Consumer Flexibility, Data Quality and Targeted Pricing

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Abstract

We investigate how firms' incentives to acquire and use customer information for targeted offers depend on data quality. We apply a duopoly model of spatial product differentiation with two-dimensional consumer heterogeneity where consumers are differentiated with respect to locations and transportation cost parameters (flexibility). Firms have perfect data on the location of consumers while data on their flexibility is imperfect. We show that when consumers are relatively similar in their flexibility in equilibrium both firms acquire customer data regardless of its quality. This increases profits but harms consumers. When consumers are relatively differentiated in flexibility, information acquisition incentives depend on its quality. If the information is sufficiently precise, both firms acquire it and their profits decrease, while consumers are better-off. Our model has particular relevance for location-based marketing such as in mobile telephony, where firms have near perfect information on the proximity of customers but may have imperfect knowledge of other consumer characteristics.

JEL-Classification: D43; L13; L15; O30.

Keywords: Price Discrimination, Customer Data, Market Segmentation.

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1 Introduction

Recent advances in information technologies allow firms to collect and analyze detailed information about customers and to use it for targeted pricing. For example, in retail loyalty programs allow shops to observe the purchase behavior and various other characteristics of their customers and send them personalized discount coupons.[1] Also the widespread use of smartphones with built in GPS chips lead to a boom of location-based marketing, allowing firms to send targeted advertisements and offers to consumers based on their precise geographic position. The improved technical means to gather information about consumers also triggered a heated debate between policy advocates and firms alike.[2] The ability of firms to convert their knowledge about customers into attractive offers depends crucially on the quality of the data. The focus of this article is on how firms' incentives to acquire and use customer information for targeted offers depends on data quality. We show that there is a subtle relationship between customer data quality, the heterogeneity of consumers and firm profits. We are also interested how improved targeting due to higher data quality influences welfare.

Our article contributes to the strand of literature on competitive price discrimination with demand side asymmetries where consumers can be classified into different groups depending on their preferences for a particular firm when firms set equal prices. The question most often analyzed in that strand resolves around how firms' ability to classify consumers into different loyalty groups and price discriminate respectively influences firm profits. For example Liu and Serfes (2004) also adopt this approach. The authors investigate firm incentives to acquire data on consumer addresses (brand preferences) in a Hotelling model depending on the quality of such data. We argue that for many markets where personalized pricing has received attention, such as retail with coupon marketing or location-based advertising, this way of capturing data quality may not be the most realistic. In the case of coupon marketing, the location dimension of consumers from a spatial model would correspond to their addresses based on which their physical distance to shops can be inferred. It is not immediate to argue that firms have imperfect information on this dimension of consumers. Address data is not only easy to get even from

[1] Davis (2007) notes that retailers use "loyalty schemes [...] to collect personal details on their customers and to link this with the purchases that they make in-store." Similarly, Trench (2010) notes that "[a]lthough shoppers benefit from discounts on products, the supermarkets also obtain a vast amount of knowledge about their customers' preferences."

[2] Mobile firms offering customer data for sale is widely discussed recently. See, for example, Goldman (2011) and Panzarino (2012).

public sources, it is also among the first bits of information consumers are requested to give, for example, when signing up for a loyalty program. In the case of traditional clipping coupons firms surely know the addresses of consumers since this is where coupons are sent. The wide availability of customer-location information is often claimed to be among the main driving factors of the mobile advertising boom.[3] Several mobile phone applications rely on the built-in GPS devices to transmit real time information on the physical location of the consumer and allow retailers to custom-target rebates.[4] It appears that interested retailers can have near perfect information on customer location. In fact, customer location is well known in most relevant examples for targeted pricing. Still, it would be naïve to say that data quality plays no role in targeted pricing. We therefore depart from the assumption of imperfect information on customer location and adopt another angle to look at imperfections in customer data quality.

In this article we rely on an augmented version of the Hotelling model where consumers are heterogeneous not only with respect to their locations but also their transportation cost parameters.[5] We assume that firms have perfect data on consumer locations on the Hotelling line. At the same time data on transportation cost parameters - which we refer to as *flexibility* - is imperfect.[6,7] Data on consumer transportation cost parameters allows firms to classify consumers into different segments according to their flexibility. These segments become finer as the quality of data improves.[8] We analyze firms' incentives to acquire data on consumer flexibility of different quality.

We show that firms' incentives to acquire customer flexibility data crucially depend on consumer heterogeneity in flexibility. When consumers are relatively homogeneous in flexibility,

[3] It is enough to search the Internet for "*proximity marketing*" to find thousands of web pages discussing the role of location-based targeting in retail.

[4] Examples include the mobile applications 8Coupons and Mobiqpons, aggregators, that collect mobile coupons (see http://www.nytimes.com/2009/08/29/technology/29coupon.html).

[5] This setup was first used in Jenzsch, Sapi and Suleymanova (2013).

[6] The term "*flexibility*" captures the intuition that consumers with higher transportation cost parameters are - everything else being equal - less willing to visit a shop further away from their own location.

[7] In summary, our model assumes perfect knowledge on consumer locations and imperfect information on consumer flexibility. This is realistic in many industries with targeted promotions. In Germany for example household addresses are to a large extent publicly available. Deutsche Post offers household-level data on demographics, living situation, purchasing power and several other dimensions. This type of data reveals much about the flexibility of households. See "Deutsche Post, Advertising by mail, Local Promotion" (see http://www.deutschepost.de/dpag?tab=1&skin=hi&check=yes&lang=de_EN&xmlFile=link1017338_1010544). Similarly, Proximus Mobility, a proximity marketing company offers consumer data to retailers which allows them to deliver targeted offers on the consumers' mobile phones (see http://proximusmobility.com/).

[8] We follow Liu and Serfes (2004) to model the quality of data on consumer preferences.

in equilibrium firms acquire such data regardless of their quality, and profits increase. Social welfare remains unchanged, while consumers are worse-off. In contrast, when consumers are relatively differentiated in flexibility, in equilibrium firms do not acquire data irrespective of their quality. The difference in these results is driven by the type of the equilibrium strategy a firm uses among its loyal consumers and the resulting balance between the competition and rent-extraction effects when data quality improves. If consumers are relatively homogeneous, in the absence of customer flexibility data a firm follows a *monopolization* strategy among its loyal consumers: For any price of the rival it serves all its loyal consumers with a given location. This makes competition very intense even without data: The rival charges the price of zero on any address on a firm's turf. Then data acquisition induces only a rent-extraction effect, and the profits of a firm(s) with data on consumer flexibility increase(s) monotonically with the improved data quality. However, if consumers are relatively differentiated in flexibility, then a firm follows a *market-sharing* strategy on its turf. Precisely, it serves all consumers with a given address on its turf only if the rival's price is relatively high. In the absence of customer flexibility data the competition effect is not very intense and the rival charges a positive price on any address on a firm's turf. Data acquisition then intensifies competition and gives rise to the rent-extraction effect. For lower levels of data quality the competition effect outweighs the rent-extraction effect as in the emerging equilibrium prices to the less flexible consumers decrease heavily due to the competition effect. In this range of data quality, profits decrease as data quality improves. However, with further improvement in data quality, the negative competition effect becomes weaker as the rival cannot go below the price of zero on some segments, and the rent-extraction effect takes over: as the net effect, profits then start to increase. Consequently, with relatively differentiated consumers firms only acquire customer flexibility data of a sufficiently high quality.

Our article makes two main contributions to the literature on competitive price discrimination in the presence of demand asymmetries. First, in contrast to most of the articles we allow consumers to have different transportation cost parameters. Second, different from most of the articles which predict a negative effect of price discrimination on industry profits, we show that profits may also increase.[9,10] In our model this is the case if either consumers are relatively ho-

[9] This result was first derived in Thisse and Vives (1998). A similar contribution is made in Bester and Petrarkis (1996) who analyze sellers' incentives to offer rebates to consumers in two distinct regions.

[10] In his analysis Borenstein (1985) also assumes that consumers are differentiated along different dimensions: reservation prices and transportation cost parameters (choosiness). His simulation results show that firms' profits increase when firms are able to discriminate based on consumer choosiness. We contribute by showing that the

mogeneous in flexibility or if consumers are relatively differentiated in flexibility and the quality of customer flexibility data is sufficiently high.

Corts (1998) famously derives as a necessary condition for price discrimination to have an unambiguous effect on firms' profits that the market exhibits *best-response asymmetry*. In that case the strong market of one firm, where with the ability to distinguish among two markets a firm charges a higher price than at the other (weak) market is not at the same time the strong market of the other firm. Our model is characterized by best-response asymmetry. When firms are able to classify consumers into two flexibility segments, the weak market of one firm is at the same time the strong market of the other firm. However, Corts does not further specify under which conditions the unambiguous effect is positive and when it is negative. We show that the effect of firms' ability to discriminate based on consumer flexibility on equilibrium prices and profits is positive (negative) when consumers are relatively homogeneous (differentiated) in flexibility.

The article most closely related to ours is Liu and Serfes (2004). Our results extend the findings of Liu and Serfes by showing more scope for profitable customer data acquisition, which at the same time harms consumers. In Liu and Serfes consumers are differentiated only by locations, and firms may acquire data of imperfect quality on this dimension of consumer heterogeneity. The model of Liu and Serfes corresponds to the version of our model with relatively differentiated consumers. In both cases a firm follows the market-sharing strategy among its loyal consumers. However, we obtain very different results with relatively homogeneous consumers. In the latter case firms acquire customer data of any quality, and consumers are always worse-off when flexibility data becomes available to the firms.

Our article is also closely related to Jenzsch, Sapi and Suleymanova (2013). These offers shows that the competitors' incentives to share customer data among each other depend on its type and on the how strongly consumers are heterogeneous in flexibility. We contribute by showing that consumer heterogeneity in flexibility is also crucial for firms' incentives to acquire customer data. Also, in our analysis customer flexibility data can be imperfect, while it is always perfect in Jenzsch, Sapi and Suleymanova.

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profit effect of the ability to price discriminate based on consumer transportation cost parameters depends on consumer heterogeneity in flexibility and the quality of customer data.

Our paper is organized as follows. In Section 2 we present the model. In Section 3 we state the results of the equilibrium analysis. Precisely, we derive firms' equilibrium incentives to acquire customer flexibility data depending on its quality and consumer heterogeneity in flexibility. Section 4 contains a detailed discussion of the results, comparing them with those in the closest related literature. Finally, in Section 5 we conclude.

2 The Model

There are two firms, A and B, producing two brands of the same product at zero marginal cost and competing on prices.[11] Firms are located at the two ends of a Hotelling line of a unit length with $x_A = 0$ and $x_B = 1$ denoting their locations. There is a unit mass of consumers. Every consumer is characterized by an address $x \in [0, 1]$, which corresponds to her preference for the ideal product. If a consumer does not buy her ideal product she incurs linear transportation costs proportional to the distance to the firm.[12] We follow Jentzsch, Sapi and Suleymanova (2012) and assume that additionally to their addresses consumers are also differentiated in transportation costs per unit distance (flexibility), $t \in \left[\underline{t}, \overline{t}\right]$, where $\overline{t} > \underline{t} \geq 0$. Each individual consumer is uniquely described by a pair (x, t). We say that consumers with addresses $x < 1/2$ ($x > 1/2$) are on the *turf* of firm A (B).

We consider two versions of our model with respect to consumer heterogeneity in flexibility measured by the ratio of the largest to the lowest transportation cost parameters, $l := \overline{t}/\underline{t}$. In the first version $\underline{t} = 0$, such that $\lim_{\underline{t} \to 0} l = \infty$. We say that in this case consumers are *relatively differentiated in flexibility.* In the second version $\underline{t} > 0$ and $l \leq 2$ so that consumers are *relatively homogeneous in flexibility.*

We assume that firms have perfect information on consumer addresses and can acquire data

[11] While the assumption of zero marginal cost is not very realistic, it is not crucial for our results. Assuming $c > 0$ would only increase all the equilibrium prices by c.

[12] Our model has particular relevance for "local search" (search in Internet for local business). As reported by Hendrix (2012), local search is widely practiced by consumers: Almost half of all consumers use local search, two-thirds use it several times per week. More than half of local search is conducted on smartphones and tablets. In the category "Restaurants and Dining" (which turns out to be one of the most popular categories for local search), "distance to the business", "prices", and "promotions-dicsounts" are among the information items consumers are seeking during local search. Also 75 percent in the groups of "heavy users" of local search have reported to make use of coupons stored on a mobile phone. Our analysis captures the main trade-off faced by a consumer performing local search between better prices and longer distance to a shop. At the same time we abstract from other possible differences between businesses in quality or brand variety.

on consumer flexibility that is imperfect.[13,14] We adopt the approach of Liu and Serfes (2004) to model imperfect customer data. Precisely, the quality of data on consumer flexibility is measured by the exogenously given parameter $k = 0, 1, 2, .., \infty$. For a given value of parameter k firms can divide the interval $t \in \left[\underline{t}, \bar{t}\right]$ into $N = 2^k$ segments and identify every consumer as belonging to one of those segments. Segment $m = 1, 2, ..., 2^k$ consists of consumers with the transportation cost parameters $t \in \left[\underline{t}^m(k); \bar{t}^m(k)\right]$, where $\underline{t}^m(k) = \underline{t}+(\bar{t}-\underline{t})(m-1)/2^k$ and $\bar{t}^m(k) = \underline{t}+(\bar{t}-\underline{t})m/2^k$ denote the most and least flexible consumers in segment m, respectively. For any segment m we can compute the ratio of the largest to the lowest transportation cost parameters, $l^m(k) := \bar{t}^m(k)/\underline{t}^m(k)$. We say that consumers are *relatively differentiated in flexibility on segment* m if $\underline{t}^m(k) = 0$, such that $\lim_{\underline{t}^m \to 0} l^m(k) = \infty$. Similarly, consumers are *relatively homogeneous in flexibility on segment* m if $\underline{t}^m(k) > 0$ and $l^m(k) \leq 2$. Segment $m = 1$ always contains the most flexible consumer (with $t = \underline{t}$).

When $k \to \infty$, firms have perfect data on the addresses and flexibility of all consumers in the market and, thus, can charge individual prices. In all other cases firms have to charge the same price to consumers belonging to one segment and having the same address. We denote the price of firm i to consumers with address x on the segment m when customer data is of quality k as $p_{im}(x, k)$.

The utility of a consumer (x, t) from buying at firm $i = \{A, B\}$ is

$$U_i(p_{im}(x, k), t, x) = v - t\,|x - x_i| - p_{im}(x, k). \tag{1}$$

In equation (1) $v > 0$ denotes the basic utility that is high enough such that the market is always covered in equilibrium. A consumer buys from a firm proposing a higher utility. If a consumer is indifferent between the two products she buys from the closer firm. The game unfolds as

[13] In our examples of smartphone advertising or post advertising by retailers, the physical location of a consumers is known to the firms, while consumers' sensitivity to prices can be measured only with some degree of accuracy. Firms can acquire the latter data from marketing firms, such as Axciom Corporation. Axciom is a marketing firm that operates the largest customer base in the world with data on 500 million active consumers worldwide. The database includes households' mailing address, demographics, buying habits etc. Among its customers are eight of the top ten telecom/media companies and seven of the top ten retailers in the U.S. (see http://www.acxiom.com/site-assets/factsheet/factsheet-multichannel-marketing-database/). Among others, Axciom provides solutions for addressable advertising.

[14] In our analysis we assume that data on consumer flexibility is exogenously given and can be acquired by the firms. In practice, marketing companies (like Axciom) posses large databases which includes data on a large share of consumers in the market. In our analysis we hence abstract from the question how this data is collected. For instance, Conitzer, Taylor and Wagman, 2012, consider a monopolist who can track consumer purchases, while consumers can keep their anonymity at a cost.

follows.

Stage 1 (Customer data acquisition). Firms observe the exogenously given quality of customer data on flexibility, k, and decide independently whether to acquire this data.

Stage 2 (Competition). First, firms independently and simultaneously choose regular prices for each address x. Subsequently the firm(s) with customer flexibility data issues (issue) discounts to consumers in different flexibility segments.

The timing of the competition stage corresponds is consistent with a large body of literature on competitive price discrimination where firms make their targeted offers after setting regular prices (e.g., Thisse and Vives, 1988; Shaffer and Zhang, 1995, 2002; Liu and Serfes, 2004, 2006). It reflects the observation that discounts issued to finer consumer groups can be changed easier than prices targeted at broader consumer groups.[15] Moreover, if firms decide simultaneously in regular prices and discounts, no equilibrium in pure strategies exists.

3 Equilibrium Analysis

We solve the game backwards and start with the competition stage where firms choose prices taking their decisions in the data acquisition stage as given. Two subgames can emerge in the second stage. In the *symmetric subgame* both firms hold customer flexibility data.[16] In the *asymmetric subgame* only one firm holds data on consumer flexibility. We analyze each subgame and compare profits to derive incentives to acquire customer flexibility data in the first stage.

Symmetric subgame: Both firms hold data on consumer flexibility. When both firms hold data on consumer flexibility they can identify each consumer as belonging to one of the flexibility segments and can charge different prices to different segments. As firms are symmetric, we focus our discussion only on the turf of firm A. Consider an address $x < 1/2$ and an arbitrary segment m. Under prices $p_{Am}(x,k)$ and $p_{Bm}(x,k)$ the transportation cost parameter of the consumer indifferent between buying from firms A and B is

$$\widetilde{t}_m(x,k) = \frac{p_{Am}(x,k) - p_{Bm}(x,k)}{1-2x}, \text{ provided } \widetilde{t}_m(x,k) \in \left[\underline{t}^m(k); \overline{t}^m(k)\right].$$

[15] We observe in many markets that regular prices change less frequently than coupon discounts. For example, www.hutfans.com (retrieved on January 26, 2013) mentions that Pizza Hut discount coupons tend to "change often." This is some indication that regular prices involve a higher level of commitment from the firm than targeted discounts. Our timing captures this by allowing regular prices to be set before discounts.

[16] If $k = 0$, this subgame is equivalent to neither of the firms holding customer flexibility data.

On segment m firm A (B) serves consumers with high (low) transportation cost parameters, i.e., those having $t \geq \widetilde{t}_m(x,k)$ ($t < \widetilde{t}_m(x,k)$). Then for any address x and any segment m under data quality k firm A maximizes the expected profit

$$E\left[\Pi_{Am}(x,k)|x < 1/2\right] = p_{Am}(x,k)\Pr\left\{t \geq \widetilde{t}_m(x,k)\right\}$$

by choosing the price function $p_{Am}(x,k)$. Firm B maximizes the expected profit

$$E\left[\Pi_{Bm}(x,k)|x < 1/2\right] = p_{Bm}(x,k)\Pr\left\{t < \widetilde{t}_m(x,k)\right\}$$

by choosing the price function $p_{Bm}(x,k)$. The following proposition states equilibrium prices and profits depending on the quality of the customer flexibility data.

Proposition 1. (Symmetric subgame.) *Assume that both firms hold customer flexibility data of quality k. Equilibrium prices, demand regions and profits depend on data quality and consumer heterogeneity in flexibility as given in Table 1.*

Proof. See Appendix.

Table 1: Equilibrium prices, demand regions on firm i's turf and equilibrium profits in the symmetric subgame.

Consumer heterogeneity in flexibility	$p^*_{im}(x,k)$	$p^*_{jm}(x,k)$	Consumers served by firm i	$\Pi_A^{A,A} = \Pi_B^{A,A}$
Relatively differentiated$^{(*)}$	$m=1$: $\frac{2\bar{t}\|1-2x\|}{3\times 2^k}$ $m \geq 2$: $\underline{t}^m(k)\,\|1-2x\|$	$m=1$: $\frac{\bar{t}\|1-2x\|}{3\times 2^k}$ $m \geq 2$: 0	$t \geq \frac{\bar{t}}{3*2^k}$	$\left[\frac{10-9\times 2^k}{9\times 2^{3+2k}} + \frac{1}{8}\right]\bar{t}$
Relatively homogeneous$^{(**)}$	$\underline{t}^m(k)\,\|1-2x\|$	0	All	$\left[\frac{l+1}{8} - \frac{l-1}{2^{3+k}}\right]\underline{t}$
$^{(*)}$ $\underline{t} = 0$; $^{(**)}$ $\underline{t} > 0$ and $l \leq 2$				

The difference in equilibria in the two versions of our model (with relatively homogeneous and differentiated consumers) is driven by the difference in the best-response functions of a firm on its turf. Precisely, it is crucial whether a firm follows a *market-sharing* or a *monopolization strategy* on its turf. To see why, it is instructive to consider a special case with $k = 0$ as benchmark. In this case firms do not possess data on consumer flexibility and can tailor prices based on consumer addresses only. Since in this case firms are symmetric we consider only the turf of firm A. If consumers are relatively differentiated in flexibility, the best-response function of firm A on its own turf (i.e., $x < 1/2$) is

$$p_A(x, p_B|\, x < 1/2) = \begin{cases} p_B & \text{if} \quad p_B \geq \bar{t}(1-2x) \\ \left[p_B + \bar{t}(1-2x)\right]/2 & \text{if} \quad p_B < \bar{t}(1-2x). \end{cases} \tag{2}$$

Since the most flexible consumers can switch brands costlessly ($\underline{t} = 0$), for firm A to attract all consumers with a given address it has to charge a price that is at least as low as that of the rival. As the best-response function (2) shows, it is optimal for firm A to *monopolize* a given address on its turf by attracting all consumers with that address only if the price of the rival is sufficiently high, with $p_B \geq \bar{t}(1-2x)$. Otherwise, firm A prefers to let the rival attract some consumers on its turf. It charges a price above that of the rival and loses the most flexible consumers. We say that firm A follows a market-sharing strategy: Its decision whether to serve all consumers with a given address on its turf depends on the rival's price. In equilibrium both firms charge positive prices. The less preferred firm B charges a relatively low price in order to attract consumers, which makes it unprofitable for firm A to monopolize any address on its own turf. As a result, for all addresses on its own turf firm A serves only the most loyal consumers while firm B attracts the least loyal ones. We now compare this with the case of relatively homogeneous consumers.

In the version of our model with relatively homogeneous consumers, the best-response function of firm A is

$$p_A(x, p_B|\, x < 1/2) = p_B + \underline{t}(1-2x) \text{ for any } p_B. \tag{3}$$

As equation (3) shows, in contrast to the case of relatively differentiated consumers the optimal strategy of firm A on every address of its turf is to serve *all* consumers, independently of firm B's price. We say that in this case firm A follows a *monopolization strategy.* With homogenous consumers it suffices for firm A to slightly reduce its price targeted at the most loyal consumers to attract all consumers with a given address. The monopolization strategy of firm A forces the rival to charge the price of zero in equilibrium, while all consumers on firm A's turf buy from their most preferred firm. Figure 1 shows equilibrium demand regions in both versions of our model.

How does the equilibrium change when the quality of customer flexibility data improves? In literature on competitive price discrimination one usually distinguishes between two effects.

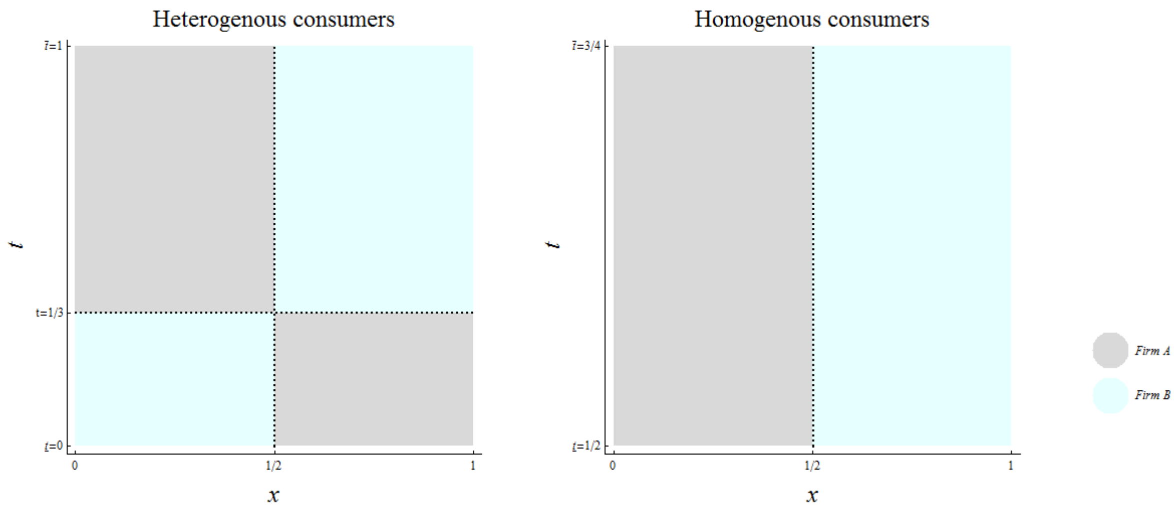

Figure 1: Equilibrium demand regions for $k = 0$. For the example we took $\bar{t} = 1$ ($\bar{t} = 3/4$) and $\underline{t} = 0$ ($\underline{t} = 1/2$) for the case of relatively heterogenous (homogenous) consumers.

Data of better quality allows firms to potentially extract more rents from consumers. To this we refer as the rent-extraction effect. Data quality may also change the intensity of competition between the firms, to which we refer as competition effect.

We consider first the case of relatively homogeneous consumers. Regardless of customer data quality consumers remain relatively homogeneous on every segment such that the firms always resort to the monopolization strategy on their turfs.[17] In equilibrium each firm targets the most flexible consumers on every segment for any address on its own turf while the rival is forced to reduce the price to zero. The improvement of customer data quality results in a situation in which every consumer is charged a (weakly) higher price. This is because each consumer is now allocated to a segment where the least loyal consumer becomes (weakly) less flexible. As a result each firm's profits unambiguously increase. If consumers are relatively homogenous in flexibility an increase in flexibility data quality improves the ability of firms to extract rents from consumers, while the competition effect is absent.

Consider now the version with relatively differentiated consumers. As we show, unlike with homogenous consumers in this case the pricing strategies of a firm on its turf depend crucially on data quality. For any quality of customer data, consumers remain relatively differentiated only on the segment $m = 1$, on all other segments they become relatively homogeneous. If

[17] Note that given $\underline{t} > 0$ and $l \leq 2$, for any m and k it holds that $l^m(k) \leq 2$.

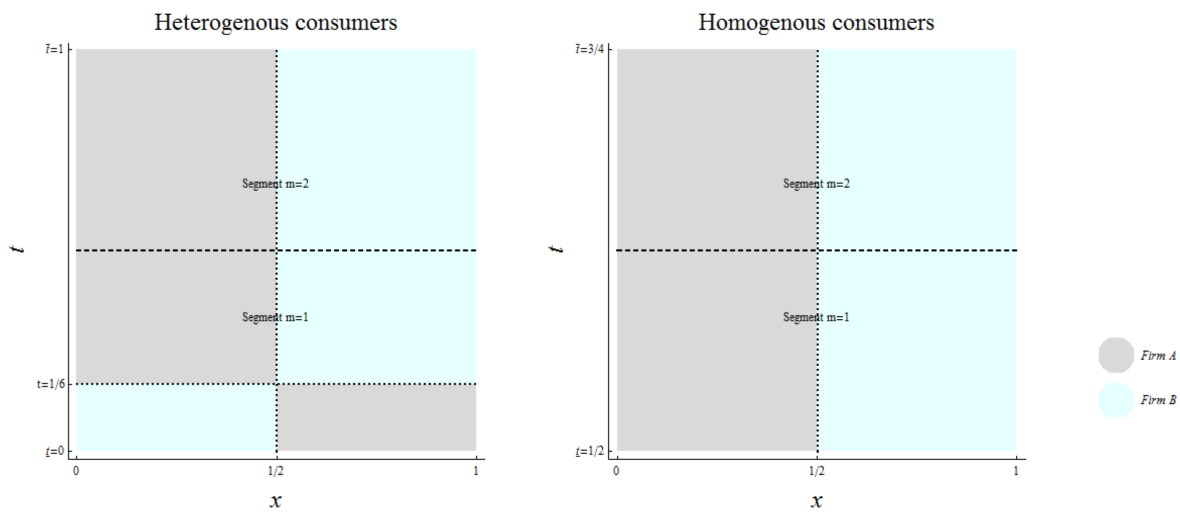

Figure 2: Equilibrium demand regions for $k = 1$. For the example we took $\bar{t} = 1$ ($\bar{t} = 3/4$) and $\underline{t} = 0$ ($\underline{t} = 1/2$) for the case of relatively heterogenous (homogenous) consumers.

$k = 0$, firms pursue a market-sharing strategy on their turfs. However, as k increases to $k = 1$, on the segment $m = 2$ firms switch to the monopolization strategy but on the segment $m = 1$ they maintain the market-sharing strategy. As a result, for any address on a firm's turf prices on both segments decrease compared to the uniform price. On the segment $m = 1$ consumers become less loyal to a firm, and on the segment $m = 2$ the rival responds aggressively to the firm's monopolization strategy and charges a price of zero. Lower prices result in lower profits. However, when k increases further, profits start to increase. The reason is that, apart from the former segment $m = 1$, a firm sticks to the monopolization strategy on all other segments where equilibrium prices increase. The prices on the former segment $m = 1$ decrease following the logic described above. Since the latter segment comprises (weakly) less than half of all consumers with a given address for any $k \geq 1$, the negative profit effect on that segment is outweighed by the positive profit effect on the other segments, such that a firm's profits increase. Figure 2 shows the equilibrium demand regions for relatively heterogenous and homogenous consumers for an example with $k = 1$.

We can summarize our results as follows. When consumers are relatively homogeneous, each firm follows the monopolization strategy on its turf, such that the rival charges the price of zero in equilibrium. The improvement in data quality results then only in a positive rent-extraction effect, while the competition effect is absent as the rival cannot go below the price of zero. When consumers are relatively differentiated, each firm follows the market-sharing strategy on its turf, where the rival charges positive prices. The improvement in data quality results in a negative competition effect, and the rival decreases its price to zero on the segments where a firm switches to the monopolization strategy. With a further improvement in data quality, the rent-extraction effect starts to dominate, and profits start to increase. Figure 3 depicts a firm's profit as a function of the customer data quality in the two versions of our model. For the example we use the values ($\underline{t} = 1$, $\bar{t} = 2$) and ($\underline{t} = 0$, $\bar{t} = 1$) for relatively homogeneous and differentiated consumers, respectively.

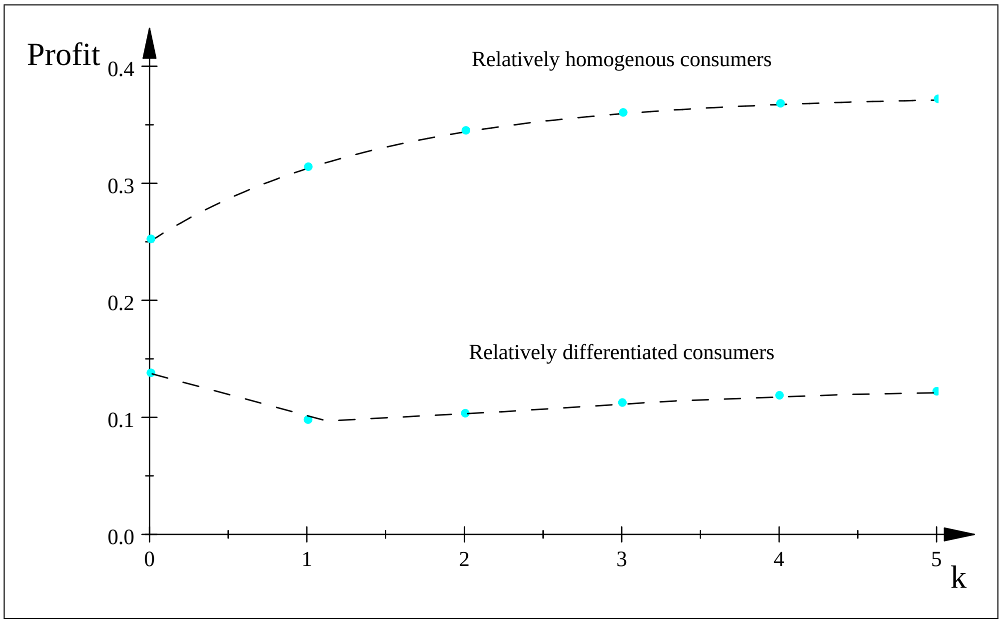

Figure 3: Individual Profits and the Quality of Customer Flexibility Data (symmetric subgame)

So far we restrict our attention to the situation where both firms acquire data on consumer flexibility. In the following we extend our analysis to the asymmetric case in which only one firm acquires customer flexibility data.

Asymmetric subgame: Only one firm holds data on consumer flexibility. We assume without loss of generality that it is firm A that acquires customer flexibility data while firm B is the one without. The latter must offer the same price to all consumers on a given address irrespective of their flexibility. In contrast, firm A can discriminate based on consumer addresses as well as flexibility. The following proposition summarizes our results for the case of relatively homogeneous consumers.

Proposition 2. (Asymmetric subgame with relatively homogenous consumers.) *Assume that consumers are relatively homogeneous and only firm A has data on consumer flexibility. Equilibrium prices, demand regions and profits depend on the parameters k and l as follows:*

i) If $l \leq 3/2$ *and* $k \geq 0$*, then firms charge prices:*

$$p^*_{Am}(x,k) = \begin{cases} \left[1+\frac{(l-1)(m-1)}{2^k}\right](1-2x)\,\underline{t} & \text{if} \quad x \leq \frac{1}{2} \\ 0 & \text{if} \quad x > \frac{1}{2}, \end{cases}$$

$$p^*_{B}(x,k) = \begin{cases} 0 & \text{if} \quad x \leq \frac{1}{2} \\ \underline{t}\,(2x-1) & \text{if} \quad x > \frac{1}{2}, \end{cases}$$

firm A serves consumers with $x \leq 1/2$*, and firms realize profits:*

$$\Pi^{A,NA}_{A}(k) = \frac{(1+l)\,\underline{t}}{8} - \frac{(l-1)\,\underline{t}}{2^{k+3}} \text{ and } \Pi^{A,NA}_{B}(k) = \frac{\underline{t}}{4}.$$

ii) If $3/2 < l \leq 2$ *and* $0 \leq k < \log_2\left[2\,(l-1)\,/(2l-3)\right]$*, then firms charge prices:*

$$p^*_{Am}(x,k) = \begin{cases} \left[1+\frac{(l-1)(m-1)}{2^k}\right]\underline{t}\,(1-2x) & \text{if} \quad x \leq \frac{1}{2} \\ \frac{(2l-3)(2x-1)\underline{t}}{4} & \text{if} \quad x > \frac{1}{2} \;\&\; m=1 \\ 0 & \text{if} \quad x > \frac{1}{2} \;\&\; m>1, \end{cases}$$

$$p^*_{B}(x,k) = \begin{cases} 0 & \text{if} \quad x \leq \frac{1}{2} \\ \frac{(2l-1)(2x-1)\underline{t}}{2} & \text{if} \quad x > \frac{1}{2}, \end{cases}$$

firm A serves consumers with $x \leq 1/2$ *and consumers with* $x > 1/2$ *and* $t \leq (2\bar{t}+\underline{t})/4$*. Firms realize profits*

$$\Pi^{A,NA}_{A}(k) = \frac{\left(12l^2-12l+1\right)\underline{t}}{64\,(l-1)} - \frac{(l-1)\,\underline{t}}{2^{k+3}} \text{ and } \Pi^{A,NA}_{B}(k) = \frac{(2l-\underline{t})^2\,\underline{t}}{32\,(l-1)}.$$

ii) If $3/2 < l \leq 2$ *and* $k \geq \log_2 [2(l-1)/(2l-3)]$*, then firms charge prices*

$$p^*_{Am}(x,k) = \begin{cases} \left[1+\frac{(l-1)(m-1)}{2^k}\right](1-2x)\underline{t} & \text{if} \quad x \leq \frac{1}{2} \\ \frac{(l-1)(2x-1)\underline{t}}{2^{k+1}} & \text{if} \quad x > \frac{1}{2} \ \& \ m=1 \\ 0 & \text{if} \quad x > \frac{1}{2} \ \& \ m>1, \end{cases}$$

$$p^*_B(x,k) = \begin{cases} 0 & \text{if} \quad x \leq \frac{1}{2} \\ \left[1+\frac{l-1}{2^k}\right](2x-1)\underline{t} & \text{if} \quad x > \frac{1}{2}, \end{cases}$$

firm A serves consumers with $x \leq 1/2$ *and consumers with* $x > 1/2$ *and* $t \leq \underline{t} + (\bar{t} - \underline{t})/2^{k+1}$*. Firms realize profits*

$$\Pi_A^{A,NA}(k) = \left[\frac{1+l}{8} - \frac{(l-1)\left(2^{k+1}-1\right)}{2^{2k+4}}\right]\underline{t} \text{ and } \Pi_B^{A,NA}(k) = \left(1+\frac{l-1}{2^k}\right)\left(1-\frac{1}{2^{k+1}}\right)\frac{\underline{t}}{4}.$$

Proof. See Appendix.

For the intuition behind the equilibrium pricing strategies when only firm A has data on flexibility and consumers are relatively homogenous, consider first the turf of firm A. Regardless of the quality of flexibility data available to firm A consumers behave as relatively homogeneous on every segment. In that case even a small reduction of a price targeted at the least flexible consumers in each segment will attract the most flexible consumers in that segment as well. Then, for any price of the rival firm, A adopts a monopolization strategy and targets the most flexible consumers on all segments on any address on its turf. It maintains this strategy regardless of the quality of flexibility data, and its best-response function is

$$p_{Am}(x, k, p_B | \, x < 1/2) = p_B + \underline{t}^m(k)(1-2x), \text{ for any } m, \, k \text{ and } p_B.$$

This aggressive strategy drives firm B's price down to zero on firm A's turf. In equilibrium, firm A serves all consumers on its own turf. As the quality of flexibility data improves (k increases), every consumer is allocated to a segment in which the most flexible consumer has (weakly) higher transportation cost parameters. All consumers then face higher prices as firm A targets the most flexible consumers on each segment on its turf. Better data on flexibility allows firm A to extract higher rents from consumers on its own turf and its profits earned there increase.

Consider now the turf of firm B, who does not hold data on consumer flexibility. For firm B it is profitable to serve all consumers on its turf only if they are strongly homogeneous, with $l \leq 3/2$. For any $x > 1/2$ on segment m the best-response function of firm A is

$$p_{Am}(x, k, p_B | \, x > 1/2) = \begin{cases} 0 & \text{if} \quad p_B \leq a \\ \left[p_B - \underline{t}^m(k)\,(2x-1)\right]/2 & \text{if} \quad a < p_B < b \\ p_B - \underline{t}^m(k)(2x-1) & \text{if} \quad p_B \geq b, \end{cases} \tag{4}$$

where $a = \underline{t}^m(k)\,(2x-1)$ and $b = \left[2\overline{t}^m(k) - \underline{t}^m(k)\right](2x-1)$. As expression (4) shows, the price of firm A on any segment of the rival's turf increases in the uniform price of firm B (provided p_B is not too small, in which case $p_A = 0$). Assume that firm B targets the most flexible consumer for some arbitrary address, x, on its own turf. Would it like to increase its price when facing the reaction function stated in expression (4)? When the uniform price of firm B increases slightly, the price of firm A in segment $m = 1$ goes up too. This makes it more attractive for firm B to increase its price above the one targeted at the most flexible consumer compared to the symmetric subgame where firms charge prices simultaneously. Firm B refrains from a price increase only if consumers are strongly homogeneous, in which case even a small price increase results in the loss of a relatively large market share. In the opposite case ($l > 3/2$), firm B prefers to lose the most flexible consumers to the rival and charge a higher price. For any data quality firm B loses consumers only on the segment $m = 1$.

How does the equilibrium on the turf of firm B change when k increases? If consumers are strongly homogeneous ($l \leq 3/2$), irrespective of data quality firm B targets the most flexible consumer on any address leaving no scope for firm A to attract away some of its consumers even with perfect customer data. This is due to the fact that the best-response strategy of firm A on the segment $m = 1$ does not change with data improvement because $\underline{t}^1(k) = \underline{t}$ for any k, and on any segment firm A targets the most flexible consumers. Then the increase in k leaves the profit of firm B unchanged, and firm A makes no profit on the turf of firm B, even with perfect customer data.

If consumers are weakly homogeneous ($l > 3/2$) firm B loses some of the more flexible consumers on segment $m = 1$. When data quality is low ($k < \log_2\left[(l-1)/(l-3/2)\right]$), with an increase in k market shares of firm A on the turf of firm B do not increase. This is the case because firm B targets consumers on segment $m = 1$, and improved data does not allow firm A

to compete better on that segment since prices there are already low. Then market shares and profits on the turf of firm B do not change with better data quality.

If customer data quality is high ($k \geq \log_2 [(l-1)/(l-3/2)]$), with finer consumer segmentation, firm B targets consumers on segment $m = 2$ (and not on $m = 1$ as before). Firm A reduces its price to those consumers, knowing that they are loyal to firm B. To retain these consumers, firm B acts aggressively and reduces its price so much that it actually expands its market share. The reason for this is as follows. With an increase in k, firm B targets segment $m = 2$, i.e. it prices so that it attracts those consumers. Then by reducing its price firm B is able to gain consumers on the segments $m = 1$ and $m = 2$ alike. On every segment firm A targets the most flexible consumers of firm B such that firm B can gain markets shares among the most loyal consumers of both segments. This makes the incentives of firm B to decrease its price stronger than before, when charging a lower price would have only gained consumers on the segment $m = 1$. However, the negative price effect dominates the positive market-share effect, and the profits of firm B decrease. The profits of firm A on the turf of firm B decrease as well as it has to reduce the price on segment $m = 1$, while its market share also gets smaller. Since the profits of firm A on the rival's turf constitute only a small share of its total profits, the latter undoubtedly increase with the improvement in customer data.

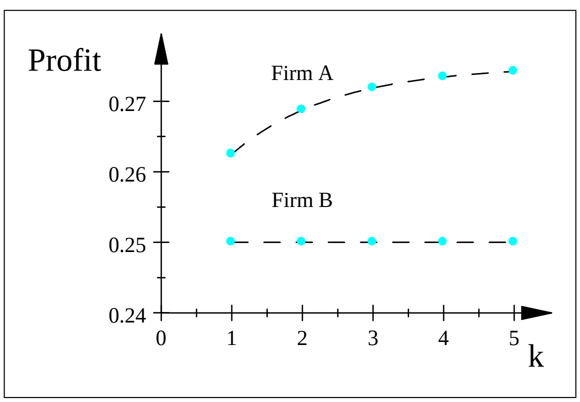

Figure 4a: $l \leq \frac{3}{2}$ with $\underline{t} = 1$, $\bar{t} = 1.2$

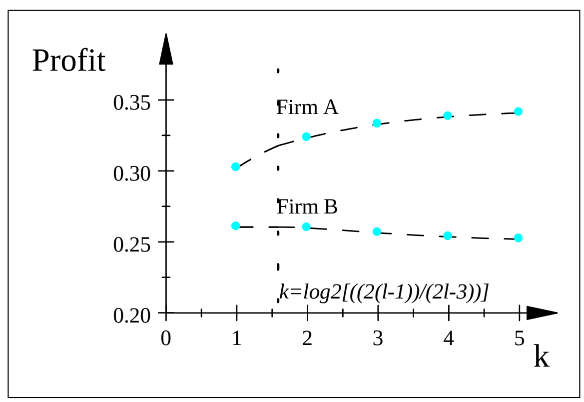

Figure 4b: $\frac{3}{2} < l \leq 2$ with $\underline{t} = 1$, $\bar{t} = 1.75$

Individual Profits and the Quality of Customer Flexibility Data (asymmetric subgame, homogenous consumers - only firm A has data on consumer flexibility

Figures 4a and 4b depict the profits depending on data quality for an example with relatively homogenous consumers. The left figure (4a) illustrates an example where $l \leq 3/2$, while in the right figure (4b) $\frac{3}{2} < l \leq 2$. We summarize our results as follows. When consumers are relatively homogeneous, for any quality of customer data firm A follows a monopolization strategy on every segment on its turf, such that for any $x \leq 1/2$ firm B charges the price of zero in equilibrium. This leaves no scope for additional competition from firm B and, on its own turf, firm A enjoys only the positive rent-extraction effect. Its profits earned there increase monotonically with the quality of customer flexibility data. The profits firm A make on the rival's turf may, however, decrease (if consumers are weakly homogeneous and k is large enough). Firm B prices more aggressively on its own turf to protect its market shares when the quality of customer data firm A holds improves. Since the profits on the turf of firm B constitute only a small share of the total profits of firm A, the latter unambiguously increase with the improvement in data quality.

We now turn to the case of relatively differentiated consumers. The following proposition describes the equilibrium in the asymmetric subgame.

Proposition 3. (Asymmetric subgame with relatively differentiated consumers.) *If consumers are relatively heterogenous and only firm A has data on consumer flexibility, then equilibrium prices, demand regions and profits are as given in Table 2.*

Proof. See Appendix.

Although firm A has information advantage over the rival in an asymmetric subgame, it does not serve all consumers on its turf when consumers are relatively differentiated. Precisely, as in the symmetric subgame it loses consumers on the segment $m = 1$. Different from all other segments where consumers are relatively homogeneous and where firm A adopts a monopolization strategy, on the segment $m = 1$ consumers are always relatively differentiated, because there are consumers who switch costlessly. Firm A therefore resorts to a market-sharing strategy. For any data quality it is profitable for firm A to charge a relatively high price on the segment $m = 1$ and lose the most flexible consumers. The profits of firm A on its turf monotonically decrease with the improvement in data quality. When k gets larger, the most loyal consumers on the segment $m = 1$ become more flexible, and for any price of the rival firm A decreases its price on that segment. Firm B then decreases its price too. The uniform price of firm B in turn puts pressure on the prices of firm A on all the segments. As a result, although firm A can better price discriminate among consumers with the improvement in data quality, the profits of firm A on its turf monotonically decrease when k gets larger due to a strong negative competition effect. This result is different from the symmetric subgame where on its own turf the profits of firm A first decrease and then increase. This difference is driven by the strength of the competition effect in the two cases. In the symmetric subgame where firm B can distinguish among flexibility segments, it charges the price of zero on any segment $m \geq 1$ on the turf of firm A. As firm B cannot go below the price of zero, the negative competition effect vanishes on those segments, and the profits of firm A exhibit a U -shaped relationship with k. In the asymmetric subgame, where firm B cannot distinguish among flexibility segments the latter reduces its price when k gets larger to target the most flexible consumers on A's turf on segment $m = 1$. This in turn gives rise to a competition effect that is present on all segments. The profits of firm B on the turf of firm A decrease monotonically with the improvement in data quality: Firm B is forced to reduce its price, while it at the same time serves less consumers.

Table 2: Equilibrium prices, demand regions and profits in the asymmetric subgame. The case of relatively differentiated consumers.

$k = 0$
$p^*_{Am}(x,k) = \begin{cases} \frac{3(1-2x)\bar{t}}{4} & \text{if } x \leq \frac{1}{2} \\ \frac{(2x-1)\bar{t}}{2} & \text{if } x > \frac{1}{2} \end{cases} \qquad p^*_{Bm}(x) = \begin{cases} \frac{(1-2x)\bar{t}}{2} & \text{if } x \leq \frac{1}{2} \\ (2x-1)\,\bar{t} & \text{if } x > \frac{1}{2} \end{cases}$
Consumers served by firm A: $\left[\begin{array}{lll} x \leq \frac{1}{2} & \& & t \geq \frac{\bar{t}}{4} \\ x > \frac{1}{2} & \& & t < \frac{\bar{t}}{2} \end{array} \right.$
$\Pi_A^{A,NA}(0) = \frac{13\bar{t}}{64} \quad \Pi_B^{A,NA}(0) = \frac{5\bar{t}}{32}$
$k \geq 1$
$p^*_A(m,x,k) = \begin{cases} \frac{3(1-2x)\bar{t}}{2^{k+2}} & \text{if } x \leq \frac{1}{2} \;\&\; m = 1 \\ \underline{t}^m(k)\,(1-2x) + p^*_{Bm}(x) & \text{if } x \leq \frac{1}{2} \;\&\; m > 1 \\ p^*_B(x) - \bar{t}^m(k)\,(2x-1) & \text{if } x > \frac{1}{2} \;\&\; m < 2^{k-1} \\ \frac{5\bar{t}(2x-1)}{2^{k+3}} & \text{if } x > \frac{1}{2} \;\&\; m = 2^{k-1} \\ \frac{\bar{t}(2x-1)}{2^{k+3}} & \text{if } x > \frac{1}{2} \;\&\; m = 2^{k-1}+1 \\ 0 & \text{if } x > \frac{1}{2} \;\&\; m > 2^{k-1}+1 \end{cases}$ $p^*_B(x) = \begin{cases} \frac{\bar{t}(1-2x)}{2^{k+1}} & \text{if } x \leq \frac{1}{2} \\ \frac{\bar{t}}{2}\left(1+\frac{1}{2^{k+1}}\right)(2x-1) & \text{if } x > \frac{1}{2} \end{cases}$
Consumers served by firm A: $\left[\begin{array}{lll} x < \frac{1}{2} & \& & t \geq \frac{\bar{t}}{2^{k+2}} \\ x \geq \frac{1}{2} & \& & \frac{\bar{t}}{2} < t < \frac{\bar{t}}{2^k}\left(\frac{2^k}{2} + \frac{1}{8}\right) \\ x \geq \frac{1}{2} & \& & 0 \leq t < \frac{\bar{t}}{2^k}\left(\frac{2^k}{2} - \frac{3}{8}\right) \end{array} \right.$
$\Pi_A^{A,NA}(k) = \frac{\bar{t}}{32}\left(5 - \frac{1}{2^k} + \frac{7}{2^{2k+2}}\right) \quad \Pi_B^{A,NA}(k) = \frac{\bar{t}}{16}\left(1 + \frac{1}{2^k} + \frac{1}{2^{2k+2}}\right)$

On the turf of firm B firm A serves half of the consumers when $k = 0$, and slightly less than half of all consumers when $k \geq 1$. This result is very different from the symmetric subgame where firm A serves consumers only on segment $m = 1$ on the rival's turf. Firm A can gain more consumers in the asymmetric subgame due to its informational advantage compared to the rival. Anticipating the informational advantage of firm A, firm B reduces its price as data quality (k)

increases to protect market shares. This competition effect harms firm A's profit. On the other hand, firm A is able to extract more rents from almost the half of the most flexible consumers on the rival's turf, which constitutes a positive rent-extraction effect. The profits of firm A first decrease when k increases from $k = 0$ to $k = 1$, then increase, however, they never reach the initial level at $k = 0$. When the quality of customer data is high enough ($k = 1$), the rent-extraction effect starts to dominate. On the turf of firm A, in contrast, the negative competition effect always dominates. As firm B can distinguish among its own loyal consumers and those of the rival, it prices more aggressively on the rival's turf where its price approaches zero when data quality becomes perfect, while on its own turf firm B's price approaches $\bar{t}(2x - 1)/2$. Firm B's profits earned on its own turf decrease monotonically with the improvement in data quality. It is forced into a downward spiral where it must charge lower prices while it still loses market shares.

Figure 5 shows one example the combined effect of data quality on profits on the two turfs ($\bar{t} = 1$). The profits of firm B monotonically decrease with the improvement in data quality. The profits of firm A in turn exhibit a U-shaped relationship with data quality, exactly as in the symmetric subgame (compare with Figure 3).

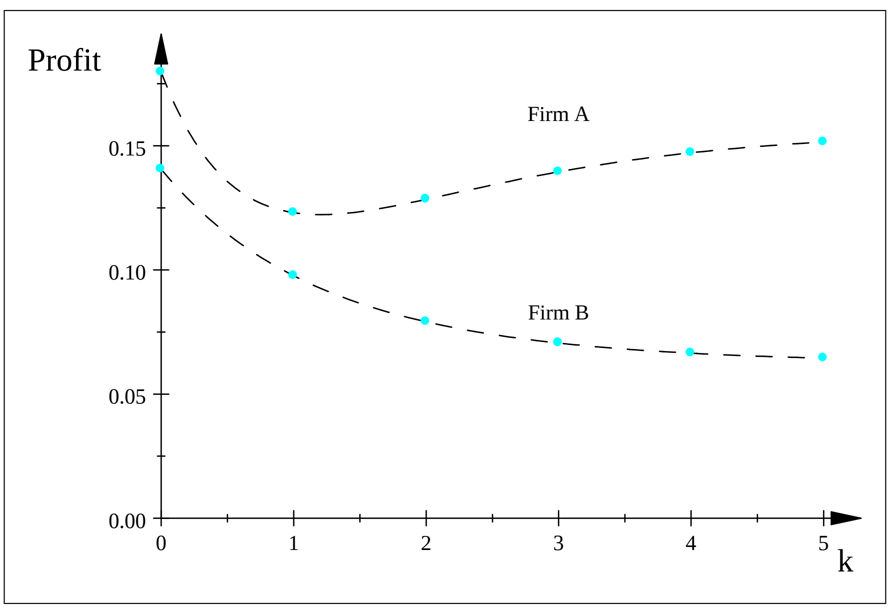

Figure 5: Individual Profits and the Quality of Customer Flexibility Data (asymmetric subgame, heterogenous consumers - only firm A has data on consumer flexibility, $\underline{t} = 0$, $\bar{t} = 1$)

We now proceed with the analysis of data acquisition incentives in Stage 1 of the game.

Customer-data acquisition. In this subsection we analyze firms' incentives to acquire customer flexibility data in the first stage of the game and its welfare implications. In particular, we assume that firms can obtain data on the flexibility of all consumers in the market with an exogenously given precision $k \geq 1$. For simplicity, we assume that the data can be acquired free of charge. Then data acquisition incentives are driven purely by the profits realized in the resulting competitive scenarios. The following proposition summarizes the main results, depending on consumer heterogeneity in flexibility.

Proposition 4. (Customer data acquisition.) *Firms' decisions to acquire customer data depend on consumer heterogeneity in flexibility as follows.*
i) If consumers are relatively homogeneous in flexibility, for any $k \geq 1$ there is a unique Nash equilibrium (in dominant strategies) in Stage 1 where both firms acquire customer flexibility data. Both firms are strictly better off compared to the case where none of the firms holds customer flexibility data.
ii) If consumers are relatively differentiated in flexibility, there are two Nash equilibria where only one of the firms acquires customer data if $k = 1$. If $k \geq 2$ a prisoners' dilemma emerges: There is a unique Nash equilibrium (in dominant strategies) where both firms acquire customer flexibility data, making them worse-off.

Proof. See Appendix.

In the version of our model with relatively homogeneous consumers in the absence of customer flexibility data every firm serves only consumers on its own turf and targets for each address the least loyal consumer. If one of the firms acquires customer data, it gains consumers on the rival's turf (if $l > 3/2$) and is able to extract more rents from consumers on its own turf. The unilateral acquisition of customer data is then always profitable. The best response to the rival acquiring customer flexibility data is to do so as well. In that case a firm gains consumers on the own turf (if $l > 3/2$) and can extract more rents from them. In equilibrium both firms acquire data and their profits increase.

With relatively homogeneous consumers, data acquisition is not hampered by a negative competition effect and the positive rent-extraction effect dominates. Then the profits of a firm with customer flexibility data are always higher than in the absence of such data irrespective of the rival's data acquisition decision. However, when consumers are relatively differentiated a prisoners' dilemma emerges when the quality of customer flexibility data is sufficiently high:

$k \geq 2$. Firm always have a unilateral incentive to acquire customer data. Moreover, a firm prefers to acquire data given that the rival holds data if $k \geq 2$. We next analyze the effect of firms' equilibrium acquisition decisions on their profits, consumer surplus and social welfare.

Proposition 5. (Profit and welfare effects of customer data acquisition.) *The effect of data acquisition on profits, social welfare and consumer surplus depends on consumer heterogeneity in flexibility.*

i) If consumers are relatively homogeneous, for any $k \geq 0$ the profits of firm $i = A, B$, consumer surplus and social welfare are respectively $\Pi_i^*(k) = \underline{t}/4 + \left(\bar{t} - \underline{t}\right)\left[1/8 - 1/\left(2^{3+k}\right)\right]$, $CS(k) = v - 3(\bar{t} + \underline{t})/8 + (\bar{t} - \underline{t})/2^{k+2}$ and $SW = v - \left(\bar{t} + \underline{t}\right)/8$.

ii) If consumers are relatively differentiated, for $k = 0$ firm profits, consumer surplus and social welfare are $\Pi_A^* = \Pi_B^* = 5\bar{t}/36$, $CS = v - 31\bar{t}/72$ and $SW = v - 11\bar{t}/72$, respectively. If $k = 1$, then $\Pi_A^* = 79\bar{t}/512$, $\Pi_B^* = 27\bar{t}/256$, $CS = v - 417\bar{t}/1024$ and $SW = v - 151\bar{t}/1024$. For $k \geq 2$, the profits of firm $i = A, B$, consumer surplus and social welfare are respectively $\Pi_i^*(k) = 5\bar{t}/\left(9 \times 2^{2(1+k)}\right) + \bar{t}\left(1/8 - 1/2^{3+k}\right)$, $CS(k) = v - 11\bar{t}/\left(9 \times 2^{2k+2}\right) + \bar{t}\left(1/2^{k-1} - 3\right)/8$ and $SW(k) = v - \bar{t}\left[1 + 1/\left(9 \times 2^{2k-1}\right)\right]/8$.

Proof. See Appendix.

When consumers are relatively homogeneous, in equilibrium both firms acquire customer flexibility data independently of the data quality. For any $k \geq 0$, each firm follows on its turf a monopolization strategy: Independently of the rival's price for any address on its turf a firm wants to serve all consumers. As consumers are relatively homogeneous, even a small decrease of a price targeted at the most flexible consumers allows them to attract all consumers. The monopolization strategy of a firm forces the rival to price very aggressively and reduce the price to zero on the rival's turf. This leaves no scope for more competition as data quality improves, because the rival's prices on a firm's turf are already zero at $k = 0$. Firms then enjoy the rent extraction effect of better data on their turfs. As a result, each firm's profits increase monotonically in k. Moreover, for any $k \geq 0$ firms serve all consumers on their own turfs in equilibrium, which maximizes social welfare. As social welfare remains unchanged with improvements in data quality, the increase in profits must go hand in hand with a reduction in consumer surplus. We conclude that when consumers are relatively homogeneous in flexibility, improvement in data quality implies higher profits to the firms, is neutral to social welfare and detrimental to consumer surplus.

When consumers are relatively differentiated in flexibility, in the absence of customer flexibility data both firms follow a market-sharing strategy on their turfs. They serve all consumers with a given address only if the rival's price is sufficiently high. Then in equilibrium a firm serves the less flexible consumers on its turf, leaving the more flexible ones for the rival. With customer flexibility data each firm prices more aggressively the most flexible consumers of the rival. This constitutes a negative competition effect. When data quality is low ($k = 1$), the negative competition effect dominates the positive rent-extraction effect, and a firm does not acquire data if the rival holds it. When the quality of customer data improves ($k \geq 2$), the rent-extraction effect becomes strong enough such a firm's optimal strategy is to acquire data when the rival has it. With further improvement in customer data firms' profits monotonically increase because firms are able to extract more rents from consumers. However, firms are best-off in the absence of customer flexibility data. If $k \geq 2$, social welfare monotonically increases and is always higher than social welfare in the absence of customer data. The improvement in the customer data quality allows each firm to better target its loyal consumers and its market share among the own loyal consumers increases. As a result, consumer transportation costs decrease and social welfare increases. The effect of the improvement in the quality of customer flexibility data on consumer surplus is different. Although consumer transportation costs decrease, the improved ability of the firms to extract rents from consumers makes them pay higher prices on average, such that consumer surplus monotonically decreases with an increase in k. However, for any $k \geq 2$, consumer surplus is higher than in the absence of customer flexibility data. The negative competition effect, induced by better targeting, is so strong that consumers are always better-off when firms acquire customer flexibility data compared to the case when $k = 0$.

4 Comparison with Related Literature

In this section we discuss our results in detail in light of some of the closest related literature. The research on competitive price discrimination often resorts to the concepts of *best-response symmetry* and *best-response asymmetry* introduced by Corts (1998) to explain the effect of competitive price discrimination on equilibrium prices and profits.[18] We find this concept particularly helpful to create more clarity about the forces at work in our model. We illustrate this

[18] In the terminology of Corts (1998), the market exhibits best response asymmetry when the *strong* market of one firm is the *weak* market of the other. A market is said to be *strong* if compared to uniform pricing a firm wishes to increase its price there if it can discriminate while it is said to be *weak* if the opposite holds.

on Proposition 1 (Symmetric subgame). When both firms hold data on flexibility and the quality of this data improves by one step on parameter k, each previously existing flexibility segment is divided into two. To predict the change in equilibrium prices on any segment following an increase in k, we check whether the best-response functions on the two new segments exhibit best-response symmetry or asymmetry. If for any price of the rival a firm charges a higher price on one segment than on the other, under best-response symmetry the rival should do the same. In all other cases best-response asymmetry holds. It can show that as data quality improves and consequently each segment is split into two, best-response functions exhibit asymmetry on the new segments. To see why this is the case consider any segment on firm A's turf. When this segment is divided into two further segments as data quality improves by one level, the less flexible newly created segment contains consumers who are more *loyal* to firm A than consumers on the more flexible new segment. Firm A prices more aggressively on the more flexible segment while firm B does the opposite in order to attract the more loyal consumers of firm A. The two firms approach the two new segments asymmetrically.

Corts (1998) argues that best-response asymmetry is a necessary condition for price discrimination to have an unambiguous effect on equilibrium prices and profits. However, he does not further specify under which conditions equilibrium prices would decrease and when they would increase. Our analysis shows that when consumers are relatively homogeneous on a given segment on a firm's turf, data quality improvement leads to an increase in equilibrium prices on the new segments with firms maintaining a monopolization strategy on those segments. In contrast, when consumers are relatively differentiated on a given segment, data quality improvement results in lower equilibrium prices on the new segments that arise. In that case on the less flexible new segment the firm to which the turf belongs switches to the monopolization strategy and sticks to the market-sharing strategy on the more flexible new segment. Our results extend Corts' analysis by specifying conditions under which best-response asymmetry results in lower and higher equilibrium prices and profits.

Our model is closely related to Liu and Serfes (2004, in the following: LS). In their article consumers are only differentiated in locations, and firms may acquire data on consumer locations that is imperfect. Better data allows firms to increase the number of location segments (k) over which they identify consumers. The authors show that when the quality of customer data improves, profits first decrease till $k = 2$, and then start to increase. The model of LS is similar to the version of our model with relatively differentiated consumers as it also has a consumer (with address $x = 1/2$) who can switch brands costlessly. Assuming sufficiently high data quality ($k \geq 2$) one can show that, in LS, firm A follows a monopolization strategy on the segments $m \leq 2^{k-1} - 1$; i.e., on all the segments on its turf apart from $m = 2^{k-1}$, where firm A follows a market-sharing strategy. When k increases, firm A sticks to the monopolization strategy on all the segments on its turf where it already follows a monopolization strategy, such that prices and profits increase. On the segment $m = 2^{k-1}$, where firm A pursues a market-sharing strategy, as k increases equilibrium prices and profits decrease. When $k = 2$, firm A follows a monopolization strategy only on the segment $m = 1$, which contains half of the consumers on its turf. As in our model, in LS profits start to increase when a firm maintains the monopolization strategy on at least half of the segments on its turf affecting half of the consumers there.[19] However, the change in profits following the improvement in data quality in the version with relatively homogeneous consumers is very different from the results of LS.

It is particularly worth highlighting the similarity and the difference of our results in the asymmetric subgame with relatively differentiated consumers with those obtained in LS. Both in our case and in LS the profits of firm A (holding more data) exhibit a U-shaped relationship with data quality. However, when $k \to \infty$, the profit of firm A in LS approaches a profit level higher than at $k = 0$, while in our case they approach the profit level which is lower than the initial level. This difference is driven by the fact that in our model both firms hold perfect data on consumer addresses, and firm B can always distinguish its own loyal consumers from those of the rival. On the rival's turf firm B follows a very aggressive strategy such that its price approaches zero when $k \to \infty$, and the negative competition effect on firm A's profits always dominates on its turf. On its own turf, the price of firm B decreases, but approaches some positive value because firm B aims to extract rents from its least flexible loyal consumers, and the negative competition effect is not that strong as on the turf of firm A. However, the profits of firm A on that turf cannot recover up to the initial level at $k = 0$, because the rent-extraction effect is not that strong as firm A collects rents from the loyal consumers of the rival. In LS firm

[19] The difference in the value of k for which profits are minimal in Liu and Serfes ($k = 2$) and in our analysis ($k = 1$) is driven by the fact that in Liu and Serfes firms have perfect data on consumer flexibility but not on addresses while in our model it is the other way around. When $k = 0$ in our analysis a firm can distinguish its loyal consumers from those of the rival, which is the case in Liu and Serfes only when $k = 1$. With $k = 1$ in our analysis a firm can distinguish the more loyal from the less loyal consumers, such that it follows a monopolization strategy among the former consumers and a market-sharing strategy among the latter. In Liu and Serfes this is the case only when k reaches 2.

B cannot distinguish among its own loyal consumers and those of the rival. It then charges a price which decreases in data quality, but approaches some positive value when $k \to \infty$ as firm B aims to extract rents from its loyal consumers , such that the negative competition effect is not that strong. Also, the positive rent-extraction effect is strong as firm A extracts rents from its own loyal consumers.

We also compare how incentives to acquire data differ in our model from the results of LS. In the version of our model with relatively homogeneous consumers in the absence of customer flexibility data every firm serves only consumers on its own turf and targets for each address the least loyal consumer. If one of the firms acquires customer data, it gains consumers on the rival's turf (if $l > 3/2$) and is able to extract more rents from consumers on its own turf. The unilateral acquisition of customer data is then always profitable. The best response to the rival acquiring customer flexibility data is to do so as well. In that case a firm gains consumers on the own turf (if $l > 3/2$) and can extract more rents from them. In equilibrium both firms acquire data and their profits increase. This result is different from LS. First, in our model with relatively homogeneous consumers firms acquire customer data of any quality, while in LS only if the quality is sufficiently high. Second, in our model with relatively differentiated consumers firms are always better-off when data is acquired, while in LS firms are worse-off with data acquisition. The results in LS are driven by the interplay of the negative competition effect and the positive rent-extraction effect. The latter starts to dominate when the quality of customer data is sufficiently high, which makes data acquisition possible. In our model with relatively homogeneous consumers the negative competition effect is absent, and the positive rent-extraction effect dominates. Then the profits of a firm with customer flexibility data are always higher than in the absence of such data irrespective of the rival's data acquisition decision. The difference in the strength of the competition effect in our model and in LS is driven

However, when consumers are relatively differentiated, we get results which are very similar to those of LS. Precisely, the prisoners' dilemma emerges only when the quality of customer flexibility data is sufficiently high: $k = 2$ in our model and $k = 3$ in LS. However, there are some differences in the underlying equilibrium strategies of the firms. Precisely, in our model a firm always has a unilateral incentive to acquire customer data, while in LS this the case only when $k \geq 3$.[20] Moreover, a firm prefers to acquire data given that the rival holds data

[20] As we showed in the previous section, the result that a firm always has a unilateral incentive to acquire customer flexibility data is not robust with respect to the assumption on the timing of firms' decisions in the sym-

if $k \geq 2$ in our model, and if $k \geq 3$ in LS. The latter difference is driven by the fact that in the symmetric subgame where both firms hold customer data the rent-extraction effect starts to dominate earlier in our model, at $k = 1$ compared to $k = 2$ in LS.

In summary, we identify more scope for customer data acquisition than LS. Precisely, when consumers are relatively homogeneous in flexibility, data on consumer flexibility is acquired regardless of the quality. Also our results show that customer data acquisition may be more detrimental to consumers than in LS. In particular, with relatively homogeneous consumers the acquisition of customer flexibility data reduces consumer surplus while it leaves social welfare unchanged. Moreover, the decrease in consumers surplus is larger if data quality is higher.

5 Conclusions

In this article we analyze firms' incentives to acquire data on consumer characteristics of the exogenously given quality and its ensuring effects on competition intensity and welfare, when customer data can be used for targeted pricing. This article makes two main contributions. First, we propose a model of price discrimination that applies particularly well to markets where firms' attempts to acquire customer data have attracted public debate, such as the use of location-based targeting on mobile devices. In contrast to typical spatial models in our setup consumer locations are known to firms, but their information on consumer transportation cost parameters (flexibility) is imperfect. Second, we show that data acquisition incentives and the resulting market outcomes crucially depend on how strongly consumers differ in flexibility. These differences are driven by the balance of the competition and rent extraction effect of the firms ability to better target consumers with the additional data. If consumers are relatively homogenous with respect to their flexibility, competition is strong when firms have no data on flexibility with no room to further intensify as firms acquire data. In this case data is used solely for rent extraction, harming consumers. However, if consumers are relatively heterogenous in flexibility, the competition effect induced by additional data is very strong. Firms acquire data only if it is of high quality. Profits then increase, but they never reach the level that could be realized in the absence of customer data. Social welfare and consumer surplus can increase with data acquisition, as long as data quality is not too high. Our results suggests that there is scope

metric subgame. If we assume that in the symmetric subgame firms also move sequentially as in the asymmetric subgame, then a firm does not have unilateral incentive to acquire customer flexibility data.

for welfare increasing privacy regulation that would limit the acquisition or use of customer data in marketing. However, such a policy needs to be nuanced, for example by being limited to cases where firms can obtain particularly detailed information about consumer characteristics.

6 Appendix

In the Appendix we provide the omitted proofs.

Proof of Proposition 1. We start with the version of our model with relatively differentiated consumers. In the following claim we state the equilibrium for $k \geq 2$.

Claim 1. Assume that consumers are relatively differentiated and $k \geq 2$. *On the turf of firm* $i = A, B$ *prices vary depending on the segment. On the segment* $m = 1$ *equilibrium prices are* $p^*_{A1}(x,k) = 2\bar{t}(1-2x)/\left(3 \times 2^k\right)$ *and* $p^*_{B1}(x,k) = \bar{t}(1-2x)/\left(3 \times 2^k\right)$, *where firm* i *serves consumers with* $t \geq \bar{t}/\left(3 \times 2^k\right)$. *On the segments* $2 \leq m \leq 2^k$ *equilibrium prices are* $p^*_{Am}(x,k) = \bar{t}\,(m-1)\,(1-2x)\,/2^k$ *and* $p^*_{Bm}(x,k) = 0$, *where firm* i *serves all consumers. Firm* i *realizes the profit* $\Pi_i^{A,A}(k) = 5\bar{t}/\left(9 \times 2^{2(1+k)}\right) + \bar{t}\left(1/8 - 1/2^{3+k}\right)$.

Proof of Claim 1. As firms are symmetric, we only consider the turf of firm A, $x < 1/2$. On segment m a consumer chooses firm A if $t \geq (p_{Am}(x) - p_{Bm}(x))/(1-2x)$. Both firms treat the consumer transportation cost parameter as a random variable and maximize their expected profits for a given x. We start with the segment $m = 1$. Best-response functions take the form:

$$p_{A1}(x,k,p_B) = \begin{cases} p_B & \text{if} \quad p_B \geq \bar{t}(1-2x)/2^k \\ \frac{2^k p_B + \bar{t}(1-2x)}{2^{k+1}} & \text{if} \quad p_B < \bar{t}(1-2x)/2^k) \end{cases},$$

$$p_{B1}(x,k,p_A) = \begin{cases} p_A - \bar{t}(1-2x)/2^k & \text{if} \quad p_A \geq 2\bar{t}(1-2x)/2^k \\ p_A/2 & \text{if} \quad p_A < 2\bar{t}(1-2x)/2^k \end{cases}.$$

The equilibrium prices are $p^*_{A1}(x,k) = 2\bar{t}(1-2x)/\left(3 \times 2^k\right)$ and $p^*_{B1}(x,k) = \bar{t}(1-2x)/\left(3 \times 2^k\right)$. Firm A serves consumers with $t \geq \bar{t}/\left(3 \times 2^k\right)$. On the segments $2 \leq m \leq 2^k$ best-response functions take the form

$$p_{Am}(x,k,p_B) = p_B + m\bar{t}(1-2x)/2^{k+1},$$

$$p_{Bm}(x,k,p_A) = \begin{cases} 0 & \text{if} \quad p_A \leq \frac{m\bar{t}(1-2x)}{2^{k+1}} \\ \frac{2^{k+1}p_A - m\bar{t}(1-2x)}{2^{k+2}} & \text{if} \quad \frac{m\bar{t}(1-2x)}{2^{k+1}} < p_A < \frac{3m\bar{t}(1-2x)}{2^{k+1}} \\ p_A - m\bar{t}(1-2x)/2^k & \text{if} \quad p_A \geq \frac{3m\bar{t}(1-2x)}{2^{k+1}}. \end{cases}$$

Those best-response functions yield the equilibrium prices $p^*_{Am}(x,k) = (m-1)\,\bar{t}(1-2x)/2^k$ and $p^*_{Bm}(x,k) = 0$. Firm A serves all consumers on the segments $2 \leq m \leq 2^k$. The profits of firm A

are computed as

$$\Pi_A^{A,A}(k) = \int_0^{1/2} \int_{\bar{t}/(3\times 2^k)}^{\bar{t}/2^k} f_t \frac{2\bar{t}(1-2x)}{3\times 2^k} dxdt + \int_{1/2}^{1} \int_0^{\bar{t}/(3*2^k)} f_t \frac{\bar{t}(2x-1)}{3\times 2^k} dxdt$$

$$+ \sum_{(a,b)=\left(\frac{\bar{t}}{2^k},\frac{2\bar{t}}{2^k}\right),\left(\frac{2\bar{t}}{2^k},\frac{3\bar{t}}{2^k}\right),\ldots,\left(\frac{\bar{t}(2^k-1)}{2^k},\bar{t}\right)} \int_0^{1/2} \int_a^b f_t a\,(1-2x)\,dxdt$$

$$= \frac{5\bar{t}}{9\times 2^{2(1+k)}} + \frac{1}{4\bar{t}}\left[\frac{\bar{t}}{2^k}\times\frac{\bar{t}}{2^k} + \ldots + \frac{\bar{t}}{2^k}\times(2^k-1)\times\frac{\bar{t}}{2^k}\right]$$

$$= \frac{5\bar{t}}{9\times 2^{2(1+k)}} + \frac{1}{4\bar{t}}\left(\frac{\bar{t}}{2^k}\right)^2 \sum_{n=1,\ldots,2^k-1} n = \frac{5\bar{t}}{9\times 2^{2(1+k)}} + \bar{t}\left(\frac{1}{8} - \frac{1}{2^{3+k}}\right).$$

This completes the proof of the Claim.

A similar analysis as in Claim 1 can be conducted for the cases $k=0$ and $k=1$. If $k=0$, then on the turf of firm i firms charge prices $p_{i1}^*(x,k) = 2\bar{t}\,|1-2x|/3$ and $p_{j1}^*(x,k) = \bar{t}\,|1-2x|/3$. Firm i serves consumers with $t \geq \bar{t}/3$ on its own turf and consumers with $t < \bar{t}/3$ on the competitor's turf and realizes the profit $\Pi_i^{A,A}(0) = 5\bar{t}/36$. If $k=1$, then on the turf of firm i firms charge prices $p_{i2}^*(x,k) = \bar{t}\,|1-2x|/2$ and $p_{j2}^*(x,k) = 0$ on the segment $m=2$ and prices $p_{i1}^*(x,k) = \bar{t}\,|1-2x|/3$ and $p_{j1}^*(x,k) = \bar{t}\,|1-2x|/6$ on the segment $m=1$. Firm i serves all consumers on the segment $m=2$, consumers with $t \geq \bar{t}/6$ on the segment $m=1$ and realizes the profit $\Pi_i^{A,A}(1) = 7\bar{t}/72$. Note finally that these equilibrium results can be derived from Claim 1 through setting $k=0$ and $k=1$, respectively.

We now turn to the version of our model with relatively homogeneous consumers. In the following claim we state the equilibrium for $k \geq 2$.

Claim 2. Assume that consumers are relatively homogeneous in flexibility and $k \geq 2$. On the turf of firm i on the segment $m = 1, \ldots, 2^k$ firms charge the prices
$p_{im}^*(x,k) = \left[\underline{t} + \left(\bar{t} - \underline{t}\right)(m-1)/2^k\right]|1-2x|$ and $p_{jm}^*(x,k) = 0$, where firm i serves all consumers.
Profits are $\Pi_i^{A,A}(k) = \underline{t}/4 + \left(\bar{t} - \underline{t}\right)\left[1/8 - 1/\left(2^{3+k}\right)\right]$.

Proof of Claim 2. We only consider the turf of firm i, $x < 1/2$. On segment m a consumer chooses firm A if $t \geq (p_{Am} - p_{Bm})/(1-2x)$. Both firms treat the consumer transportation cost parameter as a random variable and maximize their expected profits for a given x. On the segment m the best-response functions take the form:

$$p_{Am}(x,k,p_B) = p_B + \left[\underline{t} + \left(\bar{t} - \underline{t}\right)(m-1)/2^k\right](1-2x),$$

$$p_{Bm}(x,k,p_A) =$$

$$\begin{cases} 0 & \text{if} \quad \frac{p_A}{(1-2x)} \leq \frac{\underline{t}}{2} + \frac{\left(\bar{t}-\underline{t}\right)(m-1)}{2^{k+1}} \\ p_A - \left[\frac{\underline{t}}{2} + \frac{\left(\bar{t}-\underline{t}\right)(m-1)}{2^{k+1}}\right](1-2x) & \text{if} \quad \frac{\underline{t}}{2} + \frac{\left(\bar{t}-\underline{t}\right)(m-1)}{2^{k+1}} < \frac{p_A}{(1-2x)} < \underline{t} + \frac{\left(\bar{t}-\underline{t}\right)(m+1)}{2^k} \\ p_A - \left[\underline{t} + \frac{\left(\bar{t}-\underline{t}\right)m}{2^k}\right](1-2x) & \text{if} \quad \frac{p_A}{(1-2x)} \geq \underline{t} + \frac{\left(\bar{t}-\underline{t}\right)(m+1)}{2^k}. \end{cases}$$

Those best-response functions yield the equilibrium prices

$$\begin{aligned} p^*_{Am}(x,k) &= \left[\underline{t} + \left(\bar{t} - \underline{t}\right)(m-1)/2^k\right](1-2x) \ \text{ and} \\ p^*_{Bm}(x,k) &= 0. \end{aligned}$$

Firm A's profit is computed as

$$\begin{aligned} \Pi_A^{A,A}(k) &= \sum_{(a,b)=\left(\underline{t},\underline{t}+\frac{\bar{t}-\underline{t}}{2^k}\right),\left(\underline{t}+\frac{\bar{t}-\underline{t}}{2^k},\underline{t}+\frac{2\left(\bar{t}-\underline{t}\right)}{2^k}\right),\ldots,\left(\underline{t}+\frac{\left(\bar{t}-\underline{t}\right)\left(2^k-1\right)}{2^k},\bar{t}\right)} \int_0^{1/2}\int_a^b f_{t,x} a\,(1-2x)\,dxdt \\ &= \frac{1}{2^{2+k}} \sum_{a=\underline{t},\underline{t}+\frac{\bar{t}-\underline{t}}{2^k},\ldots,\underline{t}+\frac{\left(\bar{t}-\underline{t}\right)\left(2^k-1\right)}{2^k}} a = \frac{\underline{t}}{4} + \left(\bar{t}-\underline{t}\right)\left(\frac{1}{8} - \frac{1}{2^{3+k}}\right). \end{aligned}$$

This completes the proof of the Claim.

A similar analysis as in Claim 2 can be conducted for the cases $k=0$ and $k=1$. If $k=0$, then on the turf of firm i firms charge prices $p^*_{im}(x,0) = \underline{t}\,|1-2x|$ and $p^*_{jm}(x,0) = 0$, where firm i serves all consumers. The profit of firm i is $\Pi_i^{A,A}(0) = \underline{t}/4$. If $k=1$, then on the turf of firm i on the segment $m=1$ firms charge prices $p^*_{i1}(x,1) = \underline{t}\,|1-2x|$ and $p^*_{j1}(x,1) = 0$. On the segment $m=2$ equilibrium prices are $p^*_{i2}(x,1) = \left(\bar{t}+\underline{t}\right)|1-2x|/2$ and $p^*_{j2}(x,1) = 0$. Firm i serves all consumers on its turf and realizes the profit $\Pi_i^{A,A}(1) = \left(\bar{t}+3\underline{t}\right)/16$. Note finally that these equilibrium results can be derived from Claim 2 through setting $k=0$ and $k=1$, respectively. *Q.E.D.*

Proof of Proposition 2. Consider first the turf of firm A. Given p_B firm A maximizes its profit on every segment separately. The best-response function of firm A on segment m is

$p_{Am}(x,k,p_B) = p_B + \underline{t}^m(k)(1-2x)$, such that for any p_B firm A serves all consumers. Then $p^*_{Bm}(x,k) = 0$ and $p^*_{Am}(x,k) = \underline{t}^m(k)(1-2x)$. For a given address $x < 1/2$ firm A realizes the profit

$$\begin{aligned}\Pi_A(x,k) &= \int_{\underline{t}}^{\bar{t}} \left[f_t \left(\underline{t} + \left(\underline{t} + \frac{\bar{t}-\underline{t}}{2^k} \right) + ... + \left(\underline{t} + \frac{(\bar{t}-\underline{t})(2^k-1)}{2^k} \right) \right) \frac{(\bar{t}-\underline{t})}{2^k} dt \right] = \\ &= \underline{t} + \frac{(\bar{t}-\underline{t})(2^k-1)}{2^{k+1}},\end{aligned}$$

such that its total profit on its turf is

$$\Pi_A(x < 1/2, k) = (\underline{t} + \bar{t})/8 - (\bar{t}-\underline{t})/2^{k+3}, \tag{5}$$

and the profit of firm B on A's turf is zero.

Consider now the turf of firm B. The best-response function of firm A on segment m is

$$p_{Am}(x,k,p_B) = \begin{cases} 0 & \text{if} \quad \frac{p_B}{(2x-1)} \leq \underline{t}^m(k) \\ \frac{p_B}{2} - \frac{\underline{t}^m(k)(2x-1)}{2} & \text{if} \quad \underline{t}^m(k) < \frac{p_B}{(2x-1)} < 2\bar{t}^m(k) - \underline{t}^m(k) \\ p_B - \bar{t}^m(k)(2x-1) & \text{if} \quad \frac{p_B}{(2x-1)} \geq 2\bar{t}^m(k) - \underline{t}^m(k) \end{cases}$$

We have to find now the optimal price of firm B. Note that for any $m \geq 2$ and $k \geq 1$ it holds that $2\bar{t}^{m-1}(k) - \underline{t}^{m-1}(k) = \bar{t}^m(k)$. The profit function of firm B for some $x > 1/2$ takes the form

$$\Pi_B(x,k,p_B) = \begin{cases} p_B & \text{if} \quad p_B < a \\ \left[\frac{2\bar{t}-\underline{t}}{2} - \frac{p_B}{2(2x-1)}\right] \frac{p_B}{\bar{t}-\underline{t}} & \text{if} \quad a \leq p_B < b \\ \left[\bar{t} + \frac{\bar{t}-\underline{t}}{2^{k+1}} - \frac{p_B}{2x-1}\right] \frac{p_B}{\bar{t}-\underline{t}} & \text{if} \quad b \leq p_B < c \\ \left[\frac{\bar{t}}{2} + \frac{\bar{t}-\underline{t}}{2^{k+1}} - \frac{p_B}{2(2x-1)}\right] \frac{p_B}{\bar{t}-\underline{t}} & \text{if} \quad c \leq p_B < d \\ 0 & \text{if} \quad p_B \geq d, \end{cases}$$

where $a = \underline{t}(2x-1)$, $b = \left[\underline{t} + (\bar{t}-\underline{t})/2^k\right](2x-1)$, $c = \bar{t}(2x-1)$, $d = \left[\bar{t} + (\bar{t}-\underline{t})/2^k\right](2x-1)$. It is straightforward to show that $\Pi_B(x,k,p_B)$ decreases on $b \leq p_B \leq d$. Depending on l and k three options are possible. First, if $l < 3/2$, then $\Pi_B(x,k,p_B)$ increases on $p_B < a$ and decreases on $a \leq p_B < d$, such that $p^*_B(x,k) = \underline{t}(2x-1)$. For any $x > 1/2$ firm B serves all consumers. Second, if $l > 3/2$ and $k < \log_2[(l-1)/(l-3/2)]$, then $\Pi_B(x,k,p_B)$ increases on $p_B < (2\bar{t}-\underline{t})(2x-1)/2$ and decreases on $(2\bar{t}-\underline{t})(2x-1)/2 \leq p_B < d$, such that

$p_B^*(x,k) = (2\bar{t} - \underline{t})(2x-1)/2$. For any $x > 1/2$ firm B serves consumers with $t \geq (2\bar{t} + \underline{t})/4$. Third, if $l > 3/2$ and $k \geq \log_2[(l-1)/(l-3/2)]$, then $\Pi_B(x,k,p_B)$ increases on $p_B < b$ and decreases on $b \leq p_B \leq d$, such that $p_B^*(x,k) = \left[\underline{t} + (\bar{t} - \underline{t})/2^k\right](2x-1)$. For any $x > 1/2$ firm B serves consumers with $t \leq \underline{t} + (\bar{t} - \underline{t})/2^{k+1}$.

We now compute firms' profits on the turf of firm B. Consider first $l \leq 3/2$. Firm A serves no consumers on the turf of firm B, the profit of firm B is computed as

$$\Pi_B^{A,NA}(k) = \int_{1/2}^1 \int_{\underline{t}}^{\bar{t}} [f_{t,x}\underline{t}(2x-1)]\, dtdx = \underline{t}/4.$$

Consider now $l > 3/2$. Assume that $k < \log_2[(l-1)/(l-3/2)]$. The profit of firm B is computed as

$$\Pi_B^{A,NA}(k) = \int_{\frac{1}{2}}^1 \int_{\frac{2\bar{t}+\underline{t}}{4}}^{\bar{t}} \left[f_{t,x}\frac{(2\bar{t} - \underline{t})(2x-1)}{2}\right] dtdx = \frac{(2l-1)^2\, \underline{t}}{32\,(l-1)}.$$

The profit of firm A is computed as

$$\Pi_A(x > 1/2, k) = \int_{\frac{1}{2}}^1 \int_{\underline{t}}^{\frac{2\bar{t}+\underline{t}}{4}} \left[f_{t,x}\frac{\left(2\bar{t} - 3\underline{t}\right)(2x-1)}{4}\right] dtdx = \frac{(2l-3)^2\, \underline{t}}{64\,(l-1)}. \quad (6)$$

Summing up the profits (5) and (6) we get the total profit of firm A as

$$\Pi_A^{A,NA}(k) = \left[12l^2 - 12l + 1\right]\underline{t}/\left[64\,(l-1)\right] - (l-1)\,\underline{t}/2^{k+3}.$$

Assume finally that $k > \log_2[(l-1)/(l-3/2)]$. The profit of firm B is computed as

$$\Pi_B^{A,NA}(k) = \int_{\frac{1}{2}}^1 \int_{\underline{t}+\frac{\bar{t}-\underline{t}}{2^{k+1}}}^{\bar{t}} \left[f_{t,x}\left(\underline{t} + \frac{\bar{t} - \underline{t}}{2^k}\right)(2x-1)\right] dtdx = \left(1 + \frac{l-1}{2^k}\right)\left(1 - \frac{1}{2^{k+1}}\right)\frac{\underline{t}}{4}.$$

The profit of firm A is computed as

$$\Pi_A(x > 1/2, k) = \int_{\frac{1}{2}}^1 \int_{\underline{t}}^{\underline{t}+\frac{\bar{t}-\underline{t}}{2^{k+1}}} \left[f_{t,x}\frac{\left(\bar{t} - \underline{t}\right)(2x-1)}{2^{k+1}}\right] dtdx = \frac{(l-1)\,\underline{t}}{2^{2k+4}}. \quad (7)$$

Summing up the profits (5) and (7) we get

$$\Pi_A^{A,NA}(k) = \underline{t}\left[(1+l)/8 - (l-1)\left(2^{k+1} - 1\right)/2^{2k+4}\right].$$

We finally note the above derived equilibrium for $k \geq 1$ describes also the equilibrium at $k = 0$.

Q.E.D.

Proof of Proposition 3. Consider first the turf of firm A. Given $p_B(x)$ the best-response of firm A on $m = 1$ is

$$p_{A1}(x, k, p_B) = \begin{cases} p_B & \text{if} \quad p_B(x) \geq \bar{t}(1-2x)/2^k \\ \left[\bar{t}(1-2x)/2^k + p_B\right]/2 & \text{if} \quad p_B(x) < \bar{t}(1-2x)/2^k. \end{cases}$$

The best-response of firm A on $m \geq 2$ is $p_{Am}(x, k, p_B) = p_B + \underline{t}^m(k)(1-2x)$, such that firm A serves all consumers on m. Assume that $p_B(x) < \bar{t}(1-2x)/2^k$, in which case firm B serves consumers with $t \leq \bar{t}/2^{k+1} - p_B/[2(1-2x)]$ on $m = 1$. Maximization of firm B's expected profit yields $p_B^*(x,k) = \bar{t}(1-2x)/2^{k+1}$
and $p_{A1}^*(x,k) = 3\bar{t}(1-2x)/2^{k+2}$. On its turf firm A serves consumers with $t \geq \bar{t}/2^{k+2}$. The profit of firm B on the turf of firm A is

$$\Pi_B(k, x < 1/2) = \int_0^{1/2} \left[f_{x,t} \frac{\bar{t}}{2^{k+2}} \frac{\bar{t}(1-2x)}{2^{k+1}} \right] dx = \frac{\bar{t}}{2^{2k+5}}. \tag{8}$$

The profit of firm A on its turf is

$$\Pi_A(k, x < 1/2) = \int_0^{1/2} \left[f_{x,t} \frac{\bar{t}}{2^k} \left(\frac{\bar{t}(2^k-1)}{2^{k+1}} + \frac{\bar{t}}{2^k} + \frac{2\bar{t}}{2^k} + \ldots + \frac{\bar{t}(2^k-1)}{2^k} \right)(1-2x) \right] dx \tag{9}$$
$$+ \int_0^{1/2} \left[f_{x,t} \left(\frac{3}{4}\right)^2 \left(\frac{\bar{t}}{2^k}\right)^2 (1-2x) \right] dx = \frac{\bar{t}\left(2^k-1\right)}{2^{k+3}} + \frac{\bar{t}(2^{k+3}+1)}{2^{2k+6}}.$$

Consider now the turf of firm B. On m the best-response function of firm A is

$$p_{Am}(x, k, p_B) = \begin{cases} 0 & \text{if} \quad \frac{p_B}{(2x-1)} \leq \underline{t}^m(k) \\ \frac{p_B - \underline{t}^m(k)(2x-1)}{2} & \text{if} \quad \underline{t}^m(k) < \frac{p_B}{(2x-1)} < 2\bar{t}^m(k) - \underline{t}^m(k) \\ p_B - \bar{t}^m(k)(2x-1) & \text{if} \quad \frac{p_B}{(2x-1)} \geq 2\bar{t}^m(k) - \underline{t}^m(k) \end{cases}$$

The profit of firm B for some $x > 1/2$ is

$$\Pi_B(x, k, p_B) = \begin{cases} \left[\bar{t} - \frac{p_B}{2(2x-1)}\right] \frac{p_B}{\bar{t}} & \text{if} \quad 0 \leq p_B < a \\ \left[\bar{t} + \frac{\bar{t}}{2^{k+1}} - \frac{p_B}{2x-1}\right] \frac{p_B}{\bar{t}} & \text{if} \quad a \leq p_B < b \\ \left[\frac{\bar{t}}{2} + \frac{\bar{t}}{2^{k+1}} - \frac{p_B}{2(2x-1)}\right] \frac{p_B}{\bar{t}} & \text{if} \quad b \leq p_B < c \\ 0 & \text{if} \quad p_B \geq c, \end{cases}$$

where $a = \bar{t}(2x-1)/2^k$, $b = \bar{t}(2x-1)$, $c = \left(\bar{t} + \bar{t}/2^k\right)(2x-1)$. Note that $\Pi_B(x,k,p_B)$ increases on $0 \le p_B < a$, decreases on $b \le p_B < c$ and gets its maximum at $p_B^*(x,k) = \left(\bar{t}/2 + \bar{t}/2^{k+2}\right)(2x-1)$ on $a \le p_B < b$. For any $k \ge 1$ it holds $p_B^*(x,k)/(2x-1) \in \left[\bar{t}/2, \bar{t}/2 + \bar{t}/2^k\right]$. On $m = 2^{k-1}+1$ firm B serves consumers with $t \ge \bar{t}/2 + \bar{t}/2^{k+3}$, on $m = 2^{k-1}$ firm B serves consumers with $t \ge \bar{t}/2 - 3\bar{t}/2^{k+3}$. If $k \ge 2$, then firm B serves all consumers on $m \ge 2^{k-1}+2$ and firm A serves all consumers on $m \le 2^{k-1}-1$. The profit of firm B on its turf is

$$\Pi_B(x > 1/2, k) = \textstyle\int_{1/2}^{1} \left[f_{x,t} \left(\frac{\bar{t}}{2} + \frac{\bar{t}}{2^{k+2}} \right)^2 \right] dx = \frac{\bar{t}}{16} \left(1 + \frac{1}{2^k} + \frac{1}{2^{2k+2}} \right). \qquad (10)$$

Summing (10) and (10) yields the profit of firm B as

$$\Pi_B^{A,NA}(k) = \bar{t}\left(1 + 1/2^k + 3/2^{2k+2}\right)/16, \text{ for any } k \ge 1.$$

We now compute the equilibrium prices of firm A on the turf of firm B. We get $p^*_{A2^{k-1}}(x,k) = 5\bar{t}\,(2x-1)/2^{k+3}$, $p^*_{A2^{k-1}+1}(x,k) = \bar{t}\,(2x-1)/2^{k+3}$. If $k \ge 2$, then on $m \le 2^{k-1}-1$ firm A charges $p^*_{Am}(x,k) = p^*_B(x,k) - \bar{t}^m(k)\,(2x-1)$. The profit of firm A on the rival's turf is

$$\begin{aligned}
\Pi_A(x > 1/2, k) &= \textstyle\int_{1/2}^{1} \left[f_{x,t}(2x-1) \left(\left(\frac{\bar{t}}{2^{k+3}} \right)^2 + \left(\frac{5\bar{t}}{2^{k+3}} \right)^2 \right) \right] dx \\
&+ \textstyle\int_{1/2}^{1} \left[f_{x,t}(2x-1) \frac{\bar{t}}{2^k} \left(\left(\frac{\bar{t}}{2} + \frac{\bar{t}}{2^{k+2}} \right) \left(2^{k-1}-1\right) - \frac{\bar{t}}{2^k} \left(1 + 2 + ... + 2^{k-1} - 1\right) \right) \right] dx \\
&= \frac{\bar{t}\left(2^{2k+2} - 2^{k+2} + 5\right)}{2^{2k+7}}.
\end{aligned}$$

Summing up the profits of firm A on the two turfs we get

$$\Pi_A^{A,NA}(k) = \frac{\bar{t}\left(5 \times 2^{2k+2} - 2^{k+2} + 7\right)}{2^{2k+7}}, \text{ for any } k \ge 1.$$

We now derive the equilibrium on the turf of firm A for $k = 0$. The best-response function of firm A is

$$p_A(x, p_B) = \begin{cases} p_B \le 2\bar{t}\,(2x-1) & \text{if} \quad p_B/2 \\ p_B(x) > 2\bar{t}\,(2x-1)\,(2x-1) & \text{if} \quad p_B - \bar{t}(2x-1). \end{cases}$$

Assume that $p_B(x) \le 2\bar{t}\,(2x-1)$ for any $x > 1/2$, such that firm B serves consumers with

$t \geq p_B(x)/\left[2(2x-1)\right]$. Maximization of firm B's profit yields $p_B^*(x) = \bar{t}\,(2x-1) < 2\bar{t}\,(2x-1)$ and $p_A^*(x) = \bar{t}\,(2x-1)/2$. Firm B serves consumers with $t \geq \bar{t}/2$. On the turf of firm B firms realize profits $\Pi_A(x > 1/2, 0) = \bar{t}/16$ and $\Pi_B(x > 1/2, 0) = \bar{t}/8$. Summing up these profits with (9) and (8) for $k = 0$ we get $\Pi_A^{A,NA}(0) = 13\bar{t}/64$ and $\Pi_B^{A,NA}(0) = 5\bar{t}/32$. *Q.E.D.*

Proof of Proposition 4. We prove first part *i)* of the proposition. If a firm unilaterally acquires customer data, it keeps all consumers on its turf and extracts more rents from them, it also gains consumers on the rival's turf (if $l > 3/2$), such that the unilateral acquisition of data is always profitable. Assume now that firm A has customer data. We show that firm B also has an incentive to acquire data. When both firms hold data of quality $k \geq 1$, firm B realizes the profit

$$\Pi_B^{A,A}(k) = \underline{t}/4 + \left(\bar{t} - \underline{t}\right)\left[1/8 - 1/2^{3+k}\right].$$

Assume first that $l \leq 3/2$, in which case the profit of firm B is $\Pi_B^{A,NA}(k) = \underline{t}/4$ if only firm A holds data. Comparing the two profits we get

$$\Pi_B^{A,A}(k) - \Pi_B^{A,NA}(k) = \frac{\left(\bar{t} - \underline{t}\right)}{8}\left[1 - \frac{1}{2^k}\right] > 0 \text{ for any } k \geq 1,$$

such that firm B has an incentive to acquire data when the rival holds it. Assume now that $l > 3/2$ and $k < \log_2\left[(l-1)/(l-3/2)\right]$, in which case the profit of firm B is

$$\Pi_B^{A,NA}(k) = \left(2\bar{t} - \underline{t}\right)^2 / \left[32\left(\bar{t} - \underline{t}\right)\right]$$

if only the rival holds data. Comparison of the two profits yields

$$\frac{\Pi_B^{A,A}(k) - \Pi_B^{A,NA}(k)}{\underline{t}} = -\frac{(3-2l)^2}{32\,(l-1)} + \frac{(l-1)}{8}\left(1 - \frac{1}{2^k}\right) \geq -\frac{\left(2l^2 - 8l + 7\right)}{32\,(l-1)}. \tag{11}$$

The inequality in (11) follows from $1/2^k \leq 1/2$ for any $k \geq 1$. Note that $2l^2 - 8l + 7 < 0$ for any $3/2 < l \leq 2$, such that $\Pi_B^{A,A}(k) > \Pi_B^{A,NA}(k)$, and firm B has an incentive to acquire data when the rival holds it. Assume finally that $l > 3/2$ and $k \geq \log_2\left[(l-1)/(l-3/2)\right]$, in which case the profit of firm B is

$$\Pi_B^{A,NA}(k) = \underline{t}\left[1 + (l-1)/2^k\right]\left[1 - 1/2^{k+1}\right]/4$$

if only the rival holds data. Comparison of the two profits yields

$$\Pi_B^{A,A}(k) - \Pi_B^{A,NA}(k) = \frac{\underline{t}}{8}\left[(l-1)\left(1-\frac{3}{2^k}+\frac{1}{2^{2k}}\right)+\frac{1}{2^k}\right]. \tag{12}$$

The expression in (12), $1-3/2^k+1/2^{2k}$, can be either positive or negative. If $1-3/2^k+1/2^{2k} \geq 0$, then $\Pi_B^{A,A}(k) > \Pi_B^{A,NA}(k)$ for any $3/2 < l \leq 2$. Assume that $1-3/2^k+1/2^{2k} < 0$. Then for any $3/2 < l \leq 2$ it holds that

$$\Pi_B^{A,A}(k) - \Pi_B^{A,NA}(k) \geq \frac{\underline{t}}{8}\left(1-\frac{2}{2^k}+\frac{1}{2^{2k}}\right), \tag{13}$$

where we derived the RHS of (13) by plugging $l = 2$ into the RHS of (12). The derivative of the RHS of (13) with respect to k is positive for any $k \geq 1$, hence, $\Pi_B^{A,A}(k) - \Pi_B^{A,NA}(k) > \Pi_B^{A,A}(1) - \Pi_B^{A,NA}(1) = \underline{t}/32$. It follows that firm B has an incentive to acquire data when the rival holds it. We conclude that independently of the rival's data acquisition decision every firm has an incentive to acquire data.

We now prove part *ii)* of the proposition. Assume that firm B does not hold customer data. We analyze the incentives of firm A to acquire data. If firm A does not acquire data, its profit is $\Pi_A^{A,A}(0) = 5\bar{t}/36$. If firm A acquires data, its profit is

$$\Pi_A^{A,NA}(k) = \bar{t}\left(5 \times 2^{2k+2} - 2^{k+2} + 7\right)/2^{2k+7}.$$

The comparison of the two profits yields

$$\frac{\left[\Pi_A^{A,NA}(k) - \Pi_A^{A,A}(0)\right] \times 9 \times 2^{2k+7}}{\bar{t}} = 5 \times 2^{2k+2} - 9 \times 2^{k+2} + 63. \tag{14}$$

Taking derivative of the RHS of (14) with respect to k we get $2^{k+2}(\ln 2)\left(10 \times 2^k - 9\right)$, which is positive for any $k \geq 0$. Hence, for any $k \geq 1$ it holds that $\Pi_A^{A,NA}(k) > \Pi_A^{A,A}(0)$, and a firm always has a unilateral incentive to acquire customer flexibility data.

Assume now that firm A holds customer data. We analyze whether firm B also has an incentive to acquire data. If it does not acquire, its profit is

$$\Pi_B^{A,NA}(k) = \bar{t}\left(1 + 1/2^k + 3/2^{2k+2}\right)/16,$$

while if it acquires data each firm's profit is

$$\Pi_B^{A,A}(k) = 5\bar{t}/\left(9 \times 2^{2(1+k)}\right) + \bar{t}\left(1/8 - 1/2^{3+k}\right).$$

The comparison of the profits yields

$$\frac{\left[\Pi_B^{A,A}(k) - \Pi_B^{A,NA}(k)\right] \times 9 \times 2^{2k+6}}{\bar{t}} = 36 \times 2^{2k} - 108 \times 2^k + 53. \tag{15}$$

Taking derivative of the RHS of (15) with respect to k we get $9 \times 2^{k+2}(\ln 2)\left(2^{k+1} - 3\right)$, which is negative if $k = 0$ and positive if $k \geq 1$. Evaluating the RHS of (15) at $k = 1$ we get -19, and at $k = 2$ we get 187. We conclude that if $k = 1$, then a firm does not acquire data when the rival holds it, and acquires it if $k \geq 2$.

We conclude that if $k = 1$, there are two Nash equilibria where only one of the firms acquires data. If $k \geq 2$, there is a unique Nash equilibrium (in dominant strategies) where both firms acquire data. *Q.E.D.*

Proof of Proposition 5. We prove first part *i)* of the proposition. For any $k \geq 0$ in equilibrium every firm serves all consumers on its turf. Then social welfare can be computed as

$$SW^{A,A}(k) = v - 2\int_0^{1/2}\int_{\underline{t}}^{\bar{t}}\left[f_{x,t}tx\right]dtdx = v - \frac{\bar{t} + \underline{t}}{8}.$$

Consumer surplus can be computed by subtracting profits from social welfare, which yields

$$CS^{A,A}(k) = v - \frac{3\left(\bar{t} + \underline{t}\right)}{8} + \frac{\bar{t} - \underline{t}}{2^{k+2}}.$$

We turn now to part *ii)* of the proposition. If $k = 0$, then social welfare is computed as

$$SW^{A,A}(0) = v - 2\int_0^{1/2}\int_{\frac{\bar{t}}{3}}^{\bar{t}}\left[f_{t,x}tx\right]dtdx - 2\int_0^{1/2}\int_{\underline{t}}^{\frac{\bar{t}}{3}}\left[f_{t,x}t\left(1 - x\right)\right]dtdx = v - \frac{11\bar{t}}{72}.$$

Consumer surplus can be computed through subtracting profits from social welfare: $CS^{A,A}(0) = v - 31\bar{t}/72$. If $k = 1$, then only one firm acquires customer data, such that $\Pi_A^{A,NA}(1) = 79\bar{t}/512$

and $\Pi_B^{A,NA}(1) = 27\bar{t}/256$. Social welfare is computed as

$$\begin{aligned} SW^{A,NA}(1) &= v - \int_0^{1/2}\int_0^{2\bar{t}/8} [f_t t(1-x)]\, dtdx - \int_0^{1/2}\int_{\bar{t}/8}^{\bar{t}} [f_t tx]\, dtdx - \int_{1/2}^{1}\int_0^{5\bar{t}/16} [f_t tx]\, dtdx \\ &\quad - \int_{1/2}^{1}\int_{5\bar{t}/16}^{\bar{t}/2} [f_t t\,(1-x)]\, dtdx - \int_{1/2}^{1}\int_{\bar{t}/2}^{9\bar{t}/16} [f_t tx]\, dtdx - \int_{1/2}^{1}\int_{9\bar{t}/16}^{\bar{t}} [f_t t\,(1-x)]\, dtdx \\ &= v - \frac{151\bar{t}}{1024}. \end{aligned}$$

Subtracting profits from social welfare we get $CS^{A,NA}(1) = v - 417\bar{t}/1024$. If $k \geq 2$, then both firms acquire customer data in equilibrium. Social welfare is computed as

$$\begin{aligned} SW^{A,A}(k) &= v - 2\int_0^{1/2}\int_{\frac{\bar{t}}{3*2^k}}^{\bar{t}} [f_{t,x} tx]\, dtdx - 2\int_0^{1/2}\int_0^{\frac{\bar{t}}{3*2^k}} [f_{t,x} t(1-x)]\, dtdx \\ &= v - \frac{\bar{t}}{8}\left(1 + \frac{1}{9 \times 2^{2k-1}}\right). \end{aligned}$$

Subtracting profits from social welfare we get consumer surplus

$$CS^{A,A}(k) = v - \frac{11\bar{t}}{9 * 2^{2k+2}} + \frac{\bar{t}}{8}\left(\frac{1}{2^{k-1}} - 3\right).$$

Q.E.D.

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