumption 1 holds (F has a monotone hazard rate).

Proposition 2 *In the two-period model, the firm requires ex ante registration in period t if and only if*

$$k_R \leq 2\bar{u}(0) - \bar{u}(k_G). \tag{8}$$

Proposition 2 confirms that if the firm has the option of using ex ante registration requirements, it prefers to do so as long as the consumers' costs of registration are sufficiently low. Moreover, the sunk cost effect of ex ante registration benefits the firm in the current period, but also in future periods, even though registered consumers can observe their valuation and the price in future periods without having to incur any cost.

Including the option of multiple purchases also increases the consumers' value of registering: If a consumer already has an account, he realizes a higher expected surplus since he does not have to incur again the cost of setting up an account. This holds even though the consumer (correctly) anticipates a higher price if he is registered. Therefore, the range of registration costs for which ex ante registration requirements are profitable for the firm is enlarged compared to the baseline model (Assumption 1 implies that $\bar{u}(0) > \bar{u}(k_G)$).

For high registration costs k_R such that (8) is violated, no consumer would register under $r_t = ExA$. In this case, the firm is strictly better off by not requiring ex ante registration, and it has to decide whether or not to offer the option of guest checkout. To solve for the firm's optimal platform choice, we first compare the firm's per-period expected profits conditional on its platform choice in period t. If the firm chooses $r_t = G$, the consumers may nevertheless prefer to set up an account when deciding to buy; they prefer buying with an account over buying as a guest if and only if their additional expected future surplus from already having an account ($\bar{u}(0) - \bar{u}(k_G)$) is larger than the additional cost of registration ($k_R - k_G$). We show in the appendix (see the proof of Lemma 1) that there exists a critical value $\check{k}_G \in (0, k_R)$ such that, in period t, consumers prefer guest checkout over setting up an account if and only if $k_G < \check{k}_G$. If $k_G \geq \check{k}_G$, the option of guest checkout becomes irrelevant (since no consumer uses it) and the firm's profits are the same under $r_t = G$ and $r_t = ExP$.[28]

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[28]In this case consumer surplus and total welfare would be lower if user registration is not possible or allowed.

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Lemma 1 *Suppose that (8) is violated and $k_G < \check{k}_G$. Denote by $\pi_\tau (r_t = r)$ the firm's expected profit in period $\tau \in \{t, t+1\}$ when the registration policy choice in period t is $r \in \{ExP, G\}$. Then, (i) $\pi_{t+1} (r_t = ExP) > \pi_{t+1} (r_t = G)$ and (ii) $\pi_t (r_t = ExP) < \pi_t (r_t = G)$.*

The economics behind Lemma 1(i) is closely related to Proposition 1 in Section 3. With the probability that consumers are already registered and, hence, the registration cost is sunk, the firm achieves higher expected profits. For this effect, it is not crucial that the firm requires registration at the beginning of a period, before consumers can observe their valuation and the price. Lemma 1(i) shows that the same result is obtained vis-à-vis future expected profits: The firm benefits from registration requirements since this yields higher profits in future periods when consumers can buy without having to incur the cost of setting up an account. Since the firm's future profits are increasing in the share of consumers who already have an account, the firm's optimal price under $r_t = ExP$ is lower than the price $p(k_R)$ in the baseline model (for details see the proof of Lemma 1). Of course, requiring registration also affects current expected profits. Lemma 1(ii) demonstrates a countervailing effect of ex post registration requirements on the firm's profits: today's profits are reduced. Overall, the firm faces a trade-off between lower profits today and higher profits in the future when deciding whether to require ex post registration.

Proposition 3 *Consider the two-period model and suppose that $k_R > 2\bar{u}(0) - \bar{u}(k_G)$. There exists a threshold $\bar{k}_G \in \left(0, \check{k}_G\right)$ such that the firm offers the option of guest checkout in period t ($r_t = G$) if and only if $k_G < \bar{k}_G$. Otherwise, the firm requires ex post registration in period t such that consumers who buy have to set up an account ($r_t = ExP$).*

Proposition 3 states that the firm prefers to make consumers register when they want to buy, unless the advantage of guest checkout in terms of lower transaction costs is sufficiently strong. Formally, if k_G is much lower than k_R, the cost k_G of using guest checkout does not play an important role for the consumers' purchasing decision; hence, the firm is better off by providing this option even though this results in a situation in which no consumer is registered in future periods. But if k_G is increased and the consumers' additional cost of setting up an account (compared to using guest checkout) becomes lower, ex post registration becomes relatively more attractive. If k_G is above a threshold $\bar{k}_G \in \left(0, \check{k}_G\right)$, the firm is strictly better off when it does not offer the option of guest checkout and forces consumers to set up an account whenever they want to buy. Here, the firm's gain in future profits from customers who are already registered (as in Lemma 1(i)) is sufficient to outweigh the reduction in today's profits caused by a lower demand today (as in Lemma 1(ii)). Also note that when $k_G \in \left(\bar{k}_G, \check{k}_G\right)$, consumers would prefer buying with a guest account, but the firm forces
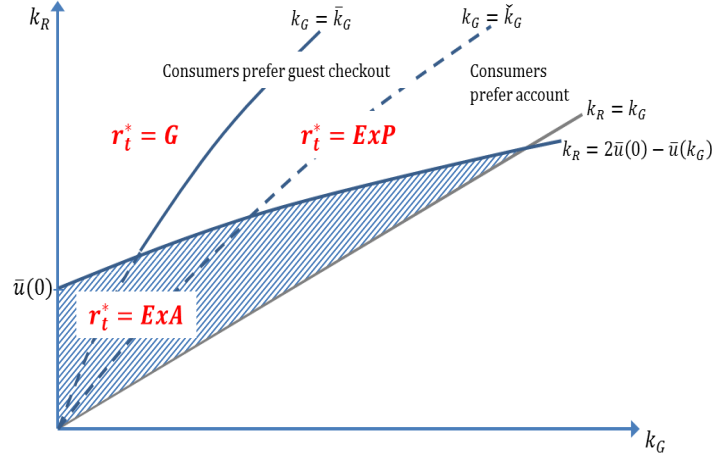
Figure 1: Optimal registration requirements in the two-period model (example for uniformly distributed valuations).

them to register. Figure 1 illustrates the results of Propositions 2 and 3 by showing the firm's optimal platform choice for parameter combinations (k_G, k_R).[29]

Besides incorporating repeat purchases as a particular feature of online shopping into our analysis, this section also served a theoretical aim. We point out that even when the firm releases all information about current prices and products, consumers will nevertheless face some uncertainty about their future expected surplus from registering (their future product valuations), for instance because they cannot fully anticipate all technology enhancements and product developments, or because of unpredictable fluctuations of future income. In particular for the latter type of uncertainty, it is clear that the firm has no possibility to influence the precision of information that a consumer holds. In this sense, this section also demonstrated that the benefit of registration requirements does not depend on the ability of the firm to "hide" product and price information but emerges whenever consumers are not completely sure about the value they derive from shopping at the firm, in the current period or with respect to future periods.

5   Value of consumer information

This section considers the firm's optimal registration policy when consumer registration generates an informational value to the firm, either because the firm can make direct use of the information that consumers provide when they register (for instance, when targeting

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[29]The critical value $\bar{k}_G$ below which the firm offers the option of guest checkout is increasing in k_R since the firm's profit under $r = ExP$ is decreasing in k_R, while its profit under $r = G$ does not depend on k_R.

certain types of consumers), or because it sells this information to other firms. We show that the value of user information to the firm adds to, and interacts with, the benefit from ex ante registration requirements identified in the previous sections. Moreover, informational benefits from user registration can provide a rationale for why firms may prefer not to offer the option of guest checkout even when aspects of future purchases are absent.

Consider the baseline model of Section 3 but suppose that, in addition to the profit from selling its product, the firm values the information that the consumers provide when registering and/or buying. Specifically, we assume that the firm gets an additional value $v_R \geq 0$ from each consumer who sets up an account (independently of the buying decision). In addition, the firm derives an informational value $v_B \geq 0$ from each consumer who buys with an account. Finally, the firm gets an informational value $v_G \geq 0$ from each consumer who buys as a guest (if this option is offered).[30] We assume that $v_R + v_B \geq v_G$, that is, the informational gain for the firm is higher if consumers set up an account and buy with their account than if consumers buy using guest checkout since in the former case the firm learns more about the consumers' preferences together with their personal characteristics.[31]

Taking into account an additional benefit from consumer information changes the firm's pricing decision. Define by $p(k, v)$ the solution to the optimization problem

$$\max_p \left(1 - F\left(p + k\right)\right)\left(p + v\right). \tag{9}$$

In case of an interior solution, $p(k, v)$ is given by

$$p\left(k, v\right) = \frac{1 - F\left(p\left(k, v\right) + k\right)}{F'\left(p\left(k, v\right) + k\right)} - v. \tag{10}$$

The solution $p(k, v)$ is the price that the firm sets if the consumers' non-monetary cost of buying is k and the firm gets an informational benefit v in case a consumer buys. Hence, if the firm requires ex ante registration, the optimal price is $p(0, v_B)$; the costs of registration

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[30] A firm may also obtain information from consumers (for example with cookies) who visit their websites but neither register nor buy. For ease of notation, we normalize the firm's benefit from this information to zero. Thus the parameters v_R, v_B, and v_G should be interpreted as the value of the *additional* information obtained from registration and purchase with account or as a guest.

[31] In what follows, we take the registration cost k_R and the distribution F of consumer valuations as given and analyze the impact of changes in v_R, v_B, and v_G. In general, there might also be a (positive or negative) correlation between v_R and/or v_B on the one hand and k_R and/or θ on the other hand. For instance, privacy concerns may be strengthened when consumers anticipate that the firm sells their personal information at high prices to third parties, which would lead to a higher k_R. If v_R represents the firm's benefit from targeted advertising, θ may be increasing and/or k_R may be decreasing in v_R. In addition, consumers may also be not fully aware of the consequences of the use of their information; in this context see also Norberg et al. (2007) on divergences of consumers' opinions and behavior and the survey by Acquisti et al. (2015) on privacy concerns and consumer behavior.

k_R and the value v_R from user registration are already 'sunk' in this case and not relevant for the firm's pricing decision. If instead the firm requires registration only ex post, it sets a price $p(k_R, v_R + v_B)$, taking into account both the registration cost k_R and the informational benefit $v_R + v_B$ per purchase with an account.

With Assumption 1 on the probability distribution F, $p(k, v)$ as given in (10) is strictly decreasing in k and in v. The informational benefit v generated if a consumer buys (with an account or as guest) leads to a lower equilibrium price since the firm derives an additional value from increased demand. If the value of user information is very large, the firm does not charge any positive price (or even subsidizes the non-monetary registration costs) but lets the consumers "pay" through their information provision.[32] The following proposition characterizes the equilibrium registration policy.

Proposition 4 *(i) Suppose that*

$$k_R \leq \int_{p(0,v_B)}^{\infty} (\theta - p(0, v_B)) \, dF(\theta). \tag{11}$$

Then, the firm requires ex ante registration ($r = ExA$) in equilibrium.
(ii) Suppose that (11) is violated. Then, in equilibrium the firm requires ex post registration ($r = ExP$) if and only if $v_R + v_B - k_R \geq v_G - k_G$, and offers the option of guest checkout ($r = G$) otherwise.

Proposition 4 confirms the firm's incentive to make use of ex ante registration requirements and offers insights into how the informational value of consumer registration interacts with the 'sunk cost' advantage of ex ante registration requirements. First, the threshold for k_R below which the firm requires ex ante registration (the right-hand side of the inequality in (11)) is increasing in the value of consumer information v_B. A higher value of consumer information leads to a lower price and, thus, makes consumers more willing to register ex ante due to the higher surplus they expect (Proposition 4(i)). Second, while ex post registration requirements are never profitable in the baseline model, this changes when the firm values the information that consumers provide when registering. If the consumers are not willing to register ex ante but the informational benefit from consumer registration is sufficiently strong (v_R and v_B are large relative to v_G) then the firm is strictly better off when requiring consumers to set up an account ex post, in case they want to buy (Proposition 4(ii)).

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[32]To be precise, allowing for negative prices and denoting the price solving (10) by $\hat{p}(k, v)$, the optimal price is given by $\max\{\hat{p}(k, v), -k\}$. In case of $r = ExA$, for instance, the firm sets a price equal to $\max\{\hat{p}(0, v_B), 0\}$, while in case of $r = ExP$ the optimal price is $\max\{\hat{p}(k_R, v_R + v_B), -k_R\}$ (at a price $p = -k_R$ all consumers register/buy; hence, the optimal price will never be lower).

With a positive value of user information, ex ante registration requirements become relatively more profitable for the firm.

Remark 3 *The firm's advantage from requiring ex ante registration as opposed to requiring registration only ex post, or to allowing guest checkout, is larger when the firm derives a value from consumer information (that is, when $v_B > 0$ or $v_R > 0$ or both, and $0 \leq v_G \leq v_R + v_B$) than in the baseline model (where $v_B = v_R = v_G = 0$).*

The higher profitability of ex ante registration requirements ($r = ExA$) is due to two effects. First, more consumer register in case of $r = ExA$ (provided that (11) holds); thus, the advantage of ex ante registration requirements (that is, the difference in profits under $r = ExA$ and under $r = ExP$ and $r = G$, respectively) is increasing in v_R. Second, since ex ante registration requirements increase the willingness of registered consumers to buy, an informational value v_B attached to the buying decision makes policy $r = ExA$ relatively more profitable. In other words, the sunk cost effect of ex ante registration requirements reinforces the informational value of consumer registration. To see this, suppose that $v_R = 0$. If $k_R \to 0$ then the firm is indifferent between ex ante and ex post registration requirements for all $v_B \geq 0$. If $k_R > 0$, however, the firm is strictly better off by choosing $r = ExA$, for all $v_B \geq 0$, and the advantage of using ex ante registration requirements becomes stronger the higher v_B since more consumers buy under $r = ExA$. An equivalent argument applies to the comparison of $r = ExA$ and $r = G$.[33]

We now evaluate the equilibrium registration requirement from a welfare perspective. As above, we take welfare to be the sum of consumer surplus and the firm's profit. The firm's choice between $r = ExP$ and $r = G$ is fully aligned with consumers' preferences. To see this, note that problem (9) is formally identical to a standard monopoly problem where a per-unit sales tax k is levied from the consumer, and a subsidy v is granted to the firm per unit sold. As in the standard tax incidence result on the irrelevance of statutory incidence for economic incidence, the equilibrium price depends only on the *net* subsidy, i.e., on the difference between the subsidy and the tax, $v - k$. Moreover, given a pass-through rate between 0 and 100%, the seller's profit and consumer surplus are both increasing in the net subsidy. Under $r = ExP$, the "net subsidy" is $v_R + v_B - k_R$; under $r = G$, it is $v_G - k_G$.

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[33]The additional incentive to require ex ante registration due to the value of consumer information carries over to the dynamic model of Section 4; moreover, when ex ante registration requirements are not feasible, the firm's incentive to require ex post registration in period t of the two-period model is strengthened if the firm also values the information consumers provide when registering. More precisely, the larger v_R and v_B (relative to v_G), the smaller becomes the range in Proposition 3 in which the firm offers the option of guest checkout; for sufficiently high $v_R + v_B$, this interval becomes empty and the firm always requires consumers to set up an account in period t.

Therefore, both the firm (compare Proposition 4(ii)) and the consumers prefer ExP over G if and only if $v_R + v_B - k_R$ is larger than $v_G - k_G$.

Under the assumptions of Proposition 4(ii), if $r = ExA$, no one registers, and welfare is zero. In contrast, both $r = ExP$ and $r = G$ lead to strictly positive welfare. Together with the considerations of the last paragraph, this implies that the firm's registration policy is welfare-maximizing when (11) is violated, that is, the firm's platform choice is either $r = ExP$ or $r = G$. On the other hand, when (11) holds, the firm chooses $r = ExA$ by Proposition 4(i). The consumers, however, always prefer $r = ExP$ over $r = ExA$ since under $r = ExP$ the price is lower ($p(k_R, v_R + v_B) < p(0, v_B)$) and, moreover, the registration costs are only incurred in case a consumer finally buys. Here, each of the three options ExA, ExP, and G can be welfare-maximizing under some parameter constellations.[34]

Summarizing, the only possible inefficiency in the firm's equilibrium registration require-ments can arise when the firm requires ex ante registration; an equilibrium choice of an ex post registration requirement is always efficient. A legal ban on ex ante registration requirements, however, does not unambiguously raise welfare, since there are parameter constellations for which ExA is indeed welfare-maximizing.

6 Discount policies and registration

This section analyzes discounts as a means to affect the consumers' registration decision. Discounts (store credit) offered conditional on buying are a widely used instrument in online markets, not least because behavior-based targeting has been facilitated by the increased information collection in the internet.[35] We show that discounts can be used to make even

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[34]It is straightforward to show this by example, assuming that θ is distributed uniformly. To understand this indeterminacy, consider the difference in welfare under $r = ExA$ and under $r = ExP$. This difference is equal to $\int_{p(0,v_B)}^{p(k_R,v_R+v_B)+k_R} (\theta + v_B) \, dF(\theta) + (1 - F(p(k_R, v_R + v_B) + k_R))(v_R - k_R)$. The first term captures the difference in the surplus from trade caused by the difference in equilibrium prices under ExA and ExP. As argued above, $p(k, v) + k$ is strictly decreasing in $v - k$; thus, this first term is positive ($p(0, v_B) < p(k_R, v_R + v_B) + k_R$) if and only if $v_R - k_R < 0$. The second term reflects the difference in direct registration costs and informational benefits caused by the fact that only a share of consumers registers under $r = ExP$. This second term is positive if and only if $v_R - k_R > 0$. Hence, there are two countervailing effects on welfare. If v_R is small compared to k_R, there is more trade under ExA than under ExP, but too many consumers register under ExA from a welfare perspective; this is the trade-off already identified in the benchmark model. If v_R is large compared to k_R, there is more trade under ExP than under ExA, but from a welfare perspective all consumers should register, which is only achieved under ExA (unless v_R is very large and $p(k_R, v_R + v_B) + k_R$ becomes zero). In the knife edge case where $v_R = k_R$, both effects are zero and welfare is the same under $r = ExA$ and $r = ExP$. Here, small perturbations can make ExA or ExP welfare-superior. When comparing $r = ExA$ to $r = G$, the latter can be welfare-superior to $r = ExA$ even in the benchmark model (compare the discussion in Section 3), while $r = ExA$ is welfare-superior, for instance, if $v_R + v_B$ is sufficiently large compared to v_G, and k_R is sufficiently small to make $r = ExA$ feasible.

[35]The OFT (2010, p.29) reports that "the most common form of online price targeting is to offer vouchers or discounts to internet users based on their online behavior."

those consumers register who have high costs of registration and can, thus, be part of a successful registration policy.

If the firm requires ex ante registration but offers price discounts to consumers who register, this affects the firm's equilibrium posted price and the consumers' beliefs about the price. In particular, if all consumers who register are offered a discount then the firm will simply increase its posted price by the amount of the discount.[36] Therefore, in the baseline model of Section 3 with homogeneous registration costs, discounts have no net effect on the profitability of ex ante registration requirements since all of the consumers who register (or none of them) will have obtained a discount.[37] But discounts have an effect when consumers differ in their concerns about registration, which is a reasonable assumption and which we make in the remainder of this section.

The simplest case to make this point is the one where there are two types of consumers: a share $1 - q$ of consumers have registration costs of k_{RH}; and a share q of consumers have registration costs of k_{RL} where $k_G \leq k_{RL} < k_{RH}$. An interpretation of this setup is that a share q of the consumers have only an opportunity cost k_{RL} of registration while the remaining share $1 - q$ has higher costs k_{RH} of registration due to privacy and security concerns.

Consider the modified game in which the firm offers a discount $d \geq 0$ (store credit) to a share $\delta \geq 0$ of consumers. The discount policy (d, δ) is chosen and announced in stage 1, together with the platform choice. In stage 2, the consumers observe the registration requirement and learn if they are offered a discount d. The discount d is offered conditional on buying. Hence, for consumers who have obtained a discount, the price to be paid is reduced from p to $p - d$. But as explained above the discount policy also affects the equilibrium price p charged by the firm. If the firm requires ex ante registration and the share of consumers who register consists both of consumers with discount and consumers without discount, the optimal price p_d is a function of d (and of δ) and fulfills

$$p_d - d < p(0) < p_d,$$

that is, the optimal price net of discount $(p_d - d)$ is smaller than the price $p(0)$ without discounts, but the posted price p_d is increased.[38] In other words, discounts are added to

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[36]Recall that in case of ex ante registration requirement the price is observed by consumers only after they have registered.

[37]In the baseline model the firm would only use discounts in case of $k_R > \bar{u}(0)$ to make some of the consumers register. When consumers with discounts decide on registration, they anticipate that all consumers who would actually register must have been offered a discount so that their expected surplus remains unchanged.

[38]This ranking follows from Assumption 1 and is similar to the ranking $p(k) < p(0) < p(k) + k$. For

the price but to less than 100%. This leads to a price distortion: Instead of selling at the optimal price $p(0)$ to registered consumers, the firm sells at effective prices $p_d - d < p(0)$ and $p_d > p(0)$ to consumers with discount and without discount, respectively.

The most interesting case emerges when $k_{RL} < \bar{u}(0) < k_{RH}$ (where consumer surplus $\bar{u}(0)$ is given in (5)). In this case, if the firm requires ex ante registration and no discounts are offered ($\delta = 0$) then only consumers with low registration costs are willing to register. In the candidate equilibrium in which the firm offers discounts as incentive for high-cost consumers to register, consumers correctly anticipate the price p_d for a given policy (d, δ). Therefore, high-cost consumers with discount register if and only if

$$\int_{p_d-d}^{\infty} (\theta - (p_d - d))\, dF(\theta) \geq k_{RH}, \tag{12}$$

while low-cost consumers without a discount register if and only if

$$\int_{p_d}^{\infty} (\theta - p_d)\, dF(\theta) \geq k_{RL}. \tag{13}$$

The firm's incentive to offer discounts depends on the degree to which it is able to target the discount to consumers who would not register without discount. In the worst case for the firm, discounts are allocated purely randomly to the consumers such that the probability that a consumer with registration cost k_{RH} receives a discount is equal to $1 - q$ (that is, equal to the probability that $k = k_{RH}$), and the probability that a consumer with low registration cost k_{RL} receives a discount is equal to q. We first show that offering discounts can be profitable for the firm even when the firm offers the discounts on a purely random basis.

Proposition 5 *Consider the case of random discounts and suppose that $k_{RL} < \bar{u}(0) < k_{RH}$ where $\bar{u}(0)$ is defined as in (5). If k_{RH} is sufficiently close to $\bar{u}(0)$, the firm achieves strictly higher profits if it requires ex ante registration and offers a discount to a random share of consumers than (i) if it requires ex ante registration and offers no discounts and (ii) if it does not require ex ante registration.*

Discounts distort the firm's pricing decision. Moreover, if the firm cannot target the discounts to consumers with high registration costs, they are also paid to consumers who would register even without discount. Nevertheless, even randomly offered discounts can increase the firm's expected profit. The intuition for Proposition 5 is as follows. When k_{RH} is close to $\bar{u}(0)$, only a small discount is needed in order that high-cost consumers with discount

details see the proof of Proposition 5.

register.[39] The firm can give such a small discount to almost all consumers. Moreover, the price p_d is close to $p(0)$; thus, all low-cost consumers will register, including those who have not received a discount, and the price distortion effect is small. Therefore, the profit of the firm is almost equal to $\pi(0)$ (where $\pi(0)$ is given in (2)). The proof of Proposition 5 shows that for any fixed $\delta \in (0,1)$, the firm's profit converges to $q\pi(0) + \delta(1-q)\pi(0)$ if $k_{RH} \to \bar{u}(0)$ (since all low-cost types and a share δ of the high-cost types register). Thus the firm can achieve a profit that is close to $\pi(0)$ when k_{RH} is close to $\bar{u}(0)$.

The case of purely random discounts is the most unfavorable case for the profitability of discounts. The better the firm is able to target the discounts to consumers with high registration costs, the less costly becomes the use of discounts, and the more attractive becomes the ex ante registration policy with discounts. We model targeting such that it reduces the probability that a low-cost type receives a discount to $q' < q$, and increases the probability that a high-cost type receives a discount to $1 - q' > 1 - q$. Of course, the share of discounts received by high-cost types cannot be higher than the share of high-cost consumers in the population. Formally, in order that a discount policy (d, δ) is feasible with targeting technology q', it must satisfy $(1 - q')\delta \leq 1 - q$.

Proposition 6 *The firm's profit in case of ex ante registration requirements with discounts is strictly increasing in the ability to target the discounts to consumers with high registration costs.*

In the extreme case in which discounts can be perfectly targeted to high-cost consumers, each additional discount offered attracts an additional consumer who registers, while in the case of purely random discounts the probability of an additional consumer is only $1 - q$ (the probability that a high-cost consumer gets the discount). Moreover, keeping the number of discounts δ fixed, improved targeting (a decrease in q') leads to a smaller price distortion since there will be more consumers without discount among the registered consumers. Both effects increase the profitability of using discounts. If the cost of making use of targeting is increasing in the 'targeting quality' $q - q'$, there exists an optimal targeting technology which takes some interior value if the first unit of targeting is sufficiently cheap but perfect targeting is prohibitively costly.

In reality, targeting will be typically imperfect, even though firms do certainly better than just randomly offering discounts. To improve the targeting, firms can use similar

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[39] The optimal choice of d is such that high-cost types are just willing to register (such that (12) holds with equality); due to the price distortion effect, the firm will not increase the discount any further. Since p_d depends on the share δ of consumers with discount, d can be expressed as a continuous function of δ. Note that the discount $d(\delta)$ necessary to induce high-cost types to register is increasing in δ since the price p_d also increases in δ: The more consumers get a discount, the stronger is the price increase, and the higher must be the discount to make a high-cost consumer willing to register.

instruments as in the context of targeted advertising and attach discounts to certain consumer characteristics which they can observe and expect to be correlated with the registration costs. This includes socioeconomic information but also information about consumer attitudes and interests and about previous purchases at this or other firms obtained, e.g., through cookies. For instance, the firm may attach the discount to the purchase of another product. Moreover, firms sometimes offer discounts to consumers who started but then canceled the registration process but already provided an e-mail address, for instance, or offer a price reduction to buyers in case they set up an account. Similarly, the use of a mobile device or a certain web browser typically allows to conclude on some consumer characteristics (such as age cohort or income group). Thus, improved information about the consumers can also be valuable in that it makes it cheaper to target certain groups of consumers and increase their willingness to register ex ante by offering discounts.

To conclude this section we note that the incentive for using discounts to attract additional consumers is stronger if the firm also values the information that consumers provide when they register (as in Section 5). Moreover, the incentive to use discounts carries over to the dynamic model: Offering discounts at the beginning of period t can increase the firm's profits and enlarge the range in which ex ante registration requirements are optimal. In the dynamic model, if ex ante registration requirements are not feasible, the firm has an incentive to offer discounts to consumers in case they register when buying in period t. As long as not all consumers are offered such a discount (valid in period $t+1$), such discounts make consumers more willing to set up an account (compared to buying with a guest checkout).

7   Conclusion

Buying at online shops usually requires the disclosure of personal information such as address and payment details and can, therefore, cause a non-monetary 'registration cost' if the consumers have privacy and security concerns. We show that firms have an incentive to shift this registration cost to an earlier stage of the shopping process and to detach it from the actual buying decision, which has implications for the firms' platform design.

In our baseline model, consumers are ex ante uncertain about the price and their product valuation. This information can, however, be released by the firm at zero cost; hence, we assume that search costs do not to play a role in this market. Firms decide *when* to release this information: before or after the consumer has signed in to the website. Our model can also be interpreted such that some information is already released ex ante (which is incorporated in the probability distribution of consumer valuations) and the firm decides when to release the residual information. We first show that a monopoly firm should require

registration at an early stage, unless privacy and security concerns are very important for consumer behavior. Making the registration costs 'sunk' at the point when consumers decide whether to buy makes the consumers more willing to buy, for instance, when credit card information is already entered and stored in the consumer's user account. This leads to higher demand and higher profits for the firm.

Then, we incorporate important additional features of online markets into the baseline model and analyze their interaction with ex ante registration requirements. First, we consider a multi-period model with the possibility of repeat purchases. If consumers consider purchasing repeatedly at a given firm, they expect a higher surplus from setting up an account at the firm. Therefore, the higher the likelihood that a consumer returns, the larger becomes the range in which the firm can profitably implement ex ante registration requirements. This holds even though registered consumers can observe price and product information without any additional registration costs in future periods. Put differently, the logic of ex ante registration requirements established in the baseline model based on 'within-period' uncertainty about the product characteristics also applies vis-à-vis future transactions, which become more likely, and therefore more profitable for the firm, if consumers are already registered. The multi-period setup also derives conditions under which the firm prefers to offer the option of guest checkout (letting consumers buy without user account).

The higher demand with ex ante registration is particularly profitable for firms if they also care about the information that consumers provide when they register. In addition, firms may value user information from consumers who register but do not buy. Both aspects make ex ante registration requirements relatively more profitable and, hence, interact with the 'sunk cost' advantage of ex ante registration, as we show in Section 5. Due to the value of consumer registration, firms may want to give consumers additional incentives to register if their privacy concerns distract them from setting up an account. Section 6 shows that discounts (store credit) offered conditional on buying can increase the share of consumers who are willing to register even though discount policies distort the firm's pricing decision and even when the firm's ability to target these discounts to the marginal consumers is low. Therefore, the optimal platform choice can involve both ex ante registration requirements and discounts offered to a share of consumers. Since discount policies become more profitable if the firm is able to target these discounts to consumers with strong privacy concerns who would not register without discount, firms may want to invest in improved targeting by offering the discounts based on observable consumer characteristics which they expect to be correlated with their registration costs.

Finally, in the online appendix we show that the firms' incentives to require ex ante registration carry over to the case of competition between firms by mitigating price competition.

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In particular, firms with loyal consumers (incumbent firms) may choose ex ante registration requirements as part of their business strategy; given that a sufficiently high share of consumers registers, they benefit from an increase in turnover as well as in the price they can charge. In contrast, ex ante registration requirements are less advisable for firms with no loyal consumers. They compete for the non-committed consumers and achieve higher profits when reducing the amount of personal information to be revealed by consumers ex ante.

The degree to which firms may want to influence the consumers' cost of registration depends on the trade-off between changes in demand and changes in the benefits from increased information revelation of the consumers, although it will hardly be possible to completely remove all consumers' privacy and security concerns. In particular, the 'registration cost' is at least partly independent of the firm at which a consumer considers to buy since privacy concerns are also caused by data collection and the use and abuse of personal information by third parties.

The profitability of the different registration policies can also interact with aspects of consumer decision-making which go beyond what we have considered in the present paper. On the one hand, consumers may strongly dislike certain types of registration requirements and 'boycott' such online shops, an aspect which may be reflected in high rates of shopping cart abandonment. On the other hand, the well-documented 'sunk-cost fallacy' could make ex ante registration requirements even more profitable when the feeling of having already incurred some costs makes consumers more willing to buy once they have gone through the process of registration.

A   Appendix

A.1   Proof of Remark 1

Under $r = G$ and $r = ExP$ the consumers can observe the price before they decide whether to buy, even in the case without price commitment. Thus the analysis above applies. In particular, with guest checkout the firm makes a profit $\pi(k_G) > \pi(k_R)$ such that it strictly prefers $r = G$ over $r = ExP$.

The profit of the firm from $r = ExA$ with price commitment is

$$\pi_C(k_R) := \max_p (1 - F(p)) p \ \ \text{s.t.} \ \ \int_p^\infty (\theta - p) \, dF(p) \geq k_R$$

whenever $k_R \leq E(\theta)$. The constraint ensures that consumers are willing to register. When k_R increases towards $E(\theta)$, the price, and thus the profit, must approach zero since otherwise

consumers are not willing to register. For $k_R > E(\theta)$, profit is zero since consumers are not willing to register ex ante at any positive price. On the other hand, if $k_R \leq \bar{u}(0)$ then the constraint on consumer registration does not bind in the optimum so that $\pi_C(k_R) = \pi(0)$. Moreover, $\pi_C(k_R)$ is decreasing in k_R and continuous. Since $\pi(0) > \pi(k_G)$ (by Proposition 1), there exists a threshold $\hat{k}_R \in (\bar{u}(0), E(\theta))$ such that the firm chooses $r = ExA$ if $k_R \leq \hat{k}_R$, and chooses $r = G$ otherwise.

A.2   Proof of Remark 2

Under $r = ExA$, the firm's optimal price is independent of k_R and equal to $p(0)$. Anticipating this price, all consumers with $k_R \leq \bar{u}(0)$ register, which leads to a profit of $H_R(\bar{u}(0))\pi(0)$, as $H_R(\bar{u}(0))$ is the share of consumers who register and $\pi(0)$ is the firm's expected profit per consumer. If $r \neq ExA$, the firm prefers $r = G$ over $r = ExP$ due to $k_G \leq k_R$ (and $k_G < k_R$ with strictly positive probability), just as in Proposition 1. Since for a given k_G a consumer buys with probability $1 - F(p + k_G)$, the firm's expected profit under $r = G$ is

$$\tilde{\pi}_G = \max_p \int_0^\infty (1 - F(p + k_G)) \, p \, dH_G(k_G).$$

Thus, the firm prefers $r = ExA$ over $r = G$ if and only if $H_R(\bar{u}(0)) \geq \tilde{\pi}_G/\pi(0)$. Obviously, $\tilde{\pi}_G/\pi(0) > 0$. It remains to show that $\tilde{\pi}_G/\pi(0) < 1$. As in the proof of Proposition 1, with $\tilde{p}$ denoting the optimal price in case of $r = G$, it holds that

$$\begin{aligned}
\pi(0) &= \int_0^\infty (1 - F(p(0))) \, p(0) \, dH_G(k_G) \\
&\geq \int_0^\infty (1 - F(\tilde{p} + k_G))(\tilde{p} + k_G) \, dH_G(k_G) \\
&> \int_0^\infty (1 - F(\tilde{p} + k_G)) \, \tilde{p} \, dH_G(k_G) = \tilde{\pi}_G.
\end{aligned}$$

A.3   Proof of Proposition 2

Suppose first that $k_R \leq \bar{u}(0)$. (Recall that $p(k)$, $\pi(k)$, and $\bar{u}(k)$ are defined in (1), (2), and (3), respectively.) In period $t + 1$, the firm's optimal policy is as in Proposition 1: It chooses $r_{t+1} = ExA$ and charges a price $p(0)$. Consumers who already have an account from period t can buy using this discount; all other consumers register due to $k_R \leq \bar{u}(0)$. Hence, a consumer's expected period $t + 1$ utility is equal to $\bar{u}(0)$ if he already has an account and equal to $\bar{u}(0) - k_R \geq 0$ otherwise. In period t, if the firm chooses $r_t = ExA$ and a price $p(0)$, a consumer's total expected utility is equal to $2\bar{u}(0) - k_R$ in case he registers and equal to

only $0 + \bar{u}(0) - k_R$ in case he does not register in t. Thus, all consumers register in period t and the firm's total profit is equal to $2\pi(0)$, which is strictly higher than what the firm can get for any $r_t \neq ExA$ (where the profit in period t is strictly less than $\pi(0)$, and the profit in $t+1$ is at most $\pi(0)$).

Now suppose that $\bar{u}(0) < k_R \leq 2\bar{u}(0) - \bar{u}(k_G)$. In period $t+1$, since $\bar{u}(0) < k_R$, consumers who do not yet have an account would not register. Therefore, the firm chooses $r_{t+1} = G$ (it does not gain anything from forcing the consumers to register ex post in the last period; compare the proof of Proposition 1), charges a price $p(0)$ to consumers who buy with an existing account, and a price $p(k_G)$ to consumers who buy as a guest.[40] All consumers can observe their valuation at no cost. Registered consumers buy using their accounts at price $p(0)$ because under Assumption 1, $p(0) < p(k_G) + k_G$ (where the latter is a consumer's total cost of buying with a guest account). Consumers who are not yet registered in period $t+1$ buy using guest checkout (since $p(k_G) + k_G < p(0) + k_R$). Therefore, registered consumers expect a period $t+1$ utility of $\bar{u}(0)$, while non-registered consumers expect a period $t+1$ utility of $\bar{u}(k_G) < \bar{u}(0)$. In period t, if the firm sets $r_t = ExA$, the total expected utility of consumers who register in t is equal to $2\bar{u}(0) - k_R$, while the total expected utility of consumers who do not register in t is equal to $0 + \bar{u}(k_G)$. Hence, if (8) holds, all consumers register in t and the firm realizes its maximum profit of $2\pi(0)$.

If (8) is violated, no consumer registers in t and the firm's total profits under $r_t = ExA$ are $0 + \pi(k_G)$ (since all consumers use the guest checkout offered in period $t+1$); the firm can get, however, a total profit of (at least) $2\pi(k_G)$ if $r_t = G$. Therefore, the firm will require ex ante registration in t if and only if (8) holds.

A.4 Proof of Lemma 1

Consider first period $t+1$. Since $r_t = ExA$ is not feasible, there will be a strictly positive mass of consumers who are not yet registered in period $t+1$ (those consumers with low θ_t). The firm sets $r_{t+1} = G$ (which, due to $\pi(k_G) > \pi(k_R)$, yields higher profits than $r_{t+1} = ExP$), charges a price $p(k_G)$ to consumers without an account, and a price $p(0)$ to consumers who buy with an existing account. Consumers with an account (from period t)

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[40]Strictly speaking, if all consumers already register in period t, the firm is indifferent between $r_{t+1} = G$ and $r_{t+1} = ExA$. With a continuum of consumers, if a single consumer deviates in period t and does not register, he has mass zero from the point of view of the firm; thus, the firm may still choose $r_{t+1} = ExA$. With a finite (but possibly very large) number of consumers, this does no longer hold and a consumer who does not register in period t can (correctly) anticipate that the firm will choose $r_{t+1} = G$. Therefore, we assume the tie-breaking rule in favor of $r_{t+1} = G$ at this point to guarantee that the range under which ex ante registration requirements are chosen in equilibrium corresponds to the case of a finite number of consumers (and, in case of a continuum of consumers, is robust to small trembles in the consumers' period t registration decisions).

prefer to sign in with their account and buy at $p(0) < p(k_G) + k_G$; consumers without an account buy using guest checkout.

Now consider period t. A consumer with valuation θ_t who sets up an account and buys in period t gets a total expected utility of

$$\theta_t - p_t - k_R + \bar{u}(0), \tag{14}$$

since he expects a surplus of $\bar{u}(0)$ in period $t+1$ where he is already registered. A consumer with valuation θ_t who buys in t using guest checkout gets a total expected utility of

$$\theta_t - p_t - k_G + \bar{u}(k_G), \tag{15}$$

since he expects a surplus of $\bar{u}(k_G)$ in period $t+1$ where he does not have an account. Comparing (14) and (15) shows that a consumer prefers using guest checkout over buying with an account if and only if

$$k_R - k_G > \bar{u}(0) - \bar{u}(k_G). \tag{16}$$

If $k_G \to 0$, the right-hand side of (16) approaches zero and (16) holds. Moreover, the right-hand side of (16) strictly increases in k_G and the left-hand side of (16) strictly decreases in k_G. If $k_G \to k_R$ then (16) is violated. Thus, there exists a unique $\check{k}_G \in (0, k_R)$ such that (16) holds if and only if $k_G < \check{k}_G$.

(i) In period $t+1$, the firm makes a profit of $\pi(0)$ per registered consumer and a profit of $\pi(k_G) < \pi(0)$ per non-registered consumer; hence, its total period $t+1$ profit is strictly increasing in the share of consumers who are already registered. Under $r_t = G$, no consumer registers in t in case of $k_G < \check{k}_G$. In contrast, if $r_t = ExP$, consumers with a sufficiently high θ_t register/buy in t. To be precise, those consumers register for whom the total expected surplus in (14) is larger than the expected total surplus from not buying in t (which is $0 + \bar{u}(k_G)$), that is, under $r_t = ExP$, the share of consumers who register in t is equal to

$$1 - F(p_t + k_R - (\bar{u}(0) - \bar{u}(k_G))) > 0.$$

Together with $\pi(k_G) < \pi(0)$ this shows that $\pi_{t+1}(r_t = ExP) > \pi_{t+1}(r_t = G)$ if $k_G < \check{k}_G$.

(ii) Suppose first that $r_t = ExP$. The firm's total expected profits $\pi_t + \pi_{t+1}$ when choosing a price p_t are

$$[1 - F(p_t + k_R - (\bar{u}(0) - \bar{u}(k_G)))](p_t + \pi(0)) + F(p_t + k_R - (\bar{u}(0) - \bar{u}(k_G)))\pi(k_G) \tag{17}$$

since the firm expects total profits of $p_t + \pi(0)$ from consumers register/buy in period t and expects total profits of $0 + \pi(k_G)$ from the remaining consumers who do not register/buy in t. The optimal choice of p_t is the solution to the first order condition

$$p_t = \frac{1 - F(p_t + k_R - (\bar{u}(0) - \bar{u}(k_G)))}{F'(p_t + k_R - (\bar{u}(0) - \bar{u}(k_G)))} - (\pi(0) - \pi(k_G)). \tag{18}$$

Ignoring the term $\pi(0) - \pi(k_G)$, the optimal choice p_t would be the price that takes into account a consumer's adjusted registration costs $k_R - (\bar{u}(0) - \bar{u}(k_G))$ (adjusted by the expected future surplus from registration). The term $\pi(0) - \pi(k_G)$ in (18), however, causes the firm's optimal price in t to be lower: A lower price in period t increases the probability that consumers register, in which case the firm's future profits increase; $\pi(0) - \pi(k_G)$ represents the relative increase in future profits if the share of registered consumers goes up. Denoting the solution to (18) by $p^*_{t,ExP}$, the period t profit of the firm is

$$\pi_t(r_t = ExP) = \left[1 - F\left(p^*_{t,ExP} + k_R - (\bar{u}(0) - \bar{u}(k_G))\right)\right] p^*_{t,ExP}.$$

Suppose that $r_t = G$. Since $k_G < \check{k}_G$, consumers buy in period t using guest checkout. Therefore, the price p_t has no implications for the period $t+1$ profit, and will be chosen by the firm to maximize the period t profit, which is

$$
\begin{aligned}
\pi_t(r_t = G) &= \max_p \left\{[1 - F(p + k_G)]\, p\right\} \\
&\geq \left[1 - F\left(p^*_{t,ExP} + k_R - (\bar{u}(0) - \bar{u}(k_G))\right)\right]\left(p^*_{t,ExP} + k_R - (\bar{u}(0) - \bar{u}(k_G)) - k_G\right) \\
&> \left[1 - F\left(p^*_{t,ExP} + k_R - (\bar{u}(0) - \bar{u}(k_G))\right)\right] p^*_{t,ExP} \\
&= \pi_t(r_t = ExP).
\end{aligned}
$$

The strict inequality follows from $k_G < \check{k}_G$ (i.e., (16) holds).

A.5 Proof of Proposition 3

If $k_G \geq \check{k}_G$, consumers prefer ex post registration over using guest checkout and the firm's total profits are the same under $r_t = G$ and under $r_t = ExP$. By our tie breaking rule, the firm chooses $r_t = ExP$ in this case. Thus, suppose in the following that $k_G < \check{k}_G$, and consider the firm's profits under the two platform choices $r_t = ExP$ and $r_t = G$. The firm's

total profits in case of $r_t = ExP$ are

$$\sum_{\tau=t,t+1} \pi_\tau (r_t = ExP) = \max_p \{[1 - F(p + k_R - (\bar{u}(0) - \bar{u}(k_G)))](p + \pi(0))$$

$$+ F(p + k_R - (\bar{u}(0) - \bar{u}(k_G))) \pi(k_G)\}. \tag{19}$$

The firms total profit in case of $r_t = G$ are $\sum_{\tau=t,t+1} \pi_\tau (r_t = G) = 2\pi(k_G)$. Let

$$\Delta := \sum_{\tau=t,t+1} \pi_\tau (r_t = ExP) - \sum_{\tau=t,t+1} \pi_\tau (r_t = G).$$

If $k_G \to 0$, total profits under $r_t = G$ approach $2\pi(0)$, while total profits under $r_t = ExP$ are strictly smaller than $2\pi(0)$; thus $\Delta < 0$ if $k_G \to 0$. Now suppose that $k_G \to \check{k}_G$ which is equivalent to $k_R - (\bar{u}(0) - \bar{u}(k_G)) \to k_G$. With (19), total profits under $r_t = ExP$ approach

$$\max_p \{[1 - F(p + k_G)](p + \pi(0)) + F(p + k_G) \pi(k_G)\}$$

$$\geq [1 - F(p(k_G) + k_G)](p(k_G) + \pi(0)) + F(p(k_G) + k_G) \pi(k_G)$$

$$> [1 - F(p(k_G) + k_G)](p(k_G) + \pi(k_G)) + F(p(k_G) + k_G) \pi(k_G)$$

$$= 2\pi(k_G),$$

where the latter is equal to total profits under $r_t = G$ (the second inequality follows from $\pi(0) > \pi(k_G)$). Therefore, $\Delta > 0$ if $k_G \to \check{k}_G$.

Finally, differentiate (19), denote the profit maximizing period price in period t under $r_t = ExP$ by $p^*_{t,ExP}$, and use the envelope theorem, to obtain

$$\frac{\partial}{\partial k_G} \sum_{\tau=t,t+1} \pi_\tau (r_t = ExP) = -F'\left(p^*_{t,ExP} + k_R - (\bar{u}(0) - \bar{u}(k_G))\right)\left(p^*_{t,ExP} + \pi(0)\right)\frac{\partial \bar{u}(k_G)}{\partial k_G}$$

$$+ F'\left(p^*_{t,ExP} + k_R - (\bar{u}(0) - \bar{u}(k_G))\right)\pi(k_G)\frac{\partial \bar{u}(k_G)}{\partial k_G}$$

$$+ F\left(p^*_{t,ExP} + k_R - (\bar{u}(0) - \bar{u}(k_G))\right)\frac{\partial \pi(k_G)}{\partial k_G}.$$

Thus, with $\partial\left(\sum_{\tau=t,t+1} \pi_\tau (r_t = G)\right)/\partial k_G = 2\partial\pi(k_G)/\partial k_G$, we get

$$\frac{\partial \Delta}{\partial k_G} = -F'\left(p^*_{t,ExP} + k_R - (\bar{u}(0) - \bar{u}(k_G))\right)\left(\pi(0) - \pi(k_G) + p^*_{t,ExP}\right)\frac{\partial \bar{u}(k_G)}{\partial k_G}$$

$$+ \left(F\left(p^*_{t,ExP} + k_R - (\bar{u}(0) - \bar{u}(k_G))\right) - 2\right)\frac{\partial \pi(k_G)}{\partial k_G},$$

which is strictly positive since $\pi(0) > \pi(k_G)$, $\partial \bar{u}(k_G)/\partial k_G < 0$, and $\partial \pi(k_G)/\partial k_G < 0$. It follows that there exists $\bar{k}_G \in (0, \check{k}_G)$ such that the firm strictly prefers $r_t = G$ over $r_t = ExP$ if and only if $k_G < \bar{k}_G$.

A.6 Proof of Proposition 4

Denote the solution to (10) by $\hat{p}(k, v)$. Allowing for negative prices, the optimal price $p(k, v)$ is given by (10) if $\hat{p}(k, v) \geq -k$, and is equal to $-k$ otherwise.

(i) Suppose that the firm chooses $r = ExA$ and that inequality (11) holds. Then, anticipating the price $p(0, v_B)$, all consumers register, and the firm's profit is equal to

$$(1 - F(p(0, v_B)))(p(0, v_B) + v_B) + v_R, \tag{20}$$

which must be (weakly) larger than the profit when choosing a price $p = p(k_R, v_R + v_B) + k_R$, that is, larger than

$$(1 - F(p(k_R, v_R + v_B) + k_R))(p(k_R, v_R + v_B) + k_R + v_B) + v_R$$
$$> (1 - F(p(k_R, v_R + v_B) + k_R))(p(k_R, v_R + v_B) + v_B + v_R),$$

where the latter is the firm's profit when choosing $r = ExP$. Similarly, the firm's profit under $r = ExA$ is (weakly) larger than when choosing a price $p = p(k_G, v_G) + k_G$, that is, larger than

$$(1 - F(p(k_G, v_G) + k_G))(p(k_G, v_G) + k_G + v_B) + v_R$$
$$> (1 - F(p(k_G, v_G) + k_G))(p(k_G, v_G) + v_B + v_R)$$
$$\geq (1 - F(p(k_G, v_G) + k_G))(p(k_G, v_G) + v_G),$$

where the latter is the firm's profit when choosing $r = G$.

(ii) Suppose that inequality (11) is violated. Then, the firm's profit under $r = ExA$ is zero since no consumer registers. The profit under $r = ExP$ is equal to

$$(1 - F(p(k_R, v_R + v_B) + k_R))(p(k_R, v_R + v_B) + v_B + v_R). \tag{21}$$

Note that (21) is strictly increasing in the value of consumer information $v_R + v_B$.[41] Under

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[41]Intuitively, if the value of consumer information increases to $v'_R + v'_B > v_R + v_B$, the firm's profit goes up even if it leaves the price unchanged (equal to $p(k_R, v_R + v_B)$).

$r = G$, the firm gets a profit equal to

$$(1 - F(p(k_G, v_G) + k_G))(p(k_G, v_G) + v_G). \tag{22}$$

Suppose that $v_R + v_B = v_G + k_R - k_G$. Then, the firm's profit under $r = ExP$ is

$$\max_p (1 - F(p + k_R))(p + v_G + k_R - k_G) = \max_x (1 - F(x + k_G))(x + v_G), \tag{23}$$

where the equality follows from replacing $x = p + k_R - k_G$. The right-hand side of (23) is equal to the profit under $r = G$. Thus the profit under $r = ExP$ equals the profit under $r = G$ when $v_R + v_B = v_G + k_R - k_G$. Since (21) is strictly increasing in $v_R + v_B$, the firm chooses $r = ExP$ if and only if $v_R + v_B \geq v_G + k_R - k_G$, and chooses $r = G$ otherwise.

A.7 Proof of Remark 3

We first compare the profits under ex ante and ex post registration requirements. Denote by $\Delta(v_R, v_B)$ the difference in profits under $r = ExA$ (as given in (20)) and under $r = ExP$ (as given in (21)), that is,

$$\begin{aligned}
\Delta(v_R, v_B) &= (1 - F(p(0, v_B)))(p(0, v_B) + v_B) + v_R \\
&\quad - (1 - F(p(k_R, v_R + v_B) + k_R))(p(k_R, v_B) + v_R + v_B).
\end{aligned}$$

Step 1: Suppose that $v_R = 0$. Using the envelope theorem, we get

$$\frac{\partial \Delta(0, v_B)}{\partial v_B} = (1 - F(p(0, v_B))) - (1 - F(p(k_R, 0 + v_B) + k_R)) \geq 0,$$

with strict inequality whenever v_B is sufficiently small such that $p(k_R, v_B) + k_R > p(0, v_B)$. (The latter is true by Assumption 1 as long as $p(k_R, v_B) > -k_R$. Note also that $p(k_R, v_B) = -k_R$ implies that $p(0, v_B) = 0$, in which case we get $\partial \Delta(0, v_B)/\partial v_B = 0$. Hence, if only non-negative prices are possible then Assumption 1 implies that $\partial \Delta(0, v_B)/\partial v_B > 0$.)

Step 2: For any $v_B \geq 0$, using again the envelope theorem,

$$\frac{\partial \Delta(v_R, v_B)}{\partial v_R} = 1 - (1 - F(p(k_R, v_B + v_R) + k_R)) \geq 0,$$

with strict inequality whenever v_B and v_R are sufficiently small.

Step 3: If $v_B = 0$, it follows by Step 2 that $\Delta(v_R, v_B) > \Delta(0, 0)$ if $v_R > 0$. If $v_B > 0$, then by Steps 1 and 2, $\Delta(0, 0) < \Delta(0, v_B) \leq \Delta(v_R, v_B)$.

Next, denote the difference in profits under $r = ExA$ and under $r = G$ (as given in (22)) by $\tilde{\Delta}(v_R, v_B, v_G)$. Note first that due to $v_G \leq v_R + v_B$, we get $\tilde{\Delta}(v_R, v_B, v_G) \geq \tilde{\Delta}(v_R, v_B, v_R + v_B)$, that is, the difference in profits is weakly larger than if the value of user information under $r = G$ is as in case of $r = ExP$ above. Since the result above for the comparison of $r = ExA$ and $r = ExP$ holds for any $k_R > 0$, it follows analogous to Steps 1-3 above that $\tilde{\Delta}(0, 0, 0) < \tilde{\Delta}(v_R, v_B, v_G)$ for any $(v_R, v_B) \neq (0, 0)$.

A.8   Proof of Proposition 5

Let $r = ExA$ and suppose that all consumers with registration cost k_{RL} register independently of whether they are offered a discount, but consumers with registration cost k_{RH} register if and only they are offered a discount. For a discount policy (d, δ), the firm's expected profit is

$$\pi_d(p; r = ExA) := \delta(1 - F(p - d))(p - d) + (1 - \delta)q(1 - F(p))p. \qquad (24)$$

This profit function takes into account (i) that a share δ of consumers register with discount and may buy at an effective price $p - d$ and (ii) that a share $(1 - \delta)q$ of consumers register without having a discount (all being low-cost types) and may buy at price p. The price p_d that maximizes (24) is given by the first order condition

$$\delta[-F'(p_d - d)(p_d - d) + 1 - F(p_d - d)] + (1 - \delta)q[-F'(p_d)p_d + 1 - F(p_d)] = 0. \qquad (25)$$

Under Assumption 1 on F, p_d is increasing in d and $p_d - d$ is decreasing in d, which can be verified by implicit differentiation of (25). Hence, p_d is larger than the price $p(0)$ (for $d = 0$ as given in (1)) but $p_d - d$ is smaller than $p(0)$. Higher discounts d lead to a stronger price distortion, which reduces the firm's profits (taking as given the share of consumers who register). Therefore, if the firm decides to offer a discount, it will choose d such that high-cost types are just willing to register. (The left-hand side of the inequality in (12) is increasing in d. The firm will choose d such that (12) holds with equality; due to the price distortion effect, the firm will not increase the discount any further.) Since p_d depends on the share δ of consumers with discount, d can be expressed as a continuous function of δ.[42] Note that the discount $d(\delta)$ necessary to induce high-cost types to register is increasing in δ since the price p_d also increases in δ: The more consumers get a discount, the stronger is the price increase, and the higher must be the discount to make a high-cost consumer willing to

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[42]For general distributions F no closed form solution for d can be obtained; for a uniform distribution on $[0, 1]$, for instance, we obtain $d(\delta) = \frac{\delta + (1 - \delta)q}{2(1 - \delta)q}(\sqrt{k_{RH}/\bar{u}(0)} - 1)$ for $k_{RH} \geq \bar{u}(0) = 1/8$.

register.[43]

Fix any $\delta \in (0,1)$ and let $k_{RH} \to \bar{u}(0)$, holding δ constant. Suppose the firm chooses the discount d such that (12) holds with equality. (If k_{RH} is close to $\bar{u}(0)$, such a discount clearly exists.) Then, by (12), $(p_d - d) \to p(0)$. By definition of $p(0)$, it follows that

$$[-F'(p_d - d)(p_d - d) + 1 - F(p_d - d)] \to 0.$$

By (25) this implies that

$$[-F'(p_d)p + 1 - F(p_d)] \to 0,$$

which means $p_d \to p(0)$. Since $(p_d - d) \to p(0)$, we conclude that $d \to 0$.

Since $p_d \to p(0)$ if $k_{RH} \to \bar{u}(0)$, the right-hand side of condition (13) approaches $\bar{u}(0)$, which is by assumption strictly greater than k_{RL}. Therefore, (13) holds for k_{RH} sufficiently close to $\bar{u}(0)$. Moreover, with $k_{RH} \to \bar{u}(0)$, the profit (24) approaches

$$\delta \pi(0) + (1 - \delta)q\pi(0) = q\pi(0) + \delta(1 - q)\pi(0),$$

where $\pi(0)$ is as defined in (2). For any $\delta > 0$, this profit is strictly greater than $q\pi(0)$, which is the profit the firm achieves when it requires ex ante registration and does not offer any discounts (since in this case only consumers with registration cost k_{RL} register). This proves part (i).

For part (ii), if the firm does not require ex ante registration, it chooses $r = G$ and realizes a profit $\pi(k_G)$ (as given in (2); compare Proposition 1). Here, the firm would not want to offer a discount since discounts distort the pricing decision. Since $\pi(0)$ and $\pi(k_G)$ do not depend on k_{RH}, there exists $\bar{\delta} < 1$ such that

$$q\pi(0) + \delta(1 - q)\pi(0) > \pi(k_G)$$

for all $\delta > \bar{\delta}$ and all $k_{RH} \geq \bar{u}(0)$. Suppose the firm chooses $\delta \in (\bar{\delta}, 1)$. Then, for k_{RH} sufficiently close to $\bar{u}(0)$, the profit from the discount scheme is sufficiently close to $q\pi(0) + \delta(1 - q)\pi(0)$ and hence strictly larger than $\pi(k_G)$.

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[43] This again follows from implicit differentiation and the assumptions on F. If $\delta \to 1$ then $p_d \to p(0) + d$: If all registered consumers have a discount, the price in the discount case just increases by the value of the discount such that the net-of-discount price remains unchanged; the discount has no effect. (By the same argument, if all consumers have the same registration costs and only consumers with discount register then $p_d = p(0) + d$ and there is no effect of offering discounts.)

A.9 Proof of Proposition 6

Under targeting technology $q' \leq q$, if the firm requires ex ante registration and chooses a discount policy (d', δ'), the optimal price is the solution to

$$\max_{p} \delta' \left(1 - F\left(p - d'\right)\right) \left(p - d'\right) + \left(q - q'\delta'\right) \left(1 - F\left(p\right)\right) p$$

since (i) a share δ' of consumers register with discount and may buy at an effective price $p - d'$ and (ii) a share $q - q'\delta'$ of consumers register without having a discount (all being low-cost types) and may buy at price p. (Since the share of low types with discount is $q'\delta'$, the share of low types without discount in the population must be $q - q'\delta'$.) Anticipating this optimal price, which we denote by $p'\left(q', \delta'\right)$, the size of the discount will be such that a high-cost consumer is just willing to register, that is, for given (q', δ'), the optimal discount $d\left(q', \delta'\right)$ fulfills

$$\int_{p' - d(q', \delta')}^{\infty} \left(\theta - \left(p' - d\left(q', \delta'\right)\right)\right) dF\left(\theta\right) = k_{RH}.$$

Consider two possible targeting technologies q' and q'' with $q'' < q'$. For targeting technology q', let δ' be part of the profit-maximizing discount policy. The total share of consumers who registers is equal to $\delta' + q - q'\delta'$ (where $q - q'\delta'$ is the share of low-cost consumers without discount). For targeting technology q'', suppose that the firm chooses $\delta'' = \delta' \left(1 - q'\right) / \left(1 - q''\right)$.[44] The total share of consumers who register under q'' is equal to

$$\delta'' + q - q''\delta'' = \delta' \left(1 - q'\right) + q$$

and is, hence, the same as under targeting q'. However, due to $1 - q'' > 1 - q'$, we get $\delta'' < \delta'$, that is, the share of consumers with discount is strictly lower under (q'', δ'') than under (q', δ'); consequently, more consumers must register/buy without discount under q''. This leads to a weaker price distortion under q'' than under q'; that is, $p\left(q'', \delta''\right) < p\left(q', \delta'\right)$. Thus, the discount necessary to make consumers with high registration costs willing to register is lower under q'' (with $\delta'' < \delta'$) than under q' (with δ'). These effects (weaker price distortion, lower discount, higher share of consumers who register without discount) cause the firm's profit to be strictly higher under q'' when choosing $\delta'' = \delta' \left(1 - q'\right) / \left(1 - q''\right)$ than under q' (with the optimal δ'). If under technology q'' the optimal $\delta \neq \delta''$, profits must be even higher.

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[44]If, with targeting technology q', δ' satisfies the feasibility requirement $(1 - q')\delta' \leq 1 - q$ then $(1 - q'')\delta'' = (1 - q'')\delta' \left(1 - q'\right) / \left(1 - q''\right) \leq 1 - q$; thus δ'' fulfills the corresponding feasibility requirement with targeting technology q''.

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Online shopping and platform design with ex ante registration requirements

ONLINE APPENDIX

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This supplementary appendix to the article "Online shopping and platform design with ex ante registration requirements" investigates the firms' equilibrium registration requirements in the presence of competition between sellers. Section B extends the baseline model of Section 3 of the article. Section C offers some brief observations on discounts, dynamics, and the value of consumer information, in a model with competing sellers. Section D extends the model with price commitment (see Remark 1 in the main article) to the case of competing sellers. Section E contains the proofs of the main propositions of this appendix.

B The baseline model with competition

In the baseline model of Section 3, a monopoly firm benefits from requiring ex ante registration, but consumers prefer the firm to offer the option of guest checkout. Therefore, competitors that do not require ex ante registration may attract (some of) the consumers, which may change the profitability of ex ante registration requirements. This appendix shows, however, that the logic of ex ante registration requirements prevails even when firms face competition.

Suppose that there are $N \geq 2$ firms that all produce an identical product at marginal cost of zero. The mass of consumers consists of a share of 'loyal' consumers who only consider to buy at a particular firm and a remaining share of non-committed consumers. We assume

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that a share β of the consumers is loyal to firm $i = 1, ..., N$ where $0 \le \beta \le 1/N$; the share of non-committed consumers is denoted by $\beta_0 := 1 - N\beta$. Brand loyalty can be a consequence of complementarities with other products, for instance, or of switching costs, network effects, consumption choices of friends, or simple unawareness of the presence of competitors.[1] Each consumer has unit demand and a valuation θ which is distributed according to F, both for loyal and for non-committed consumers.

The three-stage game of Section 3 only needs slight modifications. In stage 1, the firms simultaneously and independently make their platform choice $r_i \in \{ExA, G\}$.[2] In stage 2, the platform choices become common knowledge and firm $i \in \{1, ..., N\}$ chooses a price $p_i \ge 0$. For stage 3, we have to distinguish between loyal and non-committed consumers. Loyal consumers decide whether to trade with one particular firm only, just as in the monopoly case. If this firm does not require ex ante registration, loyal consumers observe the price and their valuation θ and decide whether to buy. If this firm requires ex ante registration, loyal consumers decide whether to register, in which case they learn θ and the price and may buy.[3] Non-committed consumers observe the prices of the firms that do not require ex ante registration. Moreover, if there is a firm with $r_i = G$, non-committed consumers learn their valuation θ. Non-committed consumers decide whether to register at a firm (if required) and decide whether and where to buy.[4] As before, consumers who register incur a cost k_R; consumers who buy using the guest checkout (if offered) incur a cost k_G.

The equilibrium analysis builds on the following observations. First, if a firm i requires ex ante registration ($r_i = ExA$), the optimal price choice in stage 2 is $p(0)$, where $p(k)$ is given by

$$p(k) = \frac{1 - F(p(k) + k)}{F'(p(k) + k)}, \tag{26}$$

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[1] For early papers on price competition with brand loyalty see Rosenthal (1980) and Narasimhan (1988). A similar structure emerges when a share of consumers is uninformed about the existence of other firms (Varian 1980, Baye et al.1992). Brand loyalty can be explained by switching cost, more specifically, for instance, by costly learning how to use new products, complementarities to other purchased products and network effects; for an overview of reasons for brand loyalty see Klemperer (1995). In Baye and Morgan (2001) loyalty emerges from local segregation of markets and can be broken down by creating a virtual marketplace on the internet. See also Baye and Morgan (2009) for a model of price competition when consumer loyalty is endogenous and affected by advertising.

[2] For brevity, we ignore the option $r = ExP$ throughout Sections B and D of this appendix. As in the baseline model, allowing firms to choose $r = ExP$ does not yield any interesting additional insights, unless one considers repeat purchases or an informational value of registration (see Section C).

[3] Thus, if $\beta \to 1/N$, the firms' decisions become completely independent and the equilibrium platform choices are exactly as characterized in Proposition 1 of Section 3.

[4] In case two or more firms require ex ante registration, the non-committed consumers can register at one firm first and observe this firm's price but are allowed to register at another firm afterwards and finally decide where to buy.

just as in equation (1) of Section 3.[5] Anticipating this price, consumers would register at this firm only if $k_R \leq \bar{u}(0)$, where

$$\bar{u}(0) = \int_{p(0)}^{\infty} (\theta - p(0)) \, dF(\theta) \tag{27}$$

as in equation (5) of Section 3; moreover, non-committed consumers expect the same surplus $\bar{u}(0)$ at either firm that requires ex ante registration. Second, if two or more firms offer the option of guest checkout, there is price competition for the non-committed consumers; this yields equilibrium prices below $p(0)$ such that non-committed consumers are strictly better off when trading with a firm i that chooses $r_i = G$ than when registering at a firm j with $r_j = ExA$. These observations lead to the following main result of this section.

Proposition 7 *(i) Suppose that $k_R \leq \bar{u}(0)$, where $\bar{u}(0)$ is defined in (27). If*

$$\beta \geq \frac{1}{N-1}\left(1 - \frac{\pi(0)}{N\pi(k_G)}\right), \tag{28}$$

in equilibrium all firms require ex ante registration. If

$$0 < \beta < \frac{1}{N-1}\left(1 - \frac{\pi(0)}{N\pi(k_G)}\right), \tag{29}$$

there are N equilibria such that exactly one firm offers the option of guest account and all other firms require ex ante registration.[6]
(ii) If $k_R > \bar{u}(0)$, all firms $i = 1, ..., N$ choose $r_i = G$.

Proof. See Section E.1 below. ∎

Price competition between firms lowers their expected profits if two or more firms do not require ex ante registration.[7] All profits from selling to the non-committed consumers are

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[5]There are again equilibria in which consumers believe that the firm chooses a very high price such that it never pays off to register at this firm and therefore, this firm has indeed no incentive to deviate from a very high price. As in the monopoly case, equilibrium refinements can eliminate these equilibria.

[6]Under the condition (29), there are also equilibria where (some) firms randomize their platform choices in stage 1, including a symmetric equilibrium in which all N firms randomize their registration requirements, choosing $r_i = ExA$ with some probability α and $r_i = G$ with probability $1 - \alpha$ (see the proof in Appendix E.1).

[7]In the proof of Proposition 7 we show that in this case, the equilibrium pricing decisions are in mixed strategies whenever $\beta > 0$. Intuitively, prices do not drop down to marginal costs since firms can make positive profits by selling to their loyal consumers only. Nevertheless, firms would like to marginally undercut their competitors in order to gain all non-committed consumers. The equilibrium of Bertrand price competition with a share of loyal consumers has been derived and applied by Narasimhan (1988) for the case of two firms, and similar structures have been analyzed, for instance, in the context of price competition with informed and uninformed consumers (Varian 1980; Baye et al. 1992).

competed away, and firm i that chooses $r_i = G$ ends up with an expected equilibrium payoff equal to $\beta\pi(k_G)$ (which is what it can guarantee itself when selling to its loyal consumers only), where

$$\pi(k) = (1 - F(p(k) + k))\, p(k) \tag{30}$$

as in equation (2) of Section 3. But if firm i requires ex ante registration, it gets a profit $\beta\pi(0) > \beta\pi(k_G)$: Even though only loyal consumers consider buying at firm i in this case, the same argument as in the baseline model (Proposition 1) shows that firm i is strictly better off when those consumers register ex ante.

If the firms' share of loyal consumers is sufficiently high then all firms choose an ex ante registration requirement in equilibrium and set prices equal to $p(0)$. The non-committed consumers register at one randomly selected firm and only consider buying at this firm since they correctly anticipate that the prices at the other firms will not be lower.[8] If a firm i deviates to 'no ex ante registration' and chooses $r_i = G$, it optimally sets a price $p(k_G) < p(0)$ and gets all non-committed consumers; but it loses the advantage of ex ante registration of its loyal consumers. Hence, a deviation to $r_i = G$ is profitable only if β becomes small such that the gain from additional non-committed consumers outweighs the lower profit extracted from the loyal consumers. Such a deviation is, however, profitable for at most one firm: Price competition about non-committed consumers deters all remaining firms $j \neq i$ from choosing $r_j = G$ whenever $\beta > 0$ (however small). In other words, in any equilibrium where firms do not randomize their choices of registration requirements, all firms except possibly one require ex ante registration.

As long as $\beta > 0$, Proposition 7 characterizes the complete set of equilibria involving registration policy choices in pure strategies, even when β is infinitesimally close to zero. The type of equilibrium in which $N - 1$ firms require ex ante registration continues to exist for $\beta = 0$, but in this case there are (multiple) additional equilibria since a firm i makes zero profits both in case of $r_i = ExA$ and when deviating to $r_i = G$ (provided that at least one other firm j chooses $r_j = G$, as none of the consumers would register at a firm if there is another firm with $r_j = G$). Therefore, the case of $\beta = 0$ is a special case in which there are multiple equilibria characterized by $m \in \{1, ..., N\}$ firms choosing $r_j = G$ and the remaining

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[8]Proposition 7 is similar to the Diamond (1971) paradox that arbitrarily small search costs imply equilibrium prices that differ drastically from marginal costs. Similarly, in our setting, arbitrarily small frictions in the form of registration costs lead to equilibrium prices above marginal costs. If (29) holds, however, prices paid by the uncommitted consumers are smaller than the monopoly price (but still strictly higher than marginal costs). Moreover, our result is different from Diamond (1971) since it relies on both registration costs ($k_R > 0$) and committed consumers ($\beta > 0$). Intuitively, while firms may not want to deviate in prices given that all firms choose $r = ExA$, the registration requirements add another dimension in which firms may deviate, which would have its analogy in Diamond's model (though being substantially different) when allowing firms to reduce the search costs to zero and in this way restore price competition in equilibrium.

$N - m$ firms choosing $r_i = ExA$.

A general message of the case of price competition is that firms with a high share of loyal consumers choose ex ante registration requirements while firms with no (of few) loyal consumers do not require ex ante registration, which can be most easily seen in the following example.

Remark 4 *Let $1 \leq n \leq N - 2$ and suppose that firms $i \in \{1, ..., n\}$ each have a share $\beta \in (0, 1/n]$ of loyal consumers but firms $j \in \{n + 1, ..., N\}$ do not have any loyal consumers. If $k_R \leq \bar{u}(0)$, there is an equilibrium in which firms $i = 1, ..., n$ choose $r_i = ExA$ and all other firms $j = n + 1, ..., N$ choose $r_j = G$.*

If two or more firms j do not have any loyal consumers, they offer the option of guest checkout, choose prices equal to marginal costs and, hence, realize zero profits, but they cannot do better by deviating to $r_j = ExA$ since in this case none of the non-committed consumers would register at their shop. Firms i with loyal consumers are, thus, strictly better off when choosing $r_i = ExA$ (in which case they get a profit of $\beta \pi(0) > 0$).

C   Remarks on discounts, dynamics, and informational value of consumer registration

Section 6 of the main article considered the incentive of a monopoly firm to use discounts as a means to increase the consumers' willingness to register. Similar effects can be derived vis-à-vis the loyal consumers in the case of competition. Moreover, discounts may also be used to attract the non-committed consumers.[9] As a simple illustration, consider the case of Proposition 7(i) and suppose that firms $j \neq i$ do not use discounts. Then, firm i can attract additional non-committed consumers by offering them an arbitrarily small discount. This will increase firm i's profit even when it cannot target the discount specifically to the non-committed consumers. As in Section 6, the firm cannot offer discounts to all consumers since this would lead to a price increase by the same amount. But since under the assumptions of Proposition 7(i) loyal consumers register even without discounts, the registered consumers will consist of consumers with and without discounts; hence, non-committed consumers who are offered a discount anticipate that their effective price at firm i is reduced, and prefer to register at firm i.

In a multi-period model with non-monetary costs of registration, some degree of consumer loyalty can also emerge endogenously. Intuitively, whenever a consumer already has an

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[9]See also Shaffer and Zhang (2002) on price competition with loyal consumers when, after setting their prices, firms can target promotions to certain customers and induce consumers to switch to their brand.

account at a firm, he is willing to pay a higher price at that firm if, at other firms, he needs to register (or use guest checkout) when buying. This generates a lock-in effect which mitigates the price competition and is, hence, profitable for the firms. In fact, when extending the two-period model of Section 4 of the main article to the case of N firms (without exogenously loyal consumers, that is, $\beta = 0$), there can be an equilibrium in which all N firms do not offer the option of guest checkout in period t but require registration ex post, that is, whenever a consumer decides to buy. Although deviating could attract additional consumers in the current period, requiring consumers to register leads to higher profits in future periods.

If firms derive an informational value from consumer registration (as in Section 5 of the main article), this strengthens their incentive to require registration also in the presence of competition. In Proposition 7(i), the range of β for which all firms require ex ante registration in equilibrium would be enlarged if firms value the information that consumers provide when registering. Overall, the incentive to use ex ante registration requirements caused by the sunk cost advantage of registration carries over to the case of competition and its value is reinforced when incorporating dynamic aspects and repeat purchases or an informational value of consumer registration.

D   Price commitment and ex ante registration under competition

Above we assumed that, when a firm requires registration, unregistered consumers cannot observe its price. Here, we consider the case where prices are binding commitments for the firms and observable to all consumers, as in Remark 1 concerning the monopoly case.

The analysis of competition in Section B yielded two main insights. First, even under price competition firms may be able to sustain prices equal to the monopoly price $p(0)$ (as in the equilibrium in which all firms require ex ante registration). Second, ex ante registration requirements continue to be profitable in the model with $N \geq 2$ firms. In this section, we show that the result of monopoly prices in equilibrium hinges on the assumption that, with ex ante registration requirements, prices are not observable for the consumers. Just as informative advertising can offer a solution to the Diamond (1971) paradox and related price obfuscation effects, observability of (and commitment to) prices in case of ex ante registration requirements fosters price competition and leads to lower profits. Ex ante registration requirements, however, are still prevalent in equilibrium; their profitability does not depend on the price obfuscation that prices of firms j with $r_j = ExA$ are unobservable to non-registered consumers.

Formally, we consider the model with $N \geq 2$ firms described in Section B above, except that we modify the timing of the game by assuming that after the firms have chosen their prices, all prices (including those of the firms that require ex ante registration) are observed by the consumers (as in Remark 1 on the monopoly case with price commitment).[10] Let

$$p_C(k) = \arg\max_p (1 - F(p)) p \quad \text{s.t.} \quad \int_p^\infty (\theta - p) \, dF(\theta) \geq k$$

denote the optimal price of a monopoly firm that chooses ex ante registration and commits to a price under the constraint that consumers with registration costs k are willing to register at this price. If k_R is low $(k_R \leq \bar{u}(0))$ then the constraint on consumer surplus does not bind such that $p_C(k_R) = p(0)$. If k_R is high $(k_R > \bar{u}(0))$ then the firm has to lower its price in order to make the consumers willing to register. The following proposition addresses the case in which the monopoly price under $r = ExA$ is higher than the monopoly price under $r = G$ (the latter is equal to $p(k_G)$ as given by (26)). Formally, this is the case when $k_R < \bar{k}$, where $\bar{k} \in (\bar{u}(0), E(\theta))$ is defined such that

$$p_C(\bar{k}) = p(k_G).$$

Proposition 8 *Consider the case in which the firms commit ex ante to their prices and suppose that $k_R < \bar{k}$.*
(i) In any equilibrium where firms do not randomize their registration requirements, all firms except possibly one will require ex ante registration.
(ii) There exists a threshold $\bar{\beta} \in (0, 1/N)$ such that in equilibrium all firms require ex ante registration if $\beta > \bar{\beta}$.

Proof. See Section E.2 below. ∎

Proposition 8 shows that as in the case without price commitment, all firms except possibly one will require ex ante registration in any equilibrium with platform choices in pure strategies. If all firms require ex ante registration and the firms' prices are observable to all consumers, this will yield price-setting in mixed strategies and prices below the monopoly price $p_C(k_R)$. Nevertheless, the firms' realized profits are sufficiently high to make a deviation to $r_j = G$ unattractive. In particular, as soon as one firm chooses $r_i = G$, no other firm $j \neq i$ would like to deviate from $r_j = ExA$ and lose the advantage from ex ante registration of their loyal consumers. If β is sufficiently high, all firms require ex ante registration in equilibrium,

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[10] As in Section B above, we ignore the option $r_i = ExP$ for brevity, as it does not provide interesting additional insights.

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but for lower β there can be an equilibrium in which exactly one firm i chooses $r_i = G$ and all other firms $j \neq i$ choose $r_j = ExA$ (for more details see the proof of Proposition 8).

Proposition 8 confirms the advantage from ex ante registration requirements when price obfuscation effects are absent. Compared to Proposition 7, the range of β in which all firms require ex ante registration becomes smaller but the range of k_R for which ex ante registration requirements are feasible is enlarged (which follows from $\bar{k} > \bar{u}(0)$), in case firms commit to their prices before consumers decide whether to register.[11] Thus, while the absence of price obfuscation effects leads to lower prices, price commitment also makes it easier for firms to induce consumers to register ex ante.

E   Additional proofs

E.1   Proof of Proposition 7

First we derive the equilibrium prices and profits for given platform choices $(r_1, ..., r_N)$. Suppose that all firms choose $r_i = ExA$. Then, given that a positive share of consumers register, it is optimal for each firm to choose a price $p(0)$. Anticipating the firms' pricing decisions, loyal consumers register if and only if $k_R \leq \bar{u}(0)$. Non-committed consumers are indifferent between registration at either firm and randomly select one of the firms. Thus, if $k_R \leq \bar{u}(0)$, firm i gets its loyal consumers and a share $1/N$ of the non-committed consumers and, hence, a profit of $(\beta + \beta_0/N)\pi(0) = \pi(0)/N$. If $k_R > \bar{u}(0)$, no consumer registers and the firms' profits are zero.

Now suppose that exactly one firm chooses $r_i = G$ and all other firms $j \neq i$ choose $r_j = ExA$. For firm i with $r_i = G$, it is optimal to set $p_i = p(k_G)$, which, by Assumption 1 (the distribution F of valuations has a monotone hazard rate), is strictly smaller than $p(0)$. Observing p_i and anticipating the prices of firms $j \neq i$, all non-committed consumers consider only buying at firm i. Therefore, firm i has no incentive to deviate to another price ($p(k_G)$ is the optimal price even in the absence of competition) and gets a profit of $(\beta + \beta_0)\pi(k_G)$ from selling to its loyal consumers and to the non-committed consumers. All other firms j (with $r_j = ExA$) can only sell to their loyal consumers; they realize a profit of $\beta\pi(0)$ if $k_R \leq \bar{u}(0)$ and a profit of zero otherwise.

Finally, suppose that $m \geq 2$ firms choose $r_i = G$ and the remaining firms choose $r_j = ExA$. The resulting subgame equilibrium is summarized in the following lemma.[12]

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[11] There are parameter values (β, k_R) for which $r_i = ExA$ for $i = 1, ..., N$ occurs in equilibrium in case of price commitment, but does not constitute an equilibrium with unobservable prices, and vice versa.

[12] Baye et al. (1992) show that the game of price competition with uninformed (loyal) and informed (non-committed) consumers has a unique symmetric equilibrium as well as a continuum of asymmetric equilibria

Lemma 2 *Let $2 \leq m \leq N$ and suppose that firms $i = 1, ..., m$ choose $r_i = G$ and the remaining firms choose $r_j = ExA$. In the symmetric equilibrium, firm $i \in \{1, ..., m\}$ randomizes according to*

$$B(p_i) = \begin{cases} 0 & \text{if } p_i \leq \underline{p} \\ 1 - \left(1 - \frac{\beta + \beta_0}{\beta_0} + \frac{\beta\pi(k_G)}{\beta_0(1 - F(p_i + k_G))p_i}\right)^{\frac{1}{m-1}} & \text{if } \underline{p} < p_i < p(k_G) \\ 1 & \text{if } p_i \geq p(k_G) \end{cases} \tag{31}$$

where $\underline{p}$ is defined as the solution to

$$(1 - F(\underline{p} + k_G))\underline{p} = \frac{\beta}{\beta + \beta_0}\pi(k_G) \tag{32}$$

that fulfills $\underline{p} < p(k_G)$. Firm $j \in \{m + 1, ..., N\}$ chooses $p_j = p(0)$. The expected equilibrium profit of firm $i \in \{1, ..., m\}$ is equal to $\beta\pi(k_G)$. The expected equilibrium profit of firm $j \in \{m + 1, ..., N\}$ is equal to $\beta\pi(0)$ if $k_R \leq \bar{u}(0)$ and equal to zero otherwise.

Proof. Consider first firms $j \in \{m + 1, ..., N\}$ with $r_j = ExA$. For those firms, equilibrium prices and profits follow as in Section 3. If a positive mass of consumers register then j's optimal price is $p(0)$. If $k_R \leq \bar{u}(0)$, all loyal consumers register at firm j, which yields a profit of $\beta\pi(0)$; otherwise, no consumer registers and j gets zero profit. Due to $p(0) > p(k_G) \geq p_i$ for $i \in \{1, ..., m\}$, non-committed consumers never consider registering/buying at firms $j \in \{m + 1, ..., N\}$.

Firms $i \in \{1, ..., m\}$ randomize according to $B(p_i)$ on the support $[\underline{p}, p(k_G)]$. Using (32), it is straightforward to verify that $B(\underline{p}) = 0$; moreover, $B(p_i)$ is strictly increasing on $(\underline{p}, p(k_G))$ with $B(p(k_G)) = 1$. Due to the regularity assumptions on F, $\underline{p}$ is uniquely defined by (32); it approaches zero for $\beta \to 0$ and approaches $p(k_G)$ for $\beta \to 1/N$.

Consider firm $i \in \{1, ..., m\}$ and suppose that all other firms $l \in \{1, ..., m\}$, $l \neq i$ randomize according to $B(p)$ in (31). If i chooses a price $p_i \in [\underline{p}, p(k_G)]$, it sells to its loyal consumers at this price; in addition, it sells to all non-committed consumers if and only if p_i is lower than the prices of all other firms, that is, with probability $(1 - B(p_i))^{m-1}$. (Recall that firms $j \in \{m + 1, ..., N\}$ choose a price $p(0) > p(k_G) \geq p_i$ and will never sell to the non-committed consumers.) Thus, firm i's expected profit when choosing $p_i \in [\underline{p}, p(k_G)]$ is

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in mixed strategies. Since the equilibria are payoff-equivalent, the following lemma focuses on the equilibrium in which the firms i with $r_i = G$ use symmetric mixed strategies, without affecting the consequences for the equilibrium platform choices.

equal to

$$
\begin{aligned}
& \left(\beta + (1 - B(p_i))^{m-1} \beta_0\right) (1 - F(p_i + k_G)) p_i \\
= {} & \left(\beta + \left(1 - \frac{\beta + \beta_0}{\beta_0} + \frac{\beta \pi(k_G)}{\beta_0 (1 - F(p_i + k_G)) p_i}\right) \beta_0\right) (1 - F(p_i + k_G)) p_i \\
= {} & \beta \pi(k_G)
\end{aligned}
$$

and is, hence, independent of p_i. In particular, if $p_i = \underline{p}$, i sells to a share $\beta + \beta_0$ of the consumers; with (32) this yields a profit of $\beta \pi(k_G)$. If $p_i = p(k_G)$, i only sells to its loyal consumers which, again, yields a profit of $\beta \pi(k_G)$. Moreover, prices below $\underline{p}$ and above $p(k_G)$ lead to a strictly lower profit. Since i is indifferent between all $p_i \in [\underline{p}, p(k_G)]$, randomization according to $B(p_i)$ is a best reply. ∎

If two or more firms choose $r_i = G$, these firms' equilibrium prices cannot be in pure strategies. To see why, suppose that $m = 2$ and that $p_1 = \tilde{p} > 0$. Firm 2's best reply is $p_2 = p(k_G)$ if $\tilde{p} > p(k_G)$ and $p_2 = \tilde{p} - \varepsilon$ otherwise, $\varepsilon > 0$ infinitesimally small.[13] But then, firm 1 strictly prefers $p_1 = p_2 - \delta$, $\delta > 0$ infinitesimally small, over $p_1 = \tilde{p}$. Moreover, p_1 cannot be zero in a pure strategy equilibrium. If $p_1 = 0$, firm 1 has zero profits, but it can achieve at least $\beta \pi(k_G) > 0$ by setting $p_1 = p(k_G)$. Thus, the equilibrium must be in mixed strategies. In any equilibrium, firms will not choose prices higher than $p(k_G)$, which is the price a firm would choose in the absence of competition, or if the other firms' prices are higher. Using standard techniques in auction theory, it can be shown that in the unique symmetric equilibrium, the firms randomize continuously on an interval $[\underline{p}, p(k_G)]$ with $\underline{p} < p(k_G)$.[14] Since $p(k_G) < p(0)$, the non-committed consumers never register at a firm j with $r_j = ExA$ since they correctly anticipate the higher price of this firm. The firms' expected profits depending on the number of firms with $r_i = G$ are summarized in Table 1.

We are now in a position to prove Proposition 7. Part (ii) (the case where $k_R > \bar{u}(0)$) is straightforward: The profit of any firm j choosing $r_j = ExA$ is zero, but $r_j = G$ leads to a profit of at least $\beta \pi(k_G) > 0$ so that all firms offer the option of guest checkout.

It remains to prove part (i) (where $k_R \leq \bar{u}(0)$). Suppose that inequality (28) holds, and all firms $j \neq i$ choose $r_j = ExA$. Consider the choice of firm i. Under $r_i = ExA$, i gets an expected profit of $(\beta + \beta_0/N) \pi(0) = \pi(0)/N$. If i deviates to $r_i = G$, its expected profit is $(\beta + \beta_0) \pi(k_G) = (1 - (N-1)\beta) \pi(k_G)$. Thus, i has no incentive to deviate if and only if

$$
\pi(0)/N \geq (1 - (N-1)\beta) \pi(k_G),
$$

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[13] To be precise, due to the continuous strategy space, we have to interpret the best reply as an ε−best reply.

[14] Technically, $\underline{p}$ is obtained such that a firm's expected profit when choosing $p = \underline{p}$ is exactly equal to its expected profit when choosing $p = p(k_G)$ and selling only to its loyal consumers.

	Number of firms with $r_i = G$		
	0	1	≥ 2
Profit of a firm with $r_i = G$	-	$(\beta + \beta_0)\,\pi\,(k_G)$	$\beta\pi\,(k_G)$
Profit of a firm with $r_i = ExA$	$(\beta + \beta_0/N)\,\pi\,(0)$	$\beta\pi\,(0)$	$\beta\pi\,(0)$

Note: $\pi(k)$ is defined in equation (30). β is firm i's share of loyal consumers, $\beta_0 = 1 - N\beta$ is the share of non-committed consumers.

Table 1: Summary of the firms' expected profits conditional on the stage 1 platform choices, for the case of $k_R \leq \bar{u}\,(0)$.

which is equivalent to (28). Since under (28), firm i has a dominant strategy to choose $r_i = ExA$ in stage 1, the equilibrium is unique.[15]

Now suppose (29) holds, and suppose that firm 1 chooses $r_1 = G$ and firms $j = 2, ..., N$ choose $r_j = ExA$. As shown above, since (28) is violated, firm 1's profit is strictly higher under $r_1 = G$ than when deviating to $r_1 = ExA$. Moreover, firm $j \in \{2, ..., N\}$ gets an expected profit of $\beta\pi\,(0)$ under $r_j = ExA$ but gets only $\beta\pi\,(k_G) < \beta\pi\,(0)$ when deviating to $r_j = G$ (the proof of the inequality uses the same argument as the proof of Proposition 1). Hence, exactly one firm chooses $r_i = G$ and all other firms $j \neq i$ choose $r_j = ExA$ in the equilibria without randomization of the registration requirements.

Since a firm strictly prefers $r_i = ExA$ over $r_i = G$ as soon as the number of firms with $r_j = G$ is strictly greater than zero, there can be no further equilibrium with platform choices in pure strategies. There are, however, additional equilibria in which firms randomize their choice of registration requirement, in case (29) holds. In particular, there is a symmetric equilibrium in which firms $i = 1, ..., N$ choose $r_i = ExA$ with probability α and $r_i = G$ with probability $1 - \alpha$, where

$$\alpha = \left(\frac{\beta N\,(\pi\,(0) - \pi\,(k_G))}{(1 - \beta N)\,(N\pi\,(k_G) - \pi\,(0))} \right)^{\frac{1}{N-1}}.$$

E.2   Proof of Proposition 8

Let

$$p_C\,(k) = \arg\max_p \,(1 - F\,(p))\,p \quad \text{s.t.} \quad \int_p^\infty (\theta - p)\,dF\,(\theta) \geq k$$

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[15]If (28) holds with equality, all firms choose $r_i = ExA$ by our tie-breaking rule.

and

$$\pi_C(k) = \max_p (1 - F(p)) p \ \text{ s.t. } \ \int_p^\infty (\theta - p) \, dF(\theta) \geq k.$$

Then, the price $p_C(k_R)$ is equal to $p(0) > p(k_G)$ for $k_R \leq \bar{u}(0)$, and $p_C(k_R)$ is strictly decreasing in k_R for $k_R > \bar{u}(0)$; moreover, $p_C(k_R) \to 0$ if $k_R \to E(\theta)$. Since $p(k_G)$ is independent of k_R, there is a uniquely defined threshold $\bar{k} \in (\bar{u}(0), E(\theta))$ for which $p_C(\bar{k}) = p(k_G)$.

To show part (i), suppose that $k_R < \bar{k}$ and that $m \geq 2$ firms choose $r_i = G$. Since $k_R < \bar{k}$ implies that $p_C(k_R) > p(k_G)$, the equilibrium of the ensuing subgame is similar to the equilibrium in the case without price commitment (see Lemma 2): Firms j with $r_j = ExA$ choose prices equal to $p_C(k_R)$ and firms i with $r_i = G$ randomize their prices just as in (31); for the latter firms, the assumption of price commitment is irrelevant since the prices of firms with $r_i = G$ are observable under both assumptions on observability of prices employed in this appendix. Thus, firms with $r_i = G$ get an expected equilibrium profit of $\beta\pi(k_G)$ and firms with $r_j = ExA$ get an expected equilibrium profit of $\beta\pi_C(k_R)$.

Since $p_C(k_R) > p(k_G)$, $p(k_G)$ is also feasible for firms j with $r_j = ExA$, which implies that

$$\begin{aligned} \beta\pi_C(k_R) \ &\geq \ \beta(1 - F(p(k_G))) p(k_G) \\ &> \ \beta(1 - F(p(k_G) + k_G)) p(k_G) = \beta\pi(k_G). \end{aligned}$$

Hence, a firm i with $r_i = G$ is strictly better off when deviating to $r_i = ExA$, in which it can get at least the profit $\beta\pi_C(k_R)$ from selling to the loyal consumers only. Thus, in any equilibrium in pure strategies on stage 1 at most one firm can choose $r_i \neq ExA$.

To show part (ii), we first characterize the (symmetric) equilibrium on the price-setting stage if all firms choose $r_i = ExA$ and prices are observable. Then, we consider the firms' incentives to deviate from $r_i = ExA$.

Lemma 3 *Suppose that $k_R < E(\theta)$ and that $r_i = ExA$ for all $i = 1, ..., N$. In the symmetric equilibrium, firm i randomizes its price according to*

$$B(p_i) = \begin{cases} 0 & \text{if } p_i \leq \underline{p} \\ 1 - \left(\left(\frac{\pi_C(k_R)}{(1 - F(p_i)) p_i} - 1 \right) \frac{\beta}{\beta_0} \right)^{\frac{1}{N-1}} & \text{if } \underline{p} < p_i \leq p_C(k_R) \\ 1 & \text{if } p_i > p_C(k_R) \end{cases} \tag{33}$$

where $\underline{p}$ is defined as the solution to

$$(\beta + \beta_0)(1 - F(\underline{p})) \underline{p} = \beta\pi_C(k_R) \tag{34}$$

that fulfills $\underline{p} < p_C (k_R)$. Firm i's expected equilibrium profit equal to $\beta \pi_C (k_R)$.

Proof. Since $(1 - F(p)) p$ is zero for $p = 0$, strictly increasing in p for $0 < p < p(0)$ (by Assumption 1) and approaches $\pi_C (k_R)$ for $p \to p_C (k_R)$, there is a unique solution $\underline{p} < p_C (k_R)$ to (34). Using (33) it is straightforward to verify that $B(\underline{p}) = 0$ and that $B(p_i)$ is strictly increasing on $(\underline{p}, p_C (k_R))$ and approaches 1 if $p_i \to p_C (k_R)$. Moreover, at prices below $p_C (k_R)$ all consumers are willing to register ex ante; non-committed consumers will register at the firm that offers the lowest price.

If all firms $j \neq i$ follow (33), firm i's expected profit when choosing a price p_i within the support of $B(p_i)$ is

$$\left(\beta + (1 - B(p_i))^{N-1} \beta_0 \right) (1 - F(p_i)) p_i$$
$$= \left(\beta + \left(\left(\frac{\pi_C (k_R)}{(1 - F(p_i)) p_i} - 1 \right) \frac{\beta}{\beta_0} \right) \beta_0 \right) (1 - F(p_i)) p_i$$
$$= \beta \pi_C (k_R) ,$$

while firm i gets a strictly lower expected profit when choosing a price $p_i \notin [\underline{p}, p_C (k_R)]$. Since firm i is indifferent between all $p_i \in [\underline{p}, p_C (k_R)]$, randomization according to $B(p_i)$ is a best reply.[16] ∎

Using the firms' expected profit $\beta \pi_C (k_R)$ in the subgame equilibrium where $r_i = ExA$ for all $i = 1, ..., N$, suppose that firms $j \neq i$ choose $r_j = ExA$ and consider firm i's incentive to deviate to $r_i = G$. The maximum profit that firm i can get under $r_i = G$ is $(\beta + \beta_0) \pi (k_G) = (1 - (N - 1) \beta) \pi (k_G)$, which i gets if it sells to its loyal consumers plus all non-committed consumers at the optimal price $p(k_G)$. Thus, if

$$\beta \geq \frac{\pi (k_G)}{\pi_C (k_R) + (N - 1) \pi (k_G)}, \tag{35}$$

firm i has no incentive to deviate to $r_i = G$. Since $\pi_C (k_R) > \pi (k_G)$, the right-hand side of (35) is strictly between 0 and $1/N$.[17] This shows part (ii).

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[16] Similar as in Baye et al. (1992) there are also asymmetric price-setting equilibria in which $m \geq 2$ firms randomize their prices (replacing N by m in (33)) and the remaining firms choose a price $p = p_C (k_R)$ with probability one; these equilibria are payoff-equivalent to the symmetric equilibrium characterized in Lemma 3.

[17] Concerning the case where exactly one firm i chooses $r_i = G$ and all other firms $j \neq i$ choose $r_j = ExA$, our argument above used an upper bound on the profit firm i can attain, but did not prove existence of an equilibrium of the pricing stage. The latter is most easily established for values of β such that firm i gets all non-committed consumers; for this to be the case, β has to be above some threshold $\tilde{\beta} \in (0, 1/N)$, to prevent firms $j \neq i$ with $r_j = ExA$ from deviating to lower prices (details are available on request). This analysis also implies that, when parameters are such that $\beta \geq \tilde{\beta}$ but β is below the threshold defined in (35), there is an equilibrium where exactly one firm i chooses $r_i = G$ and all other firms $j \neq i$ choose $r_j = ExA$.

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