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# Brand Loyalty, Volume of Trade and Leapfrogging: Consumer Behavior in Markets of Durable Experience Goods

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# Brand Loyalty, Volume of Trade and Leapfrogging: Consumer Behavior in Markets of Durable Experience Goods*

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**Abstract**

We present a dynamic model that addresses how the interaction between durability and experience affects consumers' replacement decisions. Despite obsolescence, consumers keep used goods because of quality uncertainty of new goods. Contrary to adverse selection articles, incomplete trade in secondary markets can be efficient provided experience involves idiosyncratic tastes. As some consumers decide which vintage to buy depending on past experiences, brand loyalty can be higher for new goods. When consumers' expected experience differs across brands, the best brand exhibits higher loyalty, larger sales, longer ownership spells, and higher resale prices, results consistent with evidence from the U.S. automobile industry.

JEL classification: D82, D83, L15.

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# 1 Introduction

Cars are one of the textbook examples of *durable goods*. But cars are also *experience goods*. Buyers of a new car cannot usually appraise all of its characteristics *before* purchase, but will learn more about it *after* purchase, once they used it for some time and realized whether or not such car meets their needs[1]. Regardless of the car's brand, vintage and model, a buyer is unable to observe some of its features at the time of purchase[2], or unable to discern their effect on her own utility[3]. Experience with past purchases emerges as one of the main sources of information, especially regarding the decision to replace an old car.

For durable goods such as cars, motorcycles, trucks, and airplanes, secondhand markets helps replacing a used good, as owners can sell it to another consumer. But for other durable goods such as electronics (e.g. computers, and smartphones) and appliances (e.g. washing machines and microwave ovens), the volume of trade in the secondhand market is insignificant, either because the introduction of new products make the old ones obsolete very quickly, or because the transaction costs are too high. A consumer that decides to buy a new smartphone would most likely throw away the used one. But regardless of whether it is a car or a smartphone, buyers of a new durable good face uncertainty regarding product characteristics. Hence, most durable goods are also experience goods.

This article studies a dynamic model for a good that has both properties of durability and experience to examine the optimal purchasing behavior of consumers, and the aggregate effect of their decisions on market equilibrium. It is a contribution to the literature on durable goods because uncertainty about product characteristics of new goods affects the consumer's replacement decision of a used good. Further, it explains why consumers might switch brands in their next purchase. But the article also contributes to the literature on experience goods, as durability allows consumers to reduce the frequency of purchases, and to switch between new and old vintage depending on their previous experience. Consumption patterns that emerge as a result of the interaction of durability and experience would affect not only equilibrium prices, but also firms' decision on issues such as quality, obsolescence, market coverage, and even the discontinuation of old models and introduction of new ones.

We construct a model of an infinite horizon economy with a good that lasts two periods and has two dimensions of quality, depending on whether the good's attributes can be appraised before purchase (observable quality) or after purchase (unobservable quality). Consumers have heterogeneous preferences regarding their valuation for each quality dimension, and buy at most one unit of the good. Observable quality shows obsolescence: every new vintage of the good reduces the utility provided by the previous generation. Unobservable quality can only be learned through experience

[1] Nelson (1970) introduced the concept of experience goods. In contrast, search goods are products whose characteristics can all be appraised prior to purchase.

[2] For example, consumers may not know whether they will be satisfied with the repair and maintenance services offered by the dealer, or whether some of the car pieces are defective.

[3] Consumers may not know, for example, whether the rate of acceleration is adequate for their driving style, or whether they are comfortable with a car with leather seats.

after owning the good for a period, with consumers enjoying either a good or a bad match. Based on their past experience, consumers form beliefs about their expected match with each brand and vintage of the good.

We assume that experience is idiosyncratic, so that two buyers of the same brand (e.g., a Toyota Camry, or a Samsung Galaxy) can get a different experience: one of them enjoys a good match, while the other endures a bad experience. If experience were not idiosyncratic, consumers would have no incentive to switch brands, but indicators on brand loyalty show evidence to the contrary. For example, in the U.S. new car market, less than 50% of returning customers in 2012, on average, bought the same brand than in their last purchase[4], with brands like Ford and Honda with 60% of repeating customers, while others such as Chrysler and Mazda having 26% and 34%, respectively. Among buyers of smartphones in three markets, Apple retains 76% of its customers, Samsung keeps 58%, while all other brands retain less than 33%[5]. An important implication of assuming idiosyncratic experience is that it introduces ex-post heterogeneity across consumers.

We also assume that experience is (i) brand-specific, and (ii) vintage-specific. The former implies that, for example, buying a Samsung Galaxy gives no information on the consumer's experience with an iPhone. The latter means that, even if a consumer had a good experience with a 2004 Toyota Camry, she may not get the same experience again with a 2014 Camry, or any other Toyota model. In fact, less than half of the car models available in 2004 are still currently on sale, and most of the remaining models have been updated on average every four to five years[6]. Firms introduce new models very frequently and with newer features, either because of technological progress, or perceived changes in consumers' preferences. Netbooks are one critical example: they were introduced in 2007, but most labels stopped producing them by the end of 2012, and replace them with tablets[7].

In the steady-state equilibrium when consumers have the same beliefs for all brands and vintages, we find that the consumer´s previous experience affects her replacement decision. Concretely, some owners decide to keep a used good because they do not want to face the risk of replacing it with a new good of uncertain quality, even though the used good has become obsolete. As a result, there is always incomplete trade in secondary markets. However, in contrast to the literature on adverse selection, incomplete trade can lead to an ex-post efficient outcome as long as experience involves idiosyncratic tastes, because information about the experience enjoyed by the previous owner of a used good would not guarantee that the potential buyer would also enjoy the same experience.

With experience goods, consumers switch brands after a bad experience, and stay loyal after a good experience. But we find that the introduction of durability causes brand loyalty to be larger for new goods, because in equilibrium there are always some buyers whose choice of vintage depends on their previous experience. When one of these consumers gets a bad match with a new good, she will replace it next period with an old vintage of some other brand, because of the uncertainty she faces when consuming an unknown brand. When she enjoys a good experience with a used good,

[4]J.D. Power and Associates' 2012 Customer Retention Study$^{SM}$, press release, January 11, 2012.
[5]WDS, a Xerox Company, press release, February 24, 2014.
[6]For example, Toyota started selling the Camry in 1982, and introduced its eighth generation in 2011.
[7]http://www.theguardian.com/technology/2012/dec/31/netbooks-dead-2013, retrieved January 17, 2015.

she buys a new good of the same brand in her next purchase, as her belief that she would get again a good match increases.

We also find that uncertainty and experience can cause leapfrogging behavior, a term coined by Fudenberg and Tirole (1998) to describe the existence of consumers with high valuation of quality using an old good, while consumers with lower valuation of quality purchase a new good. In our model, leapfrogging arises because consumers do not agree which brand is best, even though they all agree that new goods are superior to old ones. Most consumers are leapfrogged because they prefer to keep a used good after a good experience but, as explained above, some are leapfrogged when they decide to replace a used good after a bad experience with one of the same vintage but of a different brand. Further, leapfrogging emerges even in the presence of a secondhand market.

We extend the model to analyze the robustness of the results when consumers' beliefs are not the same for all brands and vintages. When we examine the effects of differences between vintages, we find that there is always incomplete trade and leapfrogging, as there are always consumers who keep their used goods after a good match. We also find that brand loyalty for new goods can be larger even when consumers expect a better experience with old vintages, provided that the difference in expected experience between old and new vintages is not too large.

When we examine differences between brands, we find that the brand with a higher probability of a good match would also exhibit higher customer loyalty, larger sales, smaller volume of trade in the secondary market, and higher prices for used goods. That brand provides a larger expected gross utility, which increases the demand for any of its vintages. But, as an even larger proportion of buyers of a new good of that brand gets a good match, more of them will decide to keep it as used, which reduces the supply of used goods of that brand in the secondary market. As shown below, the results on loyalty, sales and volume of trade would be consistent with evidence from the U.S. automotive market.

The article is organized as follows. The rest of the Introduction discusses some stylized facts, and examines some related literature. Section 2 introduces the baseline model. Section 3 characterizes consumer behavior, while Section 4 determines the conditions for the existence of an equilibrium. Section 5 examines the main implications of the equilibrium just found. Section 6 presents the two extensions of the model we discussed above, and Section 7 concludes. All proofs of the propositions are collected in the Appendix.

### 1.1 Empirical facts

As one of the objectives of this article is to understand the effects of experience in markets of durable goods, we examine the relationship between consumer satisfaction (using it as a proxy for consumers' experience) and other market observables. We chose the automobile industry because it has more information available freely[8]. As a first step, we needed to define an index of consumer satisfaction. For consistency, we decided to construct this index using indicators by brand collected from press

[8]Still, most information by brand is proprietary, and very little is available freely or by paying a subscription.

releases of four studies conducted by the same research firm (J.D. Power and Associates), which surveys U.S. consumers regarding their satisfaction with any recently purchased new vehicle. Each one of those surveys measures different aspects of experience at different moments of the ownership. The Automotive Performance, Execution and Layout (APEAL) Study$^{SM}$surveys consumers regarding their satisfaction with the design, content, and appeal of their new car, and is conducted after the first three months of ownership. The Initial Quality Study$^{SM}$ (IQS) captures problems experienced by owners regarding quality of design, and defects and malfunctions, during the first three months of ownership. The Customer Service Index (CSI) Study$^{SM}$measures their satisfaction with the dealer's maintenance and repair services during the first three years of ownership. Finally, the Vehicle Dependability Study$^{SM}$ (VDS) reports the number of problems experienced during the past twelve months by original owners of three-year-old cars.

The customer satisfaction index for a car sold in year $t$ includes the APEAL and IQS indices in year $t+1$, and the CSI and VDS indices in year $t+3$, given the different times at which each study is conducted. Further, observe that a larger customer satisfaction is measured by a larger index for both APEAL and CSI, and a smaller index for both IQS and VDS. Then the index of customer satisfaction that we compute for brand $j$ sold at year $t$ is $ICS_{j,t} = \frac{APEAL_{j,t+1}}{IQS_{j,t+1}} * \frac{CSI_{j,t+3}}{VDS_{j,t+3}}$. Table 1 shows the the top and bottom quartile of the index for selected years of the last decade for non-luxury brands that were still operating in 2012. Observe that Honda, Toyota and Buick have consistently appeared among the brands with higher satisfaction. In the bottom half, recurring brands include Dodge, Volkswagen and Suzuki[9].

Table 1: Customer Satisfaction

| **Top Brands** | | | **Bottom Brands** | | |
|---|---|---|---|---|---|
| **2004** | **2007** | **2010** | **2004** | **2007** | **2010** |
| Buick | Buick | Honda | Dodge | Volkswagen | MINI |
| Honda | Toyota | Toyota | Nissan | Dodge | Volkswagen |
| Toyota | Honda | Mazda | Kia | MINI | Jeep |
| GMC | Ford | Buick | Mazda | Mitsubishi | Mitsubishi |
| Hyundai | Hyundai | Chevrolet | Volkswagen | Jeep | Dodge |
| Subaru | Chevrolet | GMC | Suzuki | Suzuki | Suzuki |

A consumer satisfied with a new car is more likely to repeat purchase of the same brand, which would increase the demand for that brand. However, she might postpone the decision to replace the used car, and as a result the supply of used cars would reduce. To verify these assessments, we compute unweighted Pearson and Spearman (rank) correlation coefficients between the 2007 index of customer satisfaction we constructed, and three indicators from the automotive industry in 2012: customer loyalty, sales of new cars per model, and the percentage of cars retained by

[9] The index is available from the author upon request.

the original lessee, as a proxy for the disposal rates of used cars[10]. We also calculate the average difference between top and bottom brands (in terms of customer satisfaction) for each of these three indicators. We use a lag of five years because, on average, buyers of new cars replace them after five years of ownership. Also, most car leases last five years. As shown in Table 2, we reject the null hypothesis that (i) there is no relationship between customer satisfaction and the three indicators employed, and (ii) there are no differences between the means of top and brands in terms of customer satisfaction. Then, brands with higher customer satisfaction should exhibit higher loyalty and larger sales per model. Also, owners of those brands should choose to keep it for a longer time.

Table 2: Correlation Analysis between Customer Satisfaction and Other Indicators from the Automotive Industry

| | Brand Loyalty | Sales per Model | Lease Retention |
|---|---|---|---|
| Pearson Correlation | 52.98% | 51.66% | 62.38% |
| (P-value) | (2.37%) | (2.82%) | (1.71%) |
| Spearman Rank Correlation | 59.06% | 58.10% | 65.79% |
| (P-value) | (0.99%) | (1.15%) | (1.05%) |
| Top brands | 54.44% | 82,184 | 14.23% |
| Bottom brands | 36.78% | 47,238 | 8.91% |
| Difference, t-test | 17.67% | 34,947 | 5.31% |
| (P-value) | (0.32%) | (4.26%) | (2.36%) |

## 1.2 Related Literature

Within the literature on durable goods markets[11], our article is closely related to those that analyze the interaction between markets of new and used goods in the context of adverse selection[12]. Hendel and Lizzeri (1999) study a model in which consumers with high valuation of quality purchase new goods and sell their used goods to low-valuation consumers. Adverse selection arises because buyers of used goods cannot observe the quality of the good. Other articles include Hendel and Lizzeri (2002), and Johnson and Waldman (2003), who show that leasing of new goods helps eliminate the asymmetry in information, as dealers have no information on leased cars that are returned.

Although our article shares many features with those models, there are some important differences. First, in our model buyers also face uncertainty when purchasing a new good. We thus uncover other patterns of consumer behavior that had not been previously identified. Second, as one of our objectives is to understand the effects of experience, we abstract from explicitly introducing asymmetric information. As a result, we find that incomplete trade always arises, as owners of used goods prefer keeping it when they got a good experience because the overall quality of the

[10] The index of customer loyalty was collected from J.D. Power and Associates' 2012 Customer Retention Study$^{SM}$, press release from January 11, 2012. Sales data was obtained from Automotive News from January 6, 2014. Lease data comes from CNW Marketing Research, document 470, retrieved October 31, 2013.

[11] See the survey by Waldman (2003) for other developments on the theoretical front. Recent empirical articles includeGavazza (2011) and Schiraldi (2011), among others.

[12] Akerlof (1970) show that adverse selection can cause too little trade in a secondhand market, but he did not consider the interaction with the primary market.

replacement is uncertain. Finally, incomplete trade is ex–post efficient as long as the match of a buyer of used goods with a particular vintage and brand depends only on her previous experience with that brand, and not on the experience of the previous owner.

Our article also belongs to the growing literature on experience goods that examines the behavior of consumers with idiosyncratic experience[13], including Crémer (1984), Villas-Boas (2004, 2006), Bergemann and Valimaki (2006), and Doganoglu (2010)[14]. These models study consumers who share the expectation about the uncertain quality of a non-durable good they have not purchased before, and become differentiated once they buy the product and learn the idiosyncratic value of their match[15]. Our model extend that literature to study durable goods markets, with two important differences. First, we are the first to examine idiosyncratic experience for consumers who are vertically differentiated regarding their valuation of quality. Second, in contrast to the articles mentioned above, in our model the match of consumers with a given brand can change over time.

The articles by Villas-Boas (2004, 2006) and Doganoglu (2010) are closer in spirit to ours as both assume horizontally-differentiated consumers[16]. In a two-period model, Villas-Boas (2004) studies how the informational advantage obtained by past customers affects firms' pricing decision, which he finds to depend on the skewness of the distribution of consumer experiences. Villas-Boas (2006) extends the analysis to an infinite horizon model with overlapping generations of consumers to study how firms compete for both experienced and first-time consumers. Doganoglu (2010) follows Villas-Boas (2006), but assumed experienced customers who incur a switching cost when buying another brand. He determines sufficient conditions for the existence of an equilibrium in which consumers with low realizations of experience prefer to switch brands with positive probability.

Few articles have analyzed the interaction between durability and experience, and most of them have focused on the obsolescence decision by a monopolist producer. Johnson (2011) finds that transaction costs in the secondhand market can raise the monopolist's profits, while its choice of durability may not always minimize costs. In his model, the durable good always supplies the same utility, but may break with positive probability. Also, consumers' valuation of quality change every period, so they have no incentive to replace the good. Strausz (2009) considers a repeated game in continuous time, with a single consumer purchasing a good characterized with observable durability and unobservable quality that does not depreciate. He finds that consumer's replacement decision gives the firm incentives to provide an adequate quality level but with reduced durability. Finally, Dener (2011) examines the effect of exogenous quality uncertainty on the firm's time inconsistency problem in a two-period model with two types of consumers. She finds that the Coase Conjecture

[13]Research on experience goods focused initially on firms' strategies to overcome the asymmetric information problem, either by signaling high quality or by building a reputation. See Riordan (1986), and Milgrom and Roberts (1986).

[14]Some empirical work have also examined the importance of idiosyncratic experience on consumer behavior, but mostly on non-durable goods, including Crawford and Shum (2005) on anti-ulcer drugs, Erdem and Keane (1996) on laundry detergents, and Ackerberg (2003)on yogurts.

[15]In contrast, with common experience all consumers who buy the product obtain the same experience. See Bergemann and Valimaki (1996) and the literature thereafter.

[16]Both Crémer (1984) and Bergemann and Valimaki (2006) assumed homogeneous consumers.

can be solved when the quality dispersion of a durable good is very large, similar to the effect caused by planned obsolescence.

## 2 The Model

Consider an infinite-horizon economy in discrete time, with a unit mass of consumers born at the beginning of time, and no new consumers entering the economy at any other time.Consumers live forever and have the same discount factor $\delta$. They demand at most one unit of a durable good, which lasts up to two periods.

Let $\mathcal{J}$ denote the set of brands available in the market. For each brand $j \in \mathcal{J}$, the quality $(q_j)$ of the durable good has an *observable* $(v_j)$ and an *unobservable* $(z_j)$ dimension. The observable quality $v_j$ encompasses the set of characteristics that consumers can inspect before purchase. It is deterministic and affected by obsolescence: a new vintage of the good has observable quality $v_j^N$, but after one period of usage its quality falls to $v_j^U$. Obsolescence is assumed to be exogenous, and can be physical (i.e., the good depreciates) or technological (i.e., each new vintage reduces the quality of the previous generation). From the viewpoint of consumer behavior, both forms of obsolescence have the same effects on their gross utility. We define the obsolescence level of each vintage as $v_j^{\triangle} \equiv v_j^N - v_j^U$.

In contrast, $z_j$ represents the consumer's match with the set of attributes of the durable good that the consumer cannot observe before purchase. The consumer learns the value of $z_j$ after using the good for one period. As with $v_j$, we assume that $z_j$ can take two values[17], i.e., the consumer can enjoy a good match $(z_j^H)$, or a bad match $(z_j^L)$. We define $z_j^{\triangle} \equiv z_j^H - z_j^L > 0$. Consumers' memory about past experiences lasts for $T$ periods, which means that, with time, old experiences become irrelevant[18]. By assuming that $T < n(\mathcal{J})$, we ensure that there are always some brands that the consumer has not experienced. For consumer $i$, let $\mathcal{J}_i^O$ denote the subset of brands that she has owned in the last $T$ periods, while $\mathcal{J} \setminus \mathcal{J}_i^O$ is her subset of unknown brands.

We assume experience is *idiosyncratic*: given a vintage of the good, some consumers will enjoy a good match, while others will get a bad match. Then, information about one consumer's past experiences is of no use to another consumer. Further, experience is *vintage-specific*: if a consumer got experience $z'$ in her last purchase of a given brand, she may get a different match when she buys again a good of the same brand but of a different vintage[19]. Also, experience is *brand-specific*: a consumer who purchases the good from one brand gets no information about her match with other brands.

For any brand $j \in \mathcal{J} \setminus \mathcal{J}_i^O$, the expected experience of a prospective buyer is given by $E_j(z)$. For any brand $j \in \mathcal{J}_i^O$, the buyer believes that her experience is conditional on the match she got with

[17] A discrete state space allows us to obtain closed-form solutions for the consumer's dynamic, stochastic discrete-choice problem, and gives us more flexibility to introduce extensions.

[18] In other words, experience becomes obsolete after $T$ periods. The results do not change qualitatively if we assume instead that experience depreciates every period (e.g. at the same rate than quality).

[19] The consumer gets the same experience only when she bought a new good last period and keeps the used good today, or when she sells it but decides to buy a used good of the same brand.

her *latest* purchase of that brand[20]. If $z_j'$ denotes the last experience with brand $j$, then she expects $E_j\left(z/z_j'\right)$. Further, if $z_j' = z_j^H$, then $E_j\left(z/z_j^H\right) > E_j(z)$, but if $z_j' = z_j^L$, then $E_j\left(z/z_j^L\right) < E_j(z)$. We assume these beliefs are common knowledge across the population.

Hence, experience introduces *ex-post* differentiation within the subset of consumers who have bought a given brand, explaining why some consumers choose to stay loyal while others switch brands. The assumptions on the dynamics of experience are a reflection of the frequency of upgrades and modifications introduced by producers, which can change the consumers' match with a particular brand. Also, the latest experience obtained with a brand provides a consumer with a better conjecture of her current match with that brand, but it is still an imperfect conjecture of what to expect in her next purchase of that brand.

Consumer preferences are characterized by the pair $(\theta, \mu)$, where $\theta$ and $\mu$ denote the consumer's idiosyncratic valuation for observable and unobservable quality, respectively. Let $F(\theta)$ be the cumulative distribution function for $\theta$, defined on the interval $\left[\underline{\theta}, \overline{\theta}\right]$. In turn, $\mu$ has cumulative distribution function $G(\mu)$ defined on the interval $\left[\underline{\mu}, \overline{\mu}\right]$. Both $F(\cdot)$ and $G(\cdot)$ are continuous and increasing, and have densities $f(\theta)$ and $g(\mu)$, respectively. Then, $\theta v + \mu z$ is the gross utility[21] for a consumer that owns a good of quality $q = (v, z)$. Both $\theta$ and $\mu$ are independent of each other, fixed throughout the consumer's life, and known only by the consumer.

Let $y_j^N$ and $y_j^U$ be the constant flow of new and used units of brand $j$ coming into the market every period. We thus allow the possibility that firms continue supplying an old generation, although for most of the analysis we assume $y_j^U = 0$. We define $Y^q = \sum_{j \in \mathcal{J}} y_j^q$, and assume $2Y^N + Y^U < 1$ so that there are always some consumers who do not own a unit of the durable good, which means that the price of the old vintage is well defined. Then, we analyze how a given output flow is allocated in equilibrium under conditions of uncertainty and experience, and ignore how market structure and cost conditions may lead to this exogenous output.

We examine the following market configurations:

- In the first framework we assume a frictionless secondhand market in which owners of a used good who want to replace a used good with a new one can sell it to another consumer. In turn, firms stay inactive in this secondary market, and sell only new vintages of the good[22]. In this context, we interpret obsolescence as physical and determined by the firm when the good was manufactured. Then, $v_j^{\triangle}$ represents the quality depreciation of the good. This framework is more characteristic of products like cars and motorcycles, where technological progress is minor, and the secondary market is well developed. We use this framework to analyze the effects of experience in markets of durable goods.

[20] This "Markov property" is assumed for simplicity. It is sufficient to assume that the last experience has a weight larger than 50%.

[21] We can also write the consumer's gross utility as $\theta\left[\mu v + (1-\mu) z\right]$, where $\theta$ is the consumer's valuation of quality, while $\mu$ measures the consumers' weight of the importance of each quality component. Then $\theta_v \equiv \theta\mu$ and $\theta_z \equiv \theta(1-\mu)$.

[22] It is possible that firms buy back used goods from buyers of new goods, but then sell them back in the secondary market.

- In the second framework, we assume there is no secondhand market, so a consumer who wants a new good would throw the used one away. This framework corresponds more closely to markets subject to continuous technological progress that lead to the introduction of new and more advanced models more frequently. Then, obsolescence is technological, and $v_j^{\triangle}$ represents the utility value of the upgrade. We use this framework to analyze the effects of durability in markets of experience goods.

Given the stationarity of the environment, we focus on symmetric equilibrium outcomes at the steady state, except in subsection 6.2. where we explore differences across brands. Then, $v = \{v^U, v^N\}$ and $z = \{z^L, z^H\}$ for all brands at all times. In turn, consumers' beliefs about their expected experience can be summarized by the vector of match probabilities $\boldsymbol{\pi}_e = \left(\pi_e^L, \pi_e^0, \pi_e^H\right)$, where $\pi_e^0$ is the consumers' expected probability of a good match with an unknown brand, while $\pi_e^L$ and $\pi_e^H$ denote their belief of getting a good match when the last experience with that brand was $z' = z^L$ and $z' = z^H$, respectively.

# 3 Optimal Consumer Behavior

Consumer behavior involves a sequence of decisions regarding the vintage and brand of the good to own every period, taking into account the experience enjoyed last period. The consumer *stays loyal* to a brand if she buys the same brand she owned last period; otherwise she *switches* brands. But her decision also depends on whether she still owns the good consumed last period. A consumer is a *buyer* if she owns no good at the beginning of the period, and an *owner* if she bought a new good last period.

A buyer must decide whether or not to purchase one unit of the durable good. If she buys it, she must also choose the brand and vintage (new or used) of the good. Let $p_j^N$ and $p_j^U$ denote, respectively, the prices of a new and a used good of brand $j$. Given her pair $(\theta, \mu)$ and her past history $H_i$, her expected value function in a steady-state equilibrium is:

$$V_i^{BUY}(\theta, \mu | H_i) \equiv \max\left\{V_i^N(\theta, \mu | H_i),\ \ V_i^U(\theta, \mu | H_i),\ \ 0\right\} \tag{1}$$

where $V_i^N(\theta, \mu | H_i)$ and $V_i^U(\theta, \mu | H_i)$ denote the expected value of purchasing a new good and an old good, respectively. Both are defined as follows:

$$V_i^N(\theta, \mu | H_i) = \max\left\{\begin{array}{c} \left\{\theta v_j^N + \mu E_j\left(z | z'_{ij}\right) - p_j^N + \delta E V_i^{OWN}\left(\theta, \mu | z'_{ij}\right)\right\}_{j \in \mathcal{J}_i^O}, \\ \left\{\theta v_j^N + \mu E_j(z) - p_j^N + \delta E V_i^{OWN}(\theta, \mu)\right\}_{j \in \mathcal{J} \setminus \mathcal{J}_i^O} \end{array}\right\} \tag{2}$$

$$V_i^U(\theta, \mu | H_i) = \max\left\{\begin{array}{c} \left\{\theta v_j^U + \mu E_j\left(z | z'_{ij}\right) - p_j^U + \delta E V_i^{BUY}\left(\theta, \mu | z'_{ij}\right)\right\}_{j \in \mathcal{J}_i^O}, \\ \left\{\theta v_j^U + \mu E_j(z) - p_j^U + \delta E V_i^{BUY}(\theta, \mu)\right\}_{j \in \mathcal{J} \setminus \mathcal{J}_i^O} \end{array}\right\} \tag{3}$$

where $z'_{ij}$ represents the last experience that consumer $i$ enjoyed with brand $j \in \mathcal{J}_i^O$. Observe that buyers of new goods become owners of a used good next period, while buyers of used goods will own no good at the beginning of next period. But their value function next period also depends on the experience they would enjoy today.

In turn, an owner of a used good of brand $j \in \mathcal{J}_i^O$ must decide whether she keeps that used good. If she does, she enjoys the used good today, and becomes a buyer next period. If not, she sells it and becomes a buyer today. Her expected value function can be written as:

$$V_i^{OWN}(\theta,\mu|H_i) = \max \left\{ \begin{array}{c} \theta v_j^U + \mu z'_{ij} + \delta EV^{BUY}\left(\theta,\mu|z'_{ij}\right), \\ \mathbf{1}^S\left(p_j^U\right) + EV^{BUY}\left(\theta,\mu|z'_{ij}\right) \end{array} \right\} \tag{4}$$

where $\mathbf{1}^S$ is an indicator function of the existence of a secondhand market.

In the remainder of this Section we characterize the optimal behavior of a consumer with preferences given by $(\theta,\mu)$, by identifying the brand and vintage of the good she would consume. We expect that consumers with higher $\theta$ prefer new goods, while those with lower $\theta$ buy used goods. However, with experience, some consumers may find optimal to choose the vintage of the good based on their previous experience. Further, among buyers of new goods, some of them can decide to keep the good when used. We proceed as follows. First, we examine the optimal choice for buyers of old goods. Then, we analyze utility maximization of buyers of new goods. Finally, we explore the behavior for buyers whose choice of the vintage of good depends on their past experience. In addition to her own preferences, each consumer takes the vectors of market prices $\mathbf{p} = \left(p^N, p^U\right)$ and expected match probabilities $\boldsymbol{\pi}_e = \left(\pi_e^L, \pi_e^0, \pi_e^H\right)$ as given. For convenience, we define $p^R \equiv p^N - \delta \cdot \mathbf{1}^S\left(p^U\right)$, while $p^{\triangle} \equiv p^R - p^U$. When $\mathbf{1}^S(\cdot) = 1$, then $p^R$ represents the good's "rental" price.

### 3.1 Buyers of Used Goods

Consider the set of consumers who decide to buy a used good every period. Their expected utility in equation (1) reduces to $V^{BUY}(\theta,\mu|H_i) = \max\left\{V^U(\theta,\mu|H_i), 0\right\}$. Thus, they behave as if they were buying a non-durable good. The following Proposition describes their optimal behavior.

**Proposition 1.** *Optimal behavior for consumers who buy used goods every period depends on their experience with the good owned last period: they stay loyal after a good match, but switch to an unknown brand after a bad match.*

Hence, for buyers of used goods, the experience with the brand owned last period is the only relevant information for the decision to stay loyal or switch brands. Her latest experience with any other brand $j \in \mathcal{J}^O$ must have been a bad match, otherwise she would have continued buying that brand. By the same reasoning, if she has had previous experiences with the current brand, she must have had only good matches. As shown in the proof, the expected present value of the buyer's utility, denoted by $U_U^U\left(\theta,\mu|z^L\right)$, can be written as a weighted average of staying loyal to a brand and switching to an unknown brand, with a larger weight for staying loyal when $z' = z^H$.

Although the consumer's valuation of experience does not affect the decision of which brand to buy, it does affect the decision whether or not to buy a good. If a consumer who has never bought the durable good decides to buy a used one for the first time, her expected utility would be equivalent to that of an experienced consumer who has had a bad match in her last purchase of every brand she has bought in the last $T$ periods. Following Proposition 1, such experienced consumer would buy a used good of an unknown brand. Hence, a consumer of type $(\theta,\mu)$ would never buy a used good if $U_U^U\left(\theta,\mu|z^L\right)<0$ . Let $\theta_U^U(\mu)$ denote the marginal consumer for whom $U_U^U\left(\theta_U^U(\mu),\mu|z^L\right)=0$. We obtain the decreasing, continuous function:

$$\theta_U^U(\mu)\equiv\frac{p^U-\mu\widehat{z}}{v^U},\quad\text{with}\quad\widehat{z}\equiv\frac{\delta\pi_e^0}{1-\delta\left(\pi_e^H-\pi_e^0\right)}E\left(z|z^H\right)+\frac{1-\delta\pi_e^H}{1-\delta\left(\pi_e^H-\pi_e^0\right)}E\left(z\right). \tag{5}$$

Hence, any consumer with $\theta>\theta_U^U(\mu)$ chooses to own a durable good. Given that $\theta_U^U(\mu)$ decreases with $\mu$, then consumers with low $(\theta,\mu)$ prefer to stay out of the secondary market.

### 3.2 Buyers of New Goods

When we characterize the behavior of consumers who always purchase new goods as buyers, we must study their choice as owners regarding when to keep the used good. Given preferences $(\theta,\mu)$, the decision of an owner depends on (i) the experience enjoyed last period with the good and (ii) the expected experience with the next purchase. The next result characterizes her behavior:

**Proposition 2.** *For consumers with type $(\theta,\mu)$ that only buy new goods, optimal behavior is characterized by a continuous, strictly increasing function $\theta_N^N(\mu)$ that satisfies:*

$$\theta_N^N(\mu)=\frac{p^{\triangle}}{v^{\triangle}}+\frac{1-\pi_e^H}{1-\delta\left(\pi_e^H-\pi_e^0\right)}\mu\frac{z^{\triangle}}{v^{\triangle}} \tag{6}$$

*such that an owner keeps her used good after a good match if her valuation of quality is smaller than $\theta_N^N(\mu)$, otherwise she sells her used good and buys a new one of the same brand. They all sell a used good after a bad match, switching to an unknown brand.*

Then, experience also affects the replacement decision of an owner. Concretely, $\theta_N^N(\mu)$ defines a cutoff rule after a good match: owners with $\theta\geq\theta_N^N(\mu)$ replace the used good with a new one of the same brand, while all others keep their used good, and buy a new good of the same brand next period. However, they all discard the used good for a new one of another brand after a bad match. If a secondary market exists, they sell the used good to another consumer, otherwise they throw it away. Observe that, among buyers of new goods with $\theta<\theta_N^N(\mu)$, it is possible that, given two consumers with valuations of observable quality $\theta'$, $\theta''$, such that $\theta'>\theta''$, the consumer of type $\theta'$ could own a used good, while the one with $\theta''$ could boast a recently-bought new good.

The consumer's importance given to experience also influences the owner's decision whether or not to keep a used good. As $\theta_N^N(\mu)$ is a strictly increasing function, it is more likely that an owner keeps a used good after a good match if her valuation of experience is fairly large. When experience is idiosyncratic and non-permanent, an owner that got a good match still faces uncertainty regarding her match with a new good of the same brand. This would induce her to keep a used good, given that she has already realized the experience she can enjoy with that vintage of the brand.

### 3.3 Buyers who choose the Vintage based on Experience

We have unveiled that the consumer's previous experience affects (i) her decision as a buyer on whether to stay loyal or switch brands, and (ii) her decision as an owner on whether to keep or replace a used good. However, experience can also affect her decision as a buyer on whether to purchase a new or a used good. Given that the consumer's utility is increasing in both dimensions of quality, intuition suggests that, if a buying behavior based on experience exists, it would show consumers buying a used good after a bad match, and a new good after a good match. The next result discusses the feasibility of such behavior:

**Proposition 3.** *Define the following two continuous, strictly decreasing functions:*

$$\theta_N^K(\mu) = \frac{p^\triangle}{v^\triangle} - \frac{\delta\pi_e^0\left(1-\pi_e^H\right)}{1-\delta^2\left(1-\pi_e^0\right)\left(\pi_e^H-\pi_e^0\right)}\mu\frac{z^\triangle}{v^\triangle} \tag{7}$$

$$\theta_U^K(\mu) = \frac{p^\triangle}{v^\triangle} - \frac{\delta\pi_e^H\left(1-\pi_e^H\right)}{1-\delta\left(\pi_e^H-\pi_e^0\right)}\mu\frac{z^\triangle}{v^\triangle} \tag{8}$$

*For any given valuation of experience $\mu$, optimal behavior for a buyer of type $\theta \in \left[\theta_U^K(\mu), \theta_N^K(\mu)\right)$ is to purchase a used good after a bad match, and a new good after a good match. As an owner, she keeps her used good if she got a good match, but trades it and buys a used good of an unknown brand if she got a bad match.*

For given $\mu$, the function in equation (7) defines a cutoff rule for buyers regarding what to do after a *bad* match: those with $\theta \geq \theta_N^K(\mu)$ decide to buy a new good, while those with $\theta < \theta_N^K(\mu)$ choose a used good. In turn, equation (8) is a cutoff rule after a *good* match: those with $\theta \geq \theta_U^K(\mu)$ prefer a new good, while those with $\theta < \theta_U^K(\mu)$ go for a used one. As buyers who got a good match expect a higher experience, they have a larger willingness to pay for any vintage than buyers who got a bad match, but they have a stronger preference for a new good because it lasts longer. As a result, $\theta_U^K(\mu) < \theta_N^K(\mu)$ for any vector of prices, which means that $\theta_U^K(\mu)$ characterizes the lowest consumer of type $\mu$ that buys a new good. Observe also that, as both cutoffs decrease with $\mu$, then buyers with higher valuation of experience are more likely to purchase new goods, regardless of their last experience.

Hence, buyers with $\theta \in \left[\theta_U^K(\mu), \theta_N^K(\mu)\right)$ choose the vintage to purchase based on their last experience. As owners, they still prefer to keep a used good after a good match, rather than trade it. After a bad match, these consumers are very reluctant to try a new good of an unknown brand, so they choose to buy a used good instead. If their previous purchase was a new good, then they would be "trading down" to a good of lower quality. In contrast, after a good match, the uncertainty regarding that brand is reduced and the consumer's belief about getting again a good match is higher. If her last purchase was a used good, then she would be "trading up" to a good of higher quality.

## 4 Aggregate Behavior and Equilibrium

Based on the analysis in the previous Section, we have identified at most four possible purchasing behaviors that are optimal: two for buyers of new goods, one for buyers whose purchasing decision depends on their last experience, and one for buyers of used goods. For the former group, the two optimal strategies differ on what the consumer should do when she owns a used good that was a good match. In Figure 1 we illustrate these behaviors for any consumer with preferences $(\theta, \mu)$, for given vectors of prices $\mathbf{p} = \left(p^N, p^U\right)$ and match probabilities $\boldsymbol{\pi}_e = \left(\pi_e^L, \pi_e^0, \pi_e^H\right)$ when $\underline{\mu} = 0$. All buyers with $\theta \in \left[\theta_N^K(\mu), \overline{\theta}\right]$ prefer new goods, but only those with $\theta \in \left[\theta_N^K(\mu), \theta_N^N(\mu)\right)$ would choose to keep their old good after a good match. Consumers with $\theta \in \left[\theta_U^K(\mu), \theta_N^K(\mu)\right)$ would choose the vintage of the good depending on their last experience, while those with $\theta \in \left[\theta_U^U(\mu), \theta_U^K(\mu)\right)$ would prefer to purchase old goods every period. Finally, consumers with $\theta < \theta_U^U(\mu)$ never buy a good. In all cases, consumers switch brands if $z' = z^L$ but stay loyal if $z' = z^H$[23].

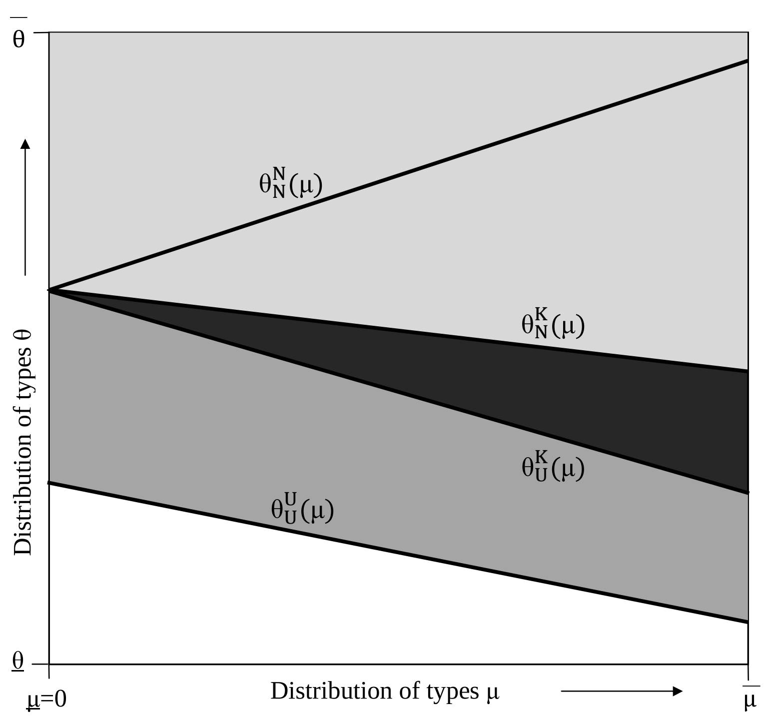


Figure 1: Optimal Purchasing Behaviors in a Stationary Symmetric Equilibrium

[23] Observe that, for non-equilibrium values of $p^N$ and $p^U$, it is possible that no types in the support of the distributions satisfy the conditions outlined here. For example, if the price of a new good is lower than that of a used good, then no one will buy used goods. In those cases some of the cutoffs will be at one of the boundaries.

To determine the equilibrium we need to identify the proportion of consumers with type $\theta \geq \theta_U^U(\mu)$ who, at any time, are (i) buying a new good, (ii) buying a used good, and (iii) keeping a used good. Let $\phi_{j,t}^v(\theta,\mu)$ be the proportion of consumers of type $(\theta,\mu)$ who would like to buy a good of vintage $v = N, U$ and brand $j$ in period $t$. The aggregate demand for a good of vintage $v$ is thus:

$$D_{j,t}^v = \int_{\underline{\mu}}^{\overline{\mu}} \left( \int_{\underline{\theta}}^{\overline{\theta}} \phi_{j,t}^v(\theta,\mu)\, dF(\theta) \right) dG(\mu)$$

Given that buyers that got a bad match would not repeat purchase of that brand for $T$ periods, demand for each brand and vintage includes buyers who have never tried that brand, as well as buyers who have already tried that brand and got a good experience last time.

The supply of new goods in every period was assumed to be constant and given by $S_{j,t}^N = y^N$. Instead, the supply of used goods in period $t$ includes (i) any net supply of the old vintage produced by each firm, and (ii) when there is a secondhand market, all consumers that bought a new good in period $t-1$, minus those who choose to keep the used good today. Let $\phi_{j,t}^K(\theta,\mu)$ denote the proportion of consumers of type $(\theta,\mu)$ who keep a used good of brand $j$ in period $t$[24]. Then the supply of used goods can be written as $S_{j,t}^U = y_{j,t}^U + \mathbf{1}^S\left(D_{j,t}^N - K_{j,t}\right)$, where $\mathbf{1}^S = 1$ when there is a secondhand market, while $K_{j,t}$ represents the set of all buyers of new goods who keep a used good as an owner, and is given by:

$$K_{j,t} = \int_{\underline{\mu}}^{\overline{\mu}} \left( \int_{\underline{\theta}}^{\overline{\theta}} \phi_{j,t}^K(\theta,\mu) \cdot dF(\theta) \right) \cdot dG(\mu).$$

We also require that buyers' beliefs regarding their expected experience are correct in equilibrium. Let $Z_{e,j,t}^v$ be the average expected experience for all consumers that buy a good of brand $j$ and vintage $v$ in period $t$, based on their beliefs about the probability of a good match, as reflected in $\boldsymbol{\pi}_e = \left(\pi_e^L, \pi_e^0, \pi_e^H\right)$. Then:

$$Z_{e,j,t}^v = \frac{1}{D_{j,t}^v} \left( \int_{\underline{\mu}}^{\overline{\mu}} \left( \int_{\underline{\theta}}^{\overline{\theta}} \left( z_{e,j,t}^v(\theta,\mu)\, \phi_{j,t}^v(\theta,\mu) \right) dF(\theta) \right) dG(\mu) \right)$$

where $z_{e,j,t}^v(\theta,\mu)$ represents the expected experience for consumers of type $(\theta,\mu)$ who buy a good of brand $j$ and vintage $v$, based on their beliefs. Let us also define the average expected experience for all buyers as $Z_{e,j,t} = \frac{D_{j,t}^N}{D_{j,t}^N + D_{j,t}^U} \cdot Z_{e,j,t}^N + \frac{D_{j,t}^U}{D_{j,t}^N + D_{j,t}^U} \cdot Z_{e,j,t}^U$.

On the other hand, we define $\boldsymbol{\pi}_x = \left(\pi_x^L, \pi_x^0, \pi_x^H\right)$ to represent the actual probabilities of enjoying a good match for all consumers, based on their last experience[25]. Then, the average experience for all buyers of a good of brand $j$ and vintage $v$ is:

$$Z_{x,j,t}^v = \frac{1}{D_{j,t}^v} \left( \int_{\underline{\mu}}^{\overline{\mu}} \left( \int_{\underline{\theta}}^{\overline{\theta}} \left( z_{x,j,t}^v(\theta,\mu)\, \phi_{j,t}^v(\theta,\mu) \right) dF(\theta) \right) dG(\mu) \right)$$

[24] For any type $\theta \geq \theta_U^U(\mu)$, we require that $\sum_j \rho_{j,t}^N(\theta,\mu) + \rho_{j,t}^U(\theta,\mu) + \rho_{j,t}^K(\theta,\mu) = 1$.

[25] As with $\boldsymbol{\pi}_e$, we also assume that $0 < \pi_x^L < \pi_x^0 < \pi_x^H < 1$.

where $z^v_{x,j,t}(\theta,\mu)$ is the average experience that a consumer of type $(\theta,\mu)$ enjoys when buying a good of brand $j$ and vintage $v$. Analogously, $Z_{x,j,t} = \frac{D^N_{j,t}}{D^N_{j,t}+D^U_{j,t}} \cdot Z^N_{x,j,t} + \frac{D^U_{j,t}}{D^N_{j,t}+D^U_{j,t}} \cdot Z^U_{x,j,t}$ denotes the average expected experience to be obtained by all buyers.

We say that consumers' beliefs are rational if $\boldsymbol{\pi}_e = \boldsymbol{\pi}_x$. If not, their beliefs are myopic. But, as the expectations in both markets must be correlated, we present two definitions of a symmetric equilibrium in a stationary economy:

**Definition 1.** *Let* $\mathbf{p} = \left(p^N, p^U\right)$ *be a vector of prices, and* $\boldsymbol{\pi}_e = \left(\pi^L_e, \pi^0_e, \pi^H_e\right)$ *a vector of match probabilities that represent consumers' beliefs. Then, in a stationary, symmetric economy:*
*(i) An industry-wide equilibrium is a pair of vectors* $(\mathbf{p}, \boldsymbol{\pi}_e)$ *that satisfy:*

$$D^U(\mathbf{p},\boldsymbol{\pi}_e) = S^U(\mathbf{p},\boldsymbol{\pi}_e), \qquad D^N(\mathbf{p},\boldsymbol{\pi}_e) = y^N, \qquad Z_e(\mathbf{p},\boldsymbol{\pi}_e) = Z_x(\mathbf{p},\boldsymbol{\pi}_e)$$

*(ii) A market-specific equilibrium is a pair of vectors* $(\mathbf{p}, \boldsymbol{\pi}_e)$ *that satisfy:*

$$\begin{aligned} D^U(\mathbf{p},\boldsymbol{\pi}_e) &= S^U(\mathbf{p},\boldsymbol{\pi}_e), & D^N(\mathbf{p},\boldsymbol{\pi}_e) &= y^N, \\ Z^U_e(\mathbf{p},\boldsymbol{\pi}_e) &= Z^U_x(\mathbf{p},\boldsymbol{\pi}_e), & Z^N_e(\mathbf{p},\boldsymbol{\pi}_e) &= Z^N_x(\mathbf{p},\boldsymbol{\pi}_e) \end{aligned}$$

**Proposition 4.** *In a stationary, symmetric economy:*
*(i) There exists an industry-wide equilibrium, even when consumers' beliefs are not rational.*
*(ii) There exists a market-specific equilibrium only when consumers' beliefs are rational.*

To be precise, the above Proposition states that rationality of consumers' beliefs is a sufficient condition for the existence of an equilibrium. But it is not a necessary condition for an industry-wide equilibrium, as we just require that $\frac{\pi^0_e}{1-\pi^H_e} = \frac{\pi^0_x}{1-\pi^H_x}$. Instead, for a market-specific equilibrium, in addition to the previous condition we also require that $\pi^H_e - \pi^0_e = \pi^H_x - \pi^0_x$, and both conditions can only be satisfied when $\pi^0_e = \pi^0_x$ and $\pi^H_e = \pi^H_x$. For both definitions, we also require that $\pi^L_e < \pi^0_e$, so that consumers never repeat purchase of a brand after a bad experience. The proof of existence of an equilibrium contains first the characterization of $\phi^N(\theta,\mu)$, $\phi^K(\theta,\mu)$ and $\phi^U(\theta,\mu)$ for each possible purchasing behavior. Then, it examines the conditions that the vector of consumers' beliefs $\boldsymbol{\pi}_e$ requires to satisfy for an equilibrium to exist. Finally, we construct a map for the price vector $\mathbf{p}$ in such a way that existence of a fixed point of this map would imply the existence of an equilibrium, and then we show that this map has indeed a fixed point.

# 5 Analysis and Discussion

In this Section we examine the implications of the equilibrium in terms of volume of trade in the secondhand market, customer loyalty, expected experience, buying behaviors, and prices. We define the volume of trade in the secondary market as the percentage of new goods that are sold when used. As in equilibrium buyers of new goods either replace or keep a used good, then:

$$VoT = 1 - \frac{K}{D^N}.$$

In turn, customer loyalty can be defined as the percentage of consumers that repeat purchase of the same brand they owned last period, regardless of its vintage. Let $\lambda^{v}_{j,t}(\theta,\mu)$ be the fraction of consumers with pair $(\theta,\mu)$ that are buying a good of vintage $v = N, U$ and brand $j$ in period $t$, given that they owned a good of brand $j$ in $t-1$ (which may have been bought that same period, or the period immediately before). Given the stationarity of the model, brand loyalty for each vintage of good is:

$$\Lambda^{v} = \frac{1}{D^{v}} \int_{\underline{\mu}}^{\overline{\mu}} \left( \int_{\underline{\theta}}^{\overline{\theta}} \lambda^{v}(\theta,\mu) \cdot \phi^{v}(\theta,\mu) \cdot dF(\theta) \right) \cdot dG(\mu).$$

The price of the old vintage can be obtained by using the fact that, at all times, the total mass of consumers owning a good must equal $2Y^{N} + Y^{U}$. Then we can solve for $p^{U}$ from:

$$1 - \int_{\underline{\mu}}^{\overline{\mu}} F\left(\theta_U^U(\mu)\right) \cdot dG(\mu) = \left(2Y^{N} + Y^{U}\right) \tag{9}$$

where $\theta_U^U(\mu)$ was determined in (5). To find the price of a new good, we use the equilibrium condition that $D^{N} = S^{N}$ to define it implicitly:

$$\int_{\underline{\mu}}^{\overline{\mu}} \left( \left[1 - F\left(\theta_N^N(\mu)\right)\right] + \frac{1}{1+\Gamma}\left[F\left(\theta_N^N(\mu)\right) - F\left(\theta_N^K(\mu)\right)\right] + \Gamma\Psi\left[F\left(\theta_N^K(\mu)\right) - F\left(\theta_U^K(\mu)\right)\right] \right) = Y^{N} \tag{10}$$

where $\theta_N^N(\mu)$, $\theta_N^K(\mu)$ and $\theta_U^K(\mu)$ were determined in equations (6), (7) and (8), respectively, while $\Gamma = \frac{\pi_x^0}{1-\pi_x^H+\pi_x^0}$ and $\Psi = \frac{1-\pi_x^H+\pi_x^0}{1-\pi_x^H+\pi_x^0+\pi_x^0\pi_x^H}$.

We organize this section as follows. First, we analyze how experience affects consumer behavior, volume of trade, and prices in markets of durable goods. Later, we discuss the effect of durability on customer loyalty, expected experience, consumer behavior and prices in markets of experience goods.

## 5.1 Effects of Experience in Markets of Durable Goods

To analyze the implications of the introduction of uncertainty regarding the quality of the good in a market of durable goods, we first characterize consumer behavior in a market with *durable non-experience* goods. In that benchmark model, consumers will be completely informed about the quality of the good. Concretely, suppose that each good has quality $q = (v, z_d)$ in the symmetric case, where $v = \left\{v^{U}, v^{N}\right\}$ as before, but $z_d$ is deterministic and the same for all brands. Suppose also that there is a secondhand market, but firms do not intervene in it by producing more units of the previous vintage, i.e. $Y^{U} = 0$. As all brands are ex-ante identical, the consumer has no incentive to switch brands. Her decision reduces to a choice between a used and a new good. Let $U_d^N(\theta,\mu)$ and $U_d^U(\theta,\mu)$ be the deterministic, discounted utilities for buying, respectively, a new and used good every period. We define the cutoffs $\theta_d^N$ and $\theta_d^U(\mu)$ so that $U_d^N\left(\theta_d^N,\mu\right) = U_d^N\left(\theta_d^N,\mu\right)$ and

$U_d^U\left(\theta_d^U(\mu),\mu\right)=0$. Given prices $\left(p_d^N, p_d^U\right)$, then:

$$\theta_d^N=\frac{p_d^{\triangle}}{v^{\triangle}} \quad \text{and} \quad \theta_d^U(\mu)=\frac{p_d^U-\mu z_d}{v^U} \tag{11}$$

where $p_d^{\triangle}=p_d^R-p_d^U$. In the stationary equilibrium, consumers with $\theta \geq \theta_d^N$ buy a new good every period, selling their used good in the process, while consumers with $\theta \geq \left[\theta_d^U(\mu), \theta_d^N\right)$ choose a used good. Prices are determined by the equilibrium conditions, which can be written as:

$$1-F\left(\theta_d^N\right)=Y^N \quad \text{and} \quad 1-\int_{\underline{\mu}}^{\overline{\mu}} F\left(\theta_d^U(\mu)\right)\cdot dG(\mu)=2Y^N \ . \tag{12}$$

### 5.1.1 Volume of Trade and Efficiency

Several papers in the durable goods literature have studied the existence of a secondhand market, ever since Akerlof (1970) found that adverse selection can shut it down. In the benchmark with durable non-experience goods, all buyers of new goods prefer to renew their good every period, so there is always full trade (i.e., $K=0$, so $VoT=1$). The following Proposition discusses how the introduction of uncertainty and experience affects volume of trade in durable goods markets.

**Proposition 5.** *In a stationary symmetric equilibrium with durable experience goods, the volume of trade is always positive but incomplete: the secondhand market never shuts down, but the volume is always less than 100%.*

Hence, there is always a positive mass of buyers of new goods who, as owners, decide to postpone the replacement of their used goods. For the secondary market shuts down, as in Akerlof (1970), then every buyer of a new good must strictly prefer to keep her used good, even after a bad match. But in such a case consumers will always get a higher utility by switching brands, rather than staying with a brand that does not suit their needs. On the other hand, for the possibility of full trade, as in the benchmark model, then all buyers of a new good must strictly prefer to sell her used good, even after a good match. But all used goods have the same price, and experience with a brand is vintage-specific. As a result, the price of a used good is not high enough to compensate consumers who got a good match from the risk of buying a new good of uncertain quality.

The most important consequence of this result is that, as long as experience involves idiosyncratic tastes for buyers of both new and used goods, then the absence of full trade is an ex-post efficient result. This contrasts the view from the adverse selection literature (e.g. Hendel and Lizzeri (1999) or Johnson and Waldman (2003)), where such lack of full trade has been interpreted as an indication of inefficiency. To understand the difference between both views observe that, in adverse selection models, only sellers in the secondhand market know the quality of used goods. Also, there are no idiosyncratic tastes. As social welfare is maximized when consumers with higher valuation consume higher quality, and with all used goods priced as providing the same quality, then asymmetric information has two effects: (i) it causes an inefficient allocation among the many types of buyers of used goods, and (ii) it forces owners of a used good of high quality to keep such good because the price is based on the average quality of a used good.

In contrast, when experience is entirely idiosyncratic, the expected utility for buyers of used goods depends only on their own past experience, and there are no informational gains from knowing the experience enjoyed by previous owners. Hence, there is no asymmetric information. As a result, (i) the allocation among buyers of used goods is efficient because they all get the same observable quality, while the expectation of a good or bad match depends on their previous experience, and (ii) some buyers of new good keep a used good as owners after a good match because of the importance they give to experience, as well as the uncertainty they face when trading it for a new good that may provide them a bad match.

The result in Proposition 5 has three further implications. First, inasmuch as incomplete trade is efficient, then any policy that attempts to achieve full trade, such as a tax on keeping a used good, or a subsidy to trade it, will actually reduce welfare, as they would lower consumers' expected utility. Second, observe that incomplete trade occurs regardless of the definition of equilibrium that we use. Finally, as some consumers with high valuation of quality keep the used good, then the mass of consumers that actually has the chance to acquire a new good is larger than when there is full trade. We return to this point when we discuss the effect of experience on prices.

### 5.1.2 Consumer Behavior and Leapfrogging

With durable, non-experience goods there are two optimal buying behaviors in equilibrium: every period consumers purchase either a new or a used good. The introduction of experience gives rise to two additional buying behaviors. On one hand, some buyers of new goods decide as owners not to replace a used good that provided them a good match. On the other hand, some consumers switch between new and used goods based on their past experience. In fact, the presence of both behaviors explains the result on incomplete volume of trade that we just discussed.

Both behaviors constitute evidence of leapfrogging, a concept introduced by Fudenberg and Tirole (1998), and defined as a situation in which some consumers with high valuation stay with an inferior good, while simultaneously some low-valuation consumers acquire a superior good. They find leapfrogging in a model with technological obsolescence but with no secondary market. In their two-period model, a durable-goods monopolist introduces an upgrade but, as there is no secondhand market, some of its former patrons (who have a higher valuation for quality than any new patron) prefer keeping the old vintage good rather than replacing it with the upgrade.

In our dynamic model we found leapfrogging because of the uncertainty in the good's quality, even when there is a secondhand market, and without making any assumption about the market structure or the information that firms possess about consumers' past behavior. Concretely, among consumers with $\theta \in \left[\theta_U^K(\mu), \theta_N^K(\mu)\right) \cup \left[\theta_N^K(\mu), \theta_N^N(\mu)\right)$, we can find a consumer with pair $(\theta', \mu')$ who owns an inferior, used good, while a consumer with pair $(\theta'', \mu'')$ buys a superior, new good, such that $\theta' \geq \theta''$ and $\mu' \geq \mu''$.

Furthermore, we distinguish two kinds of leapfrogging behavior:

- Consider a consumer with pair $(\theta', \mu')$, such that $\theta' \in \left[\theta_U^K(\mu'), \theta_N^K(\mu')\right) \cup \left[\theta_N^K(\mu'), \theta_N^N(\mu')\right)$. If she bought a new good last period and enjoyed a good match, today she will keep owning the now old vintage. Then, this consumer will be leapfrogged by those with pair $(\theta'', \mu'')$ that buy a new good, such that $\theta'' \in \left[\theta_U^K(\mu'), \theta'(\mu')\right)$ and $\mu'' < \mu'$. We define this behavior as *leapfrogging by ownership*.

- Consider now a consumer with $(\theta', \mu')$, such that $\theta' \in \left[\theta_U^K(\mu'), \theta_N^K(\mu')\right)$. If she bought a new good last period and enjoyed a bad match, today she will replace it with a used good. Then, this consumer will be leapfrogged by those with pair $(\theta'', \mu'')$ that buy a new good, such that $\theta'' \in \left[\theta_U^K(\mu'), \theta'(\mu')\right)$ and $\mu'' < \mu'$. We define this behavior as *leapfrogging by purchase*.

While the former is the type of leapfrogging identified by Fudenberg and Tirole, the latter is a consequence of experience, because there are consumers who prefer to acquire a good of inferior quality given the risk of trying an unknown brand whose overall quality is uncertain. Observe that both types of leapfrogging emerge regardless of the distribution of $\theta$ and $\mu$ across the population.

#### 5.1.3 Prices

To determine the effect of experience on the price of used durable goods, we compare the marginal buyers of a used good with and without quality uncertainty, represented by $\theta_U^U(\mu)$ and $\theta_d^U(\mu)$, respectively[26]. Assuming that the supply of new goods is the same in both frameworks, then $\int_{\underline{\mu}}^{\overline{\mu}} F\left(\theta_U^U(\mu)\right) \cdot dG(\mu) = \int_{\underline{\mu}}^{\overline{\mu}} F\left(\theta_d^U(\mu)\right) \cdot dG(\mu)$. As both $\theta_U^U(\mu)$ and $\theta_d^U(\mu)$ are linear in $\mu$, then there exists a $\mu' \in \left[\underline{\mu}, \overline{\mu}\right]$ such that $\theta_U^U(\mu') = \theta_d^U(\mu')$. If $z_d = E(z)$, then the introduction of uncertainty and experience unambiguously raises the price of used goods. To see this, observe that experience increases the expected utility of any consumer of type $(\theta, \mu)$, and as a result consumers that enjoyed a good match expect a higher utility by staying loyal to that brand. Even if they had a bad experience, they expect a higher utility by switching brands because they may get a good match. This *experience effect* is captured by the difference between $\widehat{z}$ and $E(z)$.

Instead, the effect of experience on the price of new goods is ambiguous. First, the experience effect just described is also present, as these consumers also have the choice to switch or stay loyal. There is also a *resale value effect* because of the larger price of a used good, which is actually an indirect consequence of the experience effect. But there is also a *marginal consumer effect.* Consumers with $\theta > \theta_U^K(\mu)$ will buy a new good at some point in their life, and some of them keep a used good after a good match. As $\int_{\underline{\mu}}^{\overline{\mu}}\left(\left[1 - F\left(\theta_U^K(\mu)\right)\right] > Y^N\right.$, then there are more consumers who have access to a new good in the equilibrium with experience. This shift of the marginal consumer pushes the price of new goods down, while the experience and resale value effects push the price of new goods up. The net effect depends on the distributions of $\theta$ and $\mu$ across the population.

### 5.2 Effects of Durability in Markets of Experience Goods

To understand the effects of durability in a market of experience goods, let us first characterize consumer behavior in a market of *non-durable experience* goods. In this framework, consumers have no incentive to switch between vintages, as all goods last one period. They behave in a similar

[26]They were defined in equations (5) and (11), respectively.

manner than the buyers of used goods characterized in Section 3.1, buying the same type of vintage every period, switching brands after a bad match and staying loyal after a good match. Without loss of generality, suppose each firm produces two vintages of the good: a new vintage with quality $q = \left\{v^N, z\right\}$, sold at effective price $p_x^R$, and an old vintage with quality $q = \left\{v^U, z\right\}$, sold at price $p_x^U$. In both cases, $z = \left\{z^L, z^H\right\}$ as before. Let $U_x^N(\theta, \mu)$ and $U_x^U(\theta, \mu)$ be the respective expected utilities. Then, consumers with $\theta \geq \theta_x^N$ buy the new vintage, while those with $\theta \in \left[\theta_x^U(\mu), \theta_x^N\right)$ purchase the old vintage. Both consumer thresholds are defined by:

$$\theta_x^N = \frac{p_x^{\triangle}}{v^{\triangle}} \quad \text{and} \quad \theta_x^U(\mu) = \frac{p_x^U - \mu\widehat{z}}{v^U} \tag{13}$$

where $p_x^{\triangle} = p_x^R - p_x^U$, and $\widehat{z}$ is as defined in equation (5). In equilibrium, prices are again determined from the conditions that demand equals supply in each market:

$$1 - F\left(\theta_x^N\right) = Y^N \quad \text{and} \quad 1 - \int_{\underline{\mu}}^{\overline{\mu}} F\left(\theta_x^U(\mu)\right) \cdot dG(\mu) = Y^N + Y^U \ . \tag{14}$$

For a suitable comparison with this benchmark, we assume in our model that obsolescence is technological, and that there is no secondary market. In that context, firms produce a new vintage that lasts two periods, and an old vintage that only lasts one period because it is the obsolete version of the product. Then, $p^R$ and $p^U$ constitute the prices of the new and the old vintage, respectively. However, we assume that the observable quality and the firms' supply of each vintage is the same with or without durability. Hence, the only difference is that, in our model, consumers can keep a new vintage for two periods.

### 5.2.1 Expected Experience and Brand Loyalty

When we classify buyers of any brand and vintage into those who stay loyal to that brand and those who switch brands, we realize that the concept of brand loyalty $(\Lambda^v)$ is closely related to that of expected experience $(Z_e^v)$. The expected experience of all buyers that decide to stay loyal is $E\left(z|z^H\right)$, as they all prefer to buy the same brand because last period they enjoyed a good match with that brand. The expected experience of any buyer that switches brands is $E(z)$, as they buy an unknown brand because they suffered a bad experience with some other brand last period. Hence, $Z_e^v$ must be a weighted average between $E(z)$ and $E\left(z|z^H\right)$, where $\Gamma = \frac{\pi_x^0}{1-\pi_x^H+\pi_x^0}$ is a weighted average of $\pi_x^0$ and $\pi_x^H$. In the benchmark model of non-durable experience goods, we obtain that $\Lambda^U = \Lambda^N = \Gamma$ and $Z_e^U = Z_e^N = \Gamma E\left(z|z^H\right) + (1-\Gamma)E(z)$. However, we get the following result when we introduce durability:

**Proposition 6.** *In a stationary, symmetric equilibrium with durable experience goods, brand loyalty and expected experience are both higher for buyers of new goods.*

The reason why durability has an impact on brand loyalty and expected experience lies on the existence of a non-negative mass of consumers who choose the vintage (new or old) based on experience. Consumers with $\theta \in \left[\theta_U^K(\mu), \theta_N^K(\mu)\right)$ choose to buy a used good because they had a bad experience with the good purchased last period. As a result, all of them are switching to another brand, and their expected experience is thus $E(z)$. In contrast, buyers of new goods in this subset include only consumers who enjoyed a good match last period. As they stay loyal, they all expect $E\left(z/z^h\right)$ in their next purchase. Hence, $\Lambda^U \leq \Lambda^N$ and $Z_e^U \leq Z_e^N$.

#### 5.2.2 Consumer Behavior and Prices

When experience goods are not durable, the market is segmented in consumers with higher valuation who prefer the new vintage, and those with lower valuation who opt for the old vintage. Durability allows consumers the possibility to switch between the new and the old vintage of the good, conditional on their past experience. Further it allows buyers of the new generation to use it for two periods. We denote the combination of these two features as the *durability effect*. However, the absence of a secondary market forces consumers to throw the used good away when they decide to replace it.

In any case, given our assumptions on quality and supply of both vintages, the durability effect lowers the price of the old vintage (i.e., $p^U \leq p_x^U$) because the consumers' decision to keep a used good after a good match increases the amount of goods consumed in the economy at any date. But a comparison of the prices of the new good with and without durability ($p^R$ and $p_x^R$, respectively) reveals that durability has an ambiguous effect. On one hand, the expected utility of buyers of new goods is larger when they had a good match with a new good, but is smaller when they had a bad match as they have to throw it away. On the other hand, as some consumers keep a used good, then for any $\mu$ the marginal consumer that buys a new good shifts down. We again require further information about the distributions of $\theta$ and $\mu$ across the population to determine which effect dominates.

## 6 Differences in Expected Experience

In the industry of durable experience goods analyzed so far we have assumed that consumers' beliefs about the probability of a good match is the same for all brands and all vintages. In this Section we expand the model to consider first the effect of differences in the expected experience between vintages. Later, we analyze the consequences of differences in the expected experience between brands.

### 6.1 Vintage Differences

We can think of two reasons that can explain differences in beliefs regarding the expected experience with a vintage. On one hand, when obsolescence is technological, consumers will have more information available on old vintages of the good, and their beliefs about those vintages would be more accurate. Thus, they can modify their own preferences towards old vintages and have a higher expect probability of good match. On the other hand, we found that most consumers replace a used good because they had a bad experience. When obsolescence is physical and there is a secondhand market, buyers of used goods might believe that experience is not entirely idiosyncratic, and expect to obtain a bad experience more often.

The simplest approach to examine the effects on an equilibrium with $\boldsymbol{\pi}_e^U \neq \boldsymbol{\pi}_e^N$ is to set $\boldsymbol{\pi}_e^N = \boldsymbol{\pi}_e = \left(\pi_e^L, \pi_e^0, \pi_e^H\right)$, while $\boldsymbol{\pi}_e^U = \beta \boldsymbol{\pi}_e$, where $\beta \in \left(0, \frac{1}{\pi_e^H}\right)$. But we continue to assume that all brands are ex-ante identical. We solve this extension with the same methodology used before, but setting $\boldsymbol{\pi}_e^U = \beta \boldsymbol{\pi}_e$. Appendix B contains specific details on every result that follows.

Regarding consumers' optimal buying behaviors, we find that the characterization of the optimal purchasing behaviors, illustrated in Figure 1, continues to apply as long as $\boldsymbol{\pi}_e^U < \beta^* \boldsymbol{\pi}_e$, where $\beta^* = \frac{1+\delta}{1+\delta \pi_e^H} > 1$. To be more precise, observe that differences between vintages affect only the cutoff functions that determine the existence of buyers who choose a vintage based on their past experience. For these experience-driven buyers, we solve again for $\theta_N^K(\mu, \beta)$ and $\theta_U^K(\mu, \beta)$ when $\boldsymbol{\pi}_e^U = \beta \boldsymbol{\pi}_e^N$, and obtain that $\theta_N^K(\mu, \beta) \geq \theta_U^K(\mu, \beta)$ as long as $(1-\beta) + \delta\left(1 - \beta \pi_e^H\right) \geq 0$, from which we determine $\beta^*$. Hence, behavior for experience-drive buyers continues to be as follows: as buyers, they purchase a used good after a bad match, and a new good after a good match; as owners, they keep her used good after a good match, but trade it after a bad match.

To understand the intuition for $\beta^* > 1$, observe that there are three effects at work. First, there is a *beliefs* effect, which depends on whether $\boldsymbol{\pi}_e^U$ is smaller or larger than $\boldsymbol{\pi}_e^N$. Second, the *durability* effect described in the last Section allows consumers to enjoy a larger utility when buying a new good, as they can use it for two periods. Finally, there is an *obsolescence* effect as $v^N > v^U$. When $\boldsymbol{\pi}_e^U = \boldsymbol{\pi}_e^N$, there is no belief effect, and the interaction of the durability and obsolescence effects leads experience-driven buyers to purchase a new good after a good match, and a used good after a bad match. This is also true when $\boldsymbol{\pi}_e^U < \boldsymbol{\pi}_e^N$ because the belief effect just reinforces the other two. But the belief effect is reversed when $\boldsymbol{\pi}_e^U > \boldsymbol{\pi}_e^N$, as the old vintage becomes more attractive, and thus undermines the durability and obsolescence effects, and completely offsets them when $\beta = \beta^*$. When $\beta \in [1, \beta^*]$, the combined effect of the durability and obsolescence still more than compensates the beliefs effect.

When $\boldsymbol{\pi}_e^U > \beta^* \boldsymbol{\pi}_e$, most optimal buying behaviors remain unaffected, except for experience-driven buyers, whose behavior is reversed as the belief effect dominates the gains from the other two effects. Their behavior as owners does not change but, as buyers, they now prefer a new good after a bad match, and a used good after a good match. However, we believe this case is just of theoretical interest, as we cannot think of an actual industry of durable experience goods in which consumers' beliefs are so strongly in favor of old vintages that they would prefer a used vintage after a good match, but a new vintage after a bad match.

In any case, we can prove that an equilibrium always exists when $\boldsymbol{\pi}_e^U = \beta \boldsymbol{\pi}_e^N$, by using the same methodology described in the proof of Proposition 4. More precisely, the set of industry-wide equilibria is larger as we no longer require that $\boldsymbol{\pi}_e^U = \boldsymbol{\pi}_e^N$. But, as long as there are experience-driven buyers (i.e., $\beta \neq \beta^*$), then market-specific equilibria still requires consumers to be rational, provided that $\pi_e^L < \pi_e^0$[27]. Further, even if there are no experience-driven buyers, there are still some buyers of new goods who will choose to keep it as used after a good match. As a result, there is always leapfrogging by ownership but, more importantly, the volume of trade is always positive but incomplete, for any $\beta$.

But the belief effect also has an impact on brand loyalty. When $\boldsymbol{\pi}_e^U \leq \boldsymbol{\pi}_e^N$, the belief effect reinforces the loyalty effect, and $\Lambda^N(\mathbf{p}, \boldsymbol{\pi}_e) > \Lambda^U(\mathbf{p}, \boldsymbol{\pi}_e)$. When $\beta \in (1, \beta^*)$, both effects work in opposite directions, but observe that $\Lambda^N(\mathbf{p}, \boldsymbol{\pi}_e) < \Lambda^U(\mathbf{p}, \boldsymbol{\pi}_e)$ when $\beta = \beta^*$. As a result, there exists a $\widehat{\beta} \in (1, \beta^*)$ such that loyalty is the same for both types of vintages. If the set of experience-driven buyers strictly decreases with $\beta$, then $\widehat{\beta}$ is unique, and $\Lambda^N(\mathbf{p}, \boldsymbol{\pi}_e) > \Lambda^U(\mathbf{p}, \boldsymbol{\pi}_e)$ whenever $\beta < \widehat{\beta}$.

Let us look more closely at the volume of trade when $\beta < 1$, as it would give us a more precise analysis of the effects of adverse selection. We find that the effect of a lower $\beta$ on volume of trade is ambiguous, and depends on the distribution of consumer preferences regarding both vintage and experience. To keep the analysis simple, suppose consumers are rational. Then, observe that a lower $\beta$ exerts a direct effect on consumer behavior, by reducing the gross expected utility that buyers can enjoy with an old vintage. As a result, more consumers would prefer a new good. But there is also an indirect effect because, given a fixed supply of new goods, in equilibrium the lower willingness to pay for an old vintage reduces $p^U$. Regarding $p^N$, both effects interact in opposite ways: the larger expected utility provided by a new good (compared to a used one) is thwarted by its lower resale value. If the direct effect dominates, then the price of a new good would increase.

However, when we examine the overall effect on the volume of trade, we notice that a lower $\beta$ entices more consumers to buy new goods, but it also widens the gap between $p^N$ and $p^U$ (assuming $p^N$ is increasing). If the former, direct effect is stronger, then there will be more buyers of new goods who would keep it as used when owners, and the volume of trade will be lower. However, a more thorough analysis would require to internalize the firms' decision regarding the amount of goods supplied each period.

## 6.2 Brand Differences

We have so far studied a market of durable experience goods with ex-ante identical brands: from the viewpoint of every consumer, any unknown brand provides the same expected experience, regardless of its vintage. But the empirical evidence in the Introduction revealed that brands are not identical. In this subsection we expand the model to consider brands that differ in their expected experience.

For the analysis, we introduce some simplifying assumptions. First, we assume that there are two brands, $A$ and $B$. Then, consumers' memory is limited to one period, i.e., they would recall only the experience enjoyed last period. Second, we focus on the case of rational consumers to reduce notation, so $\boldsymbol{\pi}_{e,j} = \boldsymbol{\pi}_{x,j}$ for $j = A, B$. Third, we assume that consumers' valuation of quality only takes two values, $\theta^N$ and $\theta^U$, with $\theta^N > \theta^U$, and focus on the case in which the price of new goods is high enough that only consumers with the highest valuation (i.e. $\theta^N$) get to buy a new good.

[27] Concretely, for any $\beta$ we still require that $\pi_e^{H,v} - \pi_e^{0,v} = \pi_x^{H,v} - \pi_x^{0,v}$ and $\frac{\pi_e^{0,v}}{1-\pi_e^{H,v}} = \frac{\pi_x^{0,v}}{1-\pi_x^{H,v}}$ for $v = N, U$, which is only satisfied when $\boldsymbol{\pi}_x^U = \beta \boldsymbol{\pi}_x^N$.

experience-driven buyers. Finally, we assume $Y^N = Y \leq \sigma$, where $\sigma$ is the fraction of consumers with $\theta^N$. By assuming that $\sigma \leq 1/2$, then some of the low-valuation consumers (i.e. $\theta^U$) will stay out of the market.

We introduce brand differences in the vector of match probabilities by assuming that $\boldsymbol{\pi}_A \gg \boldsymbol{\pi}_B$. Then, $E_A(z) > E_B(z)$ and $E_A(z/z') > E_B(z/z')$ for $z' = \{z^H, z^L\}$. We also set $\pi_B^H > \pi_A^0$ and $\pi_B^0 > \pi_A^L$, to prevent the possibility that (i) owners of brand $B$ switch to brand $A$ after a good match, and (ii) owners of brand $A$ stay loyal after a bad match. Otherwise, we can converge to an equilibrium in which consumers would have no interest in buying brand $B$.

We first solve this simplified model assuming identical brands. Then, there exists a consumer with pair $(\theta^N, \mu^N)$ such that buyers of new goods with $\mu > \mu^N$ prefer to keep a used good after a good match, while those with $\mu < \mu^N$ prefer to replace it. In turn, there is a consumer with pair $(\theta^U, \mu^U)$ such that those with $\mu > \mu^U$ buy a used good every period, while those with $\mu < \mu^U$ stay out of the market. The values of $\mu^N$ and $\mu^U$ are obtained from the equilibrium conditions in the market of new and used goods:

$$G(\mu^N) = \frac{Y}{\sigma} - \frac{1}{\Gamma}\left(1 - \frac{Y}{\sigma}\right) \quad \text{and} \quad G(\mu^U) = \frac{1-2Y}{1-\sigma}.$$

We require that $Y \geq \frac{1}{1+\Gamma}\sigma$ to avoid that $\mu^U \leq \overline{\mu}$. Regarding prices, from the definitions of $\mu^U$ and $\mu^N$ (which can be obtained from (5) and (6)), we get:

$$p^U = \theta^U v^U + \mu^U \widehat{z} \quad \text{and} \quad p^N = \theta^H v^{\triangle} + (1+\delta)\, p^U - \frac{(1-\pi_e^H)}{(1-\delta(\pi_e^H - \pi_e^0))}\mu^N z^{\triangle}. \tag{15}$$

As expected, a larger supply of new goods leads to less consumers with $\theta^H$ keeping their used goods after a good match, which increases the supply of used goods available for consumers with $\theta^L$. This lowers both $p^U$ and $p^N$. To understand the intuition on $p^N$ observe that, with a larger $\mu$, consumers' gross utility when keeping a used good grows. By the marginal consumer effect (represented by the last term), then a larger $Y$ implies a lower $p^N$ to motivate consumers to buy the new good. By the experience and resale value effects (represented respectively by the first two terms), consumers are also less willing to pay for the new good as they receive a lower payment when selling the used goods.

In addition to prices, we are interested in the effect of brand differences on customer loyalty, expected experience, and volume of trade in the secondary market. As there is no leapfrogging, then for all brands $\Lambda_j^N = \Lambda_j^U$ and $Z_j^N = Z_j^U$. When brands are identical, then $\Lambda^v = \Gamma$ and $Z^v = \Gamma E(z|z^H) + (1-\Gamma)E(z)$, where $\Gamma = \frac{\pi^0}{1-\pi^H+\pi^0}$ is a weighted average between $\pi^0$ and $\pi^H$. Regarding volume of trade, observe that we write it as $VoT_j = 1 - \frac{K_j}{D_j^N}$, where $K_j$ is the set of owners that do not replace their used goods. Then, a brand that shows a smaller volume of trade would also exhibit a larger proportion of consumers who keep a used good. With two identical brands, we get $K = \frac{1}{2}\frac{\Gamma}{1+\Gamma}\left[1 - G(\mu^N)\right]$ and $D^N = \frac{1}{2}\left(G(\mu^N) + \frac{1}{1+\Gamma}\left[1 - G(\mu^N)\right]\right)$.

Suppose now that brands differ in their expected experience. Our first result establishes a relationship between match probabilities and sales.

**Proposition 7.** *In a stationary equilibrium with durable experience goods and different brands, the brand with larger probability of a good match will always exhibit larger sales.*

Hence, a steady state equilibrium with $y_A = y_B$ exists if and only if $\boldsymbol{\pi}_A = \boldsymbol{\pi}_B$. When the probability of a good match is larger for one of the brands, then a larger proportion of consumers with pair $(\theta, \mu)$ will choose to own the best brand, regardless of their preferred buying behavior. Observe also that, as long as consumers switch after a bad experience and stay loyal after a good match, then differences in the gross utility provided by the unobservable dimension of quality will have no impact on sales.

We then proceed by setting $y_A > y_B$ so that $\mu_A^N = \mu_B^N = \mu^N$. In other words, the behavior among consumers who buy new goods is consistent regardless of the brand: owners with $\mu < \mu^N$ always replace their used goods, while those with $\mu \geq \mu^N$ always keep a used good after a good match. The following Proposition summarizes the impact of brand differences on the main market observables.

**Proposition 8.** *In a stationary equilibrium with durable experience goods and different brands, the brand with a larger probability of a good match exhibits a smaller volume of trade, a larger price for used goods, and higher customer loyalty. In addition, buyers of that brand expect to enjoy a larger experience with that brand.*

To explain the intuition behind brand $A$'s smaller volume of trade, observe that, as $\boldsymbol{\pi}_A > \boldsymbol{\pi}_B$, then more consumers demand brand $A$, as stated by Proposition 7. However, the proportion of buyers with pair $\left(\theta^N, \mu \geq \mu^N\right)$ that get a good match with brand $A$ is even larger, and they all decide not to replace their used good next period. Hence $\frac{K_A}{D_A^N} \geq \frac{K_B}{D_B^N}$, with equality only when $\mu^N = \overline{\mu}$, i.e., when the supply of new goods allows all consumers of type $\theta^N$ to buy a new good every period. As $S_j^U = D_j^N - K_j$, then $VoT_A > VoT_B$.

Regarding the effect on both customer loyalty and expected experience, recall that buyers who remain loyal to a brand are those who enjoyed a good match with that brand last period. Then, loyalty is higher for brand $A$ because it is the brand that gives a larger probability of a good match, regardless of the experience that motivated consumers to purchase that brand in the first place. Further, as the expected experience of all consumers who remain loyal to brand $A$ equals $E_A\left(z|z^H\right)$, and the proportion of consumers who get a good match with brand $A$ is larger, then $Z_A^v \geq Z_B^v$ for $v = U, N$.

Finally, to understand why a used good of brand $A$ would be more expensive, observe first that the percentage of used goods of brand $A$ available for purchase is lower because of the higher proportion of consumers with $\theta^N$ who want to keep a used car of that brand. Second, a larger proportion of consumers with $\theta^U$ demand brand $A$ because it offers a greater chance of enjoying a good experience. In particular, $\mu_A^L > \mu_B^L$. All these factors determine that $p_A^U > p_B^U$.

We can extend the results from Proposition 8 to cases in which the supply of new goods ($Y = y_A + y_B$) is (i) so high that even some low-type consumers can buy a new good, and (ii) so low that some high-type consumers are forced to buy a used good. To be more precise, as long as $\boldsymbol{\pi}_A > \boldsymbol{\pi}_B$, and the behavior of consumers who buy new goods is always consistent after a good match, then customer loyalty and expected experience will be higher for brand $A$. Moreover, a larger proportion of consumers will demand brand $A$, and on average those consumers will enjoy a higher expected utility. Then, the volume of trade of brand $A$ will be smaller, and its used goods will be more expensive.

A second way to introduce brand differences is to assume that the utility that a consumer can enjoy from experience is larger for brand $A$, so that $z_A^H \geq z_B^H$ and $z_A^L \geq z_B^L$. Suppose also that $z_B^H > z_A^L$, to avoid that consumers always prefer brand A. However, by Proposition 7, $y_A = y_B$ if and only if $\boldsymbol{\pi}_A = \boldsymbol{\pi}_B$, so $\mu_A^N = \mu_B^N$ and $\mu_A^U = \mu_B^U$. Hence, differences in experience outcomes by themselves will not have an effect on customer loyalty, expected experience and volume of trade in a steady-state equilibrium when consumers stay loyal after a good match and switch after a bad experience. But $p_A^U > p_B^U$ because $E_A(z) > E_B(z)$ and $E_A(z|z') > E_B(z|z')$ for $z' = \{z^H, z^L\}$, which means that the difference in expected utility from switching from $B$ to $A$ after a bad match is always larger than the difference from switching the other way around.

We finalize with some comments regarding the ambiguous effect of brand differences on prices of new goods. Recall that the effect of experience on $p^N$ was ambiguous because we found an experience effect and a resale value effect, which both push the price up, but also a marginal consumer effect, which pushes the price down. In essence, the impact of brand differences on prices of new goods depends on how those three effects change. For tractability reasons, we consider the case in which brands differ in their experience outcomes. Then $\boldsymbol{\pi}_A = \boldsymbol{\pi}_B$ but $z_A^H \geq z_B^H$ and $z_A^L \geq z_B^L$, so we abstract from the effects on volume of trade and customer loyalty. Then, the difference in prices of new goods between both brands can be written as:

$$p_A^R - p_B^R = \frac{1}{1-\delta}\left(\frac{(1+\delta)\left(1-\delta\pi^H\right)-\delta\pi^0(1-\delta)}{1+\delta\pi^H-\delta\pi^0}\left(p_A^U-p_B^U\right)-\frac{2\delta\left(1-\pi^H\right)}{1+\delta\pi^H-\delta\pi^0}\mu^N\left(E_A(z)-E_B(z)\right)\right).$$

The first term in the parenthesis represents the effect of brand differences on the consumers' experience and resale value effects that we identified in section 5, which arises because consumers' utility is larger when keeping a used good after a good match, and replacing it after a bad match. When $\boldsymbol{\pi}_A = \boldsymbol{\pi}_B$, we find that $p_A^U - p_B^U = \mu^U(E_A(z) - E_B(z))$. In turn, the second term shows how brand differences affect the marginal consumer effect, which appears as incomplete trade means that more consumers have access to new goods. As $E_A(z) > E_B(z)$, then both effects are larger for the best brand, which means that the price of the best brand is more sensitive to changes in the supply of the new good.

Then, the difference between $p_A^R$ and $p_B^R$ comes down to the relationship between $\mu^U$ and $\mu^N$. Observe that, when the supply of new goods for brands is small enough that $\mu^U \geq \mu^N$, then $p_A^N > p_B^N$, because in that case $p_A^R - p_B^R \geq p_A^U - p_B^U$. Hence $\mu^U \geq \mu^N$ is a sufficient condition for the price of a new good to be higher for the best brand, but it is not a necessary condition, since it is possible that $p_A^N > p_B^N$ even if $p_A^R - p_B^R < p_A^U - p_B^U$. Notice also that $p_A^R - p_B^R \leq p_A^U - p_B^U$ is a sufficient (but not necessary) condition for $\frac{p_A^U}{p_A^N} > \frac{p_B^U}{p_B^N}$, which means that the price decline is smaller for the best brand. In the special case with myopic consumers ($\delta \to 0$), then $p_A^R - p_B^R = p_A^U - p_B^U$, so both conditions ($\frac{p_A^U}{p_A^N} > \frac{p_B^U}{p_B^N}$ and $p_A^N > p_B^N$) are always satisfied.

# 7 Concluding Remarks

We presented a model for a good that exhibits durability and experience, and found how the interaction of both characteristics affects the buying behavior of consumers. We determined that an equilibrium exists, even when consumers' beliefs about the expected experience they would get with a given brand and vintage are myopic, provided that consumers consider all vintages as part of the same industry.

We showed that there are always some consumers who decide to keep a durable good. For this result we do not need asymmetric information, or even the presence of a secondhand market. We only require that the consumer's match with a brand can change across vintages. Any owner of a used good already knows all of its attributes, and are thus reluctant to try out a newer product, even if it is of the same brand, for fear of getting a bad experience. Then, the firms' obsolescence decision becomes thus crucial for the consumers' replacement decision.

When used goods can be traded in a secondary market, we also found that there is incomplete trade as long as experience is idiosyncratic, which actually raises consumer surplus. Hence, idiosyncratic experience offsets the negative effects of adverse selection. We thus recommend policy-makers to be cautious when pursuing a scrapping policy, as it pushes consumers to replace a known but used good for a new but unknown one. This would reduce consumers' expected gross utility, which in turn would lower total surplus.

We also documented that the interaction of durability and experience allows some consumers to obtain a higher utility by choosing the vintage of the durable good based on their past experience. When these consumers decide to switch brands after a bad experience, they prefer an old vintage to test the unknown brand for the first time, and trade up to a new vintage if and only if they got a good match with this first try. With this buying behavior, firms have an incentive not only to continue supporting old vintages, but also to expand the range of qualities offered to consumers because, as we find out, brand loyalty tends to be larger for durable goods of higher quality.

We showed as well how uncertainty and experience affects consumer behavior when their beliefs differ across brands, as the best brands will have larger sales, higher brand loyalty, and and longer ownership spells. But observe that it is possible to converge to converge to equilibria in which brands with lower expected experience are phased out of the market, unless their price is sufficiently low. As an example, if there are two groups of brands, with one group of "good" brands offering a higher expected experience, then a consumer who gets a bad match with a "good" brand would prefer switching to another "good" brand, unless the price of the "bad" brands is sufficiently low.

Eventually, buyers of "bad" brands may only include those who got a good match. An extension of this model to look at non-stationary equilibria would explain why firms discontinue some models, and introduce new ones, as mentioned in the Introduction.

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# Appendix A: Proofs of the Propositions

## Proof of Proposition 1

Consider a buyer of used goods with pair $(\theta, \mu)$. Suppose she bought a used good of brand $j$ last period and got experience $z'_j$. Today, the buyer can (i) stay loyal and buy a used good of brand $j$ again; (ii) switch to an unknown brand $k \in \mathcal{J} \setminus \mathcal{J}_i^O$; or (iii) switch to brand $k \in \mathcal{J}_i^O \setminus \{j\}$, so that she tries a brand (other than $j$) that she has experienced in the last $T$ periods.

Define $U_U^U(\theta, \mu/z')$ to be the present value of the buyer's utility under her optimal purchasing policy when her last experience was $z'$. Then:

$$U_U^U(\theta, \mu/z') = \theta v^U - p^U + \mu E(z/a') + \delta EV^{BUY}(\theta, \mu/a')$$

where $a'$ is the optimal action that the consumer must take when her last experience was $z'$. Let $E(z/a') = \pi_U^U(a') z^H + \left(1 - \pi_U^U(a')\right) z^L$, while

$$EV^{BUY}(\theta, \mu/a') = \pi_U^U(a') U_U^U\left(\theta, \mu/z^H\right) + \delta\left(1 - \pi_U^U(a')\right) U_U^U\left(\theta, \mu/z^L\right)$$

where $\pi_U^U(a')$ denotes the probability that the consumer gets a good match under her optimal action $a'$. When $z'_j = z^H$, then $\pi_U^U\left(a^H\right) = \pi_e^H$ if the buyer stays loyal, $\pi_U^U\left(a^H\right) = \pi_e^0$ if she switches to brand $k \in \mathcal{J} \setminus \mathcal{J}_i^O$, while a switch to brand $k \in \mathcal{J}_i^O \setminus \{j\}$ implies $\pi_U^U\left(a^H\right) = \left\{\pi_e^L, \pi_e^H\right\}$, depending on the last experience with that brand. Similarly, when $z'_j = z^L$, then $\pi_U^U\left(a^L\right) = \pi_e^L$ when the consumer stays loyal, while $\pi_U^U\left(a^L\right) = \pi_e^0$ again with brand $k \in \mathcal{J} \setminus \mathcal{J}_i^O$, and $\pi_U^U\left(a^L\right) = \left\{\pi_e^L, \pi_e^H\right\}$ with brand $k \in \mathcal{J}_i^O \setminus \{j\}$. Solving for $U_U^U(\theta, \mu/z')$ for $z' = \left\{z^L, z^H\right\}$, we obtain:

$$U_U^U(\theta, \mu/z') = \frac{1}{1-\delta}\left[\alpha_U^U(z')\left[\theta v^U + \mu E\left(z/z^H\right) - p^U\right] + \left(1 - \alpha_U^U(z')\right)\left[\theta v^U + \mu E(z) - p^U\right]\right] \tag{16}$$

where $\alpha_U^U\left(z^H\right) \equiv \frac{1-\delta\left(1-\pi_U^U\left(a^L\right)\right)}{1-\delta\left(\pi_U^U\left(a^H\right)-\pi_U^U\left(a^L\right)\right)}$ and $\alpha_U^U\left(z^L\right) \equiv \frac{\delta\pi_U^U\left(a^L\right)}{1-\delta\left(\pi_U^U\left(a^H\right)-\pi_U^U\left(a^L\right)\right)}$. Thus, the buyer's expected utility is simply a weighted average of staying loyal to a brand after a good match and switching to an unknown brand after a bad match. To determine the optimal values of $\pi_U^U\left(a^H\right)$ and $\pi_U^U\left(a^L\right)$, observe that:

$$\frac{\partial U_U^U\left(\theta, \mu/z^H\right)}{\partial \pi_U^U\left(a^H\right)} \geq 0 \quad \text{and} \quad \frac{\partial U_U^U\left(\theta, \mu/z^L\right)}{\partial \pi_U^U\left(a^L\right)} \geq 0$$

As $\pi_e^H = \max\left\{\pi_U^U\left(a^H\right)\right\}$, then the optimal purchasing behavior for a buyer of a used good when $z'_j = z^H$ is to remain loyal to brand $j$, regardless of her choice when $z'_j = z^L$ (i.e., regardless of the value for $\pi_U^U\left(a^L\right)$). Also, the consumer's last experience with any brand $k \in \mathcal{J}_i^O \setminus \{j\}$ must have been a bad match, otherwise the consumer would have stayed loyal to that brand. With this in mind, then $\pi_e^0 = \max\left\{\pi_U^U\left(a^L\right)\right\}$, so consumers switch to an unknown brand when $z'_j = z^L$. Therefore $\alpha_U^U\left(z^H\right) = \frac{1-\delta\left(1-\pi_e^0\right)}{1-\delta(\pi_e^H-\pi_e^0)}$ and $\alpha_U^U\left(z^L\right) = \frac{\delta\pi_e^0}{1-\delta(\pi_e^H-\pi_e^0)}$.□

## Proof of Proposition 2

First, consider a consumer who always chooses to trade her used good with a new one, regardless of her experience. This is akin to the consumer "renting" a new good at a price $p^R = p^N - \delta p^U$. Using the same arguments in Proposition 1, the consumer would stay loyal to a brand after a good match, but would switch to an unknown brand after a bad match. If $U_N^N(\theta, \mu/z')$ denotes the expected utility of a buyer of new goods under such optimal behavior, then:

$$U_N^N\left(\theta,\mu/z'\right)=\frac{1}{1-\delta}\left[\alpha_N^N\left(z'\right)\left[\theta v^N+\mu E\left(z/z^H\right)-p^R\right]+\left(1-\alpha_N^N\left(z'\right)\right)\left(\theta v^N+\mu E\left(z\right)-p^R\right)\right] \tag{17}$$

where $\alpha_N^N\left(z'\right)=\alpha_U^U\left(z'\right)$, as defined above.

Suppose now that the consumer, as an owner, keeps her used good after a good match, while still trading it after a bad match. If she keeps the used good, then she would purchase a new good of the same brand next period. If instead she sells the used good, then she would buy a new good of an unknown brand. Let $U_N^K\left(\theta,\mu/z'\right)$ be the expected utility when she is a buyer and her last experience was $z'$, so that:

$$U_N^K\left(\theta,\mu/z'\right)=\theta v^N+\mu E\left(z/a'\right)-p^N+\delta EV^{OWN}\left(\theta,\mu/a'\right)$$

where $E\left(z/a'\right)=\pi_N^K\left(a'\right)z^H+\left(1-\pi_N^K\left(a'\right)\right)z^L$, and

$$EV^{OWN}\left(\theta,\mu/a'\right)=\left(1-\pi_N^K\left(a'\right)\right)\left(p^U+U_N^K\left(\theta,\mu/z^L\right)\right)+\pi_N^K\left(a'\right)\left(\theta v^U+\mu z^H+\delta U_N^K\left(\theta,\mu/z^H\right)\right).$$

Given that $\pi_N^K\left(a^H\right)=\pi_e^H$ and $\pi_N^K\left(a^L\right)=\pi_e^0$, the solution to $U_N^K\left(\theta,\mu/z'\right)$ for $z'=\left\{z^L,z^H\right\}$ is:

$$\begin{aligned} U_N^K\left(\theta,\mu/z'\right) &= \frac{1}{1-\delta} \quad \left[\left(\alpha_{N,1}^K\left(z'\right)\right)\left[\theta v^N+\mu E\left(z/z^H\right)-p^R\right]\right. \\ &\quad + \left(\alpha_{N,2}^K\left(z'\right)\right)\left[\theta v^N+\mu E\left(z\right)-p^R\right] \\ &\quad \left. + \left(1-\alpha_{N,1}^K\left(z'\right)-\alpha_{N,2}^K\left(z'\right)\right)\left[\theta v^U+\mu z^H-p^U\right]\right] \end{aligned} \tag{18}$$

For $z'=z^H$, we obtain $\alpha_{N,1}^K\left(z^H\right)=\frac{1-\delta\left(1-\pi_e^0\right)}{1+\delta\pi_e^0-\delta^2\left(\pi_e^H-\pi_e^0\right)}$ and $\alpha_{N,2}^K\left(z^H\right)=\frac{\delta\left(1-\pi_e^H\right)}{1+\delta\pi_e^0-\delta^2\left(\pi_e^H-\pi_e^0\right)}$ while, for $z'=z^L$, then $\alpha_{N,1}^K\left(z^L\right)=\frac{\delta^2\pi_e^0}{1+\delta\pi_e^0-\delta^2\left(\pi_e^H-\pi_e^0\right)}$ and $\alpha_{N,2}^K\left(z^L\right)=\frac{1-\delta^2\pi_e^H}{1+\delta\pi_e^0-\delta^2\left(\pi_e^H-\pi_e^0\right)}$. In both cases, the expected utility is the present value of a weighted average of (i) buying a new good after a good match, (ii) buying a new good after a bad match, and (iii) keeping the used good. Observe that the weights for keeping a used good and buying a new good after a good experience are both larger for $z'=z^H$.

A comparison between the two purchasing behaviors characterized above reveals that a consumer prefers trading the used good rather than keeping it when $U_N^N\left(\theta,\mu/z'\right)\geq U_N^K\left(\theta,\mu/z'\right)$, i.e., when:

$$\left(1-\delta\left(\pi_e^H-\pi_e^0\right)\right)\left[\theta v^{\triangle}-p^{\triangle}\right]\geq\left(1-\pi_e^H\right)\mu z^{\triangle} \tag{19}$$

from which we obtain the cutoff rule $\theta_N^N\left(\mu\right)$ defined in (6). □

## Proof of Proposition 3

In this proof, we first show the optimality of the behavior described in the statement of the Proposition by solving for the two cutoff rules in equations (7) and (8). Then, we discuss that other buying behaviors that involve choosing the vintage based on experience are not optimal.

The Proposition states that buyers that choose the vintage based on experience purchase a used good after a bad match, and a new good after a good match. As owners, they keep a used good after a good match (and buys a new good of the same brand next period), but trades it after a bad match. Let $U_U^K\left(\theta,\mu/z'\right)$

denote the present value of the utility for this consumer when she is a buyer, so that:

$$
\begin{aligned}
U_U^K\left(\cdot/z^H\right) &= \theta v^N + \mu E\left(z/z^H\right) - p^N + \delta\left[\left(1-\pi_e^H\right)\left(p^U + U_N^K\left(\cdot/z^L\right)\right) + \pi_e^H\left(\theta v^U + \mu z^H + \delta U_N^K\left(\cdot/z^H\right)\right)\right] \\
U_U^K\left(\cdot/z^L\right) &= \theta v^U + \mu E\left(z\right) - p^U + \delta\left[\left(1-\pi_e^0\right) U_U^K\left(\cdot/z^L\right) + \pi_e^H U_U^K\left(\cdot/z^H\right)\right]
\end{aligned}
$$

where the two terms in brackets represent the expected utility as an owner and as a buyer, respectively. The solution to $U_U^K\left(\theta,\mu/z'\right)$ for $z' = \left\{z^L, z^H\right\}$ is:

$$
\begin{aligned}
U_U^K\left(\theta,\mu/z'\right) = \frac{1}{1-\delta} & \left[\left(\alpha_{U,1}^K\left(z'\right)\right)\left[\theta v^N + \mu E\left(z/z^H\right) - p^R\right]\right. \\
& + \left(\alpha_{U,2}^K\left(z'\right)\right)\left[\theta v^U + \mu E\left(z\right) - p^U\right] \\
& \left. + \left(1-\alpha_{U,1}^K\left(z'\right) - \alpha_{U,2}^K\left(z'\right)\right)\left[\theta v^U + \mu z^H - p^U\right]\right]
\end{aligned} \tag{20}
$$

where $\alpha_{U,1}^K\left(z^H\right) = \frac{1-\delta\left(1-\pi_e^0\right)}{1+\delta\pi_e^0-\delta^2\pi_e^H\left(1-\pi_e^0\right)}$ and $\alpha_{U,2}^K\left(z^H\right) = \frac{\delta\left(1-\pi_e^H\right)}{1+\delta\pi_e^0-\delta^2\pi_e^H\left(1-\pi_e^0\right)}$ for $z' = z^H$, while $\alpha_{U,1}^K\left(z^L\right) = \frac{\delta\pi_e^0}{1+\delta\pi_e^0-\delta^2\pi_e^H\left(1-\pi_e^0\right)}$ and $\alpha_{U,2}^K\left(z^L\right) = \frac{1-\delta^2\pi_e^H}{1+\delta\pi_e^0-\delta^2\pi_e^H\left(1-\pi_e^0\right)}$ for $z' = z^L$. In both cases, the expected utility is again the present value of a weighted average between three choices, which in this case are (i) buying a new good after a good match, (ii) buying a used good after a bad match, and (iii) keeping the used good after a good match.

To obtain $\theta_N^K\left(\mu\right)$, we compare the present value of utility in (18) with the one we just found in (20). Observe that the difference between both behaviors lies on the decision of the vintage to buy after a bad match: the consumer in (18) favors a new good of an unknown brand, while the consumer in (20) prefers a used good. We obtain that $U_N^K\left(\theta,\mu/z'\right) \geq U_U^K\left(\theta,\mu/z'\right)$ whenever:

$$
\left(1-\delta^2\left(1-\pi^0\right)\left(\pi^H-\pi^0\right)\right)\left[\theta v^{\triangle} - p^{\triangle}\right] \geq -\delta\pi^0\left(1-\pi^H\right)\mu z^{\triangle} \tag{21}
$$

which defines the marginal consumer stated in (7). For $\theta_U^K\left(\mu\right)$, we compare the present value of utility in (20) with that in (16). In this case, the difference in behavior rests on the decision of the vintage to buy after a good match: the consumer's choice in (20) is to buy a new good, while the buyer in (16) prefers a used good. We get that $U_U^K\left(\theta,\mu/z^h\right) \geq U_U^U\left(\theta,\mu/z^h\right)$ occurs when:

$$
\left(1-\delta\left(\pi^H-\pi^0\right)\right)\left[\theta v^{\triangle} - p^{\triangle}\right] \geq -\delta\pi^H\left(1-\pi^{Hh}\right)\mu z^{\triangle} \tag{22}
$$

From (22), we obtain the marginal consumer defined in (8). Looking at both (21) and (22), consumers with a high pair $(\theta,\mu)$ would prefer to buy a new good, while those with a low pair $(\theta,\mu)$ would favor a used good.

For completeness, we show briefly other buying behaviors that also involve choosing the vintage based on experience but that are not optimal. The first one assumes consumers that buy a used good after a bad match, and a new good after a good match (just as the behavior above) but, as owners, they never keep a used good, even after a good match. Hence, they buy a good every period. Solving for the discounted present value of the buyer's utility in the same manner than the previous cases, we obtain:

$$
U_U^N\left(\theta,\mu/z'\right) = \frac{1}{1-\delta}\left[\alpha_U^N\left(z'\right)\left(\theta v^N + \mu E\left(z/z^h\right) - p^R\right) + \left(1-\alpha_U^N\left(z'\right)\right)\left(\theta v^U + \mu E\left(z\right) - p^U\right)\right] \tag{23}
$$

where $\alpha_U^N\left(z'\right) = \alpha_U^U\left(z'\right)$ for $z' = \left\{z^L, z^H\right\}$, as defined in Proposition 1. However, it is not optimal as $U_U^N\left(\theta,\mu/z'\right) \leq \max\left\{U_N^N\left(\theta,\mu/z'\right), U_U^U\left(\theta,\mu/z'\right)\right\}$.

An additional pair of buying behaviors assumes that a buyer purchases a *new* good after a *bad* match, and a *used* good after a good match. In the first behavior, owners renew the good every period. The present value of the buyer's utility under that circumstance is:

$$U_N^U(\theta,\mu/z') = \frac{1}{1-\delta}\left[\alpha_N^U(z')\left(\theta v^U + \mu E\left(z/z^h\right) - p^R\right) + \left(1-\alpha_N^U(z')\right)\left(\theta v^N + \mu E(z) - p^U\right)\right] \tag{24}$$

where $\alpha_N^U(z') = \alpha_U^U(z')$. In the second behavior, owners keep the used good after a good match, so their discounted utility is:

$$\begin{aligned} U_K^U(\theta,\mu/z') &= \frac{1}{1-\delta} \quad \left[\left(\alpha_{K,1}^U(z')\right)\left[\theta v^U + \mu E\left(z/z^H\right) - p^U\right]\right. \\ &\quad + \left(\alpha_{K,2}^U(z')\right)\left[\theta v^U + \mu z^H - p^U\right] \\ &\quad \left. + \left(1-\alpha_{K,1}^U(z') - \alpha_{K,2}^U(z')\right)\left[\theta v^N + \mu E(z) - p^R\right]\right] \end{aligned} \tag{25}$$

where $\alpha_{K,1}^U\left(z^H\right) = \frac{1-\delta\left(1-\pi_e^0\right)}{1-\delta(\pi_e^H-\pi_e^0)+\delta^2\pi_e^0(1-\pi_e^H)}$ and $\alpha_{K,2}^U\left(z^H\right) = \frac{\delta^2\pi_e^0\left(1-\pi_e^H\right)}{1-\delta(\pi_e^H-\pi_e^0)+\delta^2\pi_e^0(1-\pi_e^H)}$ for $z' = z^H$, while $\alpha_{K,1}^U\left(z^L\right) = \frac{\delta^2\pi_e^0}{1-\delta(\pi_e^H-\pi_e^0)+\delta^2\pi_e^0(1-\pi_e^H)}$ and $\alpha_{K,2}^U\left(z^L\right) = \frac{\delta\pi_e^0\left(1-\delta\pi_e^H\right)}{1-\delta(\pi_e^H-\pi_e^0)+\delta^2\pi_e^0(1-\pi_e^H)}$ for $z' = z^L$. The behavior in (24) can be discarded by checking that $U_N^U(\theta,\mu/z') \leq \max\left\{U_N^N(\theta,\mu/z'), U_U^U(\theta,\mu/z')\right\}$. To discard the behavior in (25), we found that $U_K^U(\theta,\mu/z') < \max\left\{U_K^N(\theta,\mu/z'), U_U^U(\theta,\mu/z')\right\}$ for any consumer with pair $(\theta,\mu)$ and any $z' = \left\{z^L, z^H\right\}$. Hence, both purchasing strategies are never optimal. □

**Proof of Proposition 4**

The first step is to find $\phi^N(\theta,\mu)$, $\phi^U(\theta,\mu)$ and $\phi^K(\theta,\mu)$ for each of the four optimal buying behaviors. Let $J = |\mathcal{J}|$ denote the number of brands. To simplify some of the expressions, we define the parameters $\Gamma = \frac{\pi_x^0}{1-\pi_x^H+\pi_x^0}$ and $\Psi = \frac{1-\pi_x^H+\pi_x^0}{1-\pi_x^H+\pi_x^0+\pi_x^0\pi_x^H}$.

- Consumers of type $\theta \in \left[\theta_N^N(\mu), \overline{\theta}\right]$ buy new goods every period, and sell their used goods accordingly. Hence $\phi_{j,t}^K(\theta,\mu) = \phi_{j,t}^U(\theta,\mu) = 0$ for all $j$ and $t$. Consumers that buy a new good of brand $j$ at period $t$ include (i) all consumers who bought a new good of brand $j$ in period $t-1$, and (ii) some of the consumers who bought brand $k \neq j$ and got a bad match; of those consumers, only a fraction $\rho_{k,j,t}^N$ will choose to buy a new good of brand $j$, taking into account every possible history in which the consumer has not purchased brand $j$ in the last $T$ periods. Let $\gamma_{j,t}^N(\theta,\mu)$ denote the proportion of consumers who get a good match with a new good of brand $j$ in period $t$, so that $\phi_{j,t}^N(\theta,\mu) - \gamma_{j,t}^N(\theta,\mu)$ are those who got a bad match. Then:

$$\phi_{j,t}^N(\theta,\mu) = \gamma_{j,t-1}^N(\theta,\mu) + \textstyle\sum_{k\neq j}\rho_{k,j,t-1}^N \cdot \left(\phi_{k,t-1}^N(\theta,\mu) - \gamma_{k,t-1}^N(\theta,\mu)\right).$$

  To determine $\gamma_{j,t}^N(\theta,\mu)$, observe that consumers that stay loyal will get a good match again with probability $\pi_x^H$, while those who switch brands will get a good match with probability $\pi_x^0$. Then:

$$\gamma_{j,t}^N(\theta,\mu) = \pi_x^H \cdot \gamma_{j,t-1}^N(\theta,\mu) + \pi_x^0 \cdot \textstyle\sum_{k\neq j}\rho_{k,j,t-1}^N \cdot \left(\phi_{j,t}^N(\theta,\mu) - \gamma_{j,t}^N(\theta,\mu)\right).$$

  In a stationary symmetric equilibrium we have that $\rho_{k,j,t}^N = \frac{1}{J-1}$ and $\phi_{j,t}^N(\theta,\mu) = \frac{1}{J}$ for any $j$ and $t$, so that $\gamma^N(\theta,\mu) = \frac{1}{J}\Gamma$.

- Consumers of type $\theta \in \left[\theta_N^K(\mu), \theta_N^N(\mu)\right)$ never buy used goods, so $\phi_{j,t}^U(\theta,\mu) = 0$ for all $j$ and $t$, but all of them keep a used good after a good match, so $\phi_{j,t}^K(\theta,\mu) = \gamma_{j,t-1}^N(\theta,\mu)$. Then

$$
\begin{aligned}
\phi_{j,t}^N(\theta,\mu) &= \phi_{j,t-1}^K(\theta,\mu) + \textstyle\sum_{k\neq j}\rho_{k,j,t-1}^N \cdot \left(\phi_{j,t-1}^N(\theta,\mu) - \gamma_{j,t-1}^N(\theta,\mu)\right) \\
\gamma_{j,t}^N(\theta,\mu) &= \pi_x^H \cdot \phi_{j,t-1}^K(\theta,\mu) + \pi_x^0 \cdot \textstyle\sum_{k\neq j}\rho_{k,j,t-1}^N \cdot \left(\phi_{j,t}^N(\theta,\mu) - \gamma_{j,t}^N(\theta,\mu)\right).
\end{aligned}
$$

The solution is similar to the previous case, although now $\phi_{j,t}^N(\theta,\mu) + \phi_{j,t}^K(\theta,\mu) = \frac{1}{J}$ for any $j$ and $t$, but $\gamma^N(\theta,\mu) = \Gamma\phi^N(\theta,\mu)$ again. Solving, we obtain $\phi^N(\theta,\mu) = \frac{1}{J}\frac{1}{1+\Gamma}$ and $\phi^K(\theta,\mu) = \frac{1}{J}\frac{\Gamma}{1+\Gamma}$.

- Consumers of type $\theta \in \left[\theta_U^K(\mu), \theta_N^K(\mu)\right)$ buy both new and used goods. Buyers of new goods of brand $j$ include (i) consumers who purchased a used good of this brand in period $t-1$ and got a good match, and (ii) consumers who bought a new good of this brand in period $t-2$ and kept it in period $t-1$ because they got a good match. Then:

$$
\phi_{j,t}^N(\theta,\mu) = \gamma_{j,t-1}^U(\theta,\mu) + \phi_{j,t-1}^K(\theta,\mu)
$$

where $\gamma_{j,t}^U(\theta,\mu)$ is the proportion of consumers who got a good match with a used good, while $\phi_{j,t}^K(\theta,\mu)$ is as defined above. In turn, buyers of used goods include a proportion of consumers who bought a good (either new or used) of brand $k \neq j$ in period $t-1$, and decide to switch brands because they got a bad experience. Then:

$$
\phi_{j,t}^U(\theta,\mu) = \textstyle\sum_{k\neq j}\rho_{j,i,t}^N \cdot \left(\phi_{j,t-1}^N(\theta,\mu) - \gamma_{j,t-1}^N(\theta,\mu)\right) + \textstyle\sum_{k\neq j}\rho_{j,i,t}^U \cdot \left(\phi_{j,t-1}^U(\theta,\mu) - \gamma_{j,t-1}^U(\theta,\mu)\right)
$$

where $\rho_{j,i,t}^N(\theta,\mu)$ and $\gamma_{j,t}^N(\theta,\mu)$ were defined before, while $\rho_{k,j,t}^U$ is the fraction of consumers who bought a used good of brand $k$ last period and chose to switch to brand $j$, given that they have not tried it in the last $T$ periods. Observe that all consumers who buy a new good of brand $j$ are staying loyal to that brand, while buyers of a used good of brand $j$ are switching from some other brand. Hence:

$$
\gamma_{j,t}^N(\theta,\mu) = \pi_x^H \cdot \phi_{j,t}^N(\theta,\mu) \quad \text{and} \quad \gamma_{j,t}^U(\theta,\mu) = \pi_x^0 \cdot \phi_{j,t}^U(\theta,\mu)
$$

In a stationary symmetric equilibrium we would have that $\rho_{k,j,t}^N = \rho_{k,j,t}^N = \frac{1}{J-1}$ and $\phi_{j,t}^N(\theta,\mu)+\phi_{j,t}^K(\theta,\mu)+\phi_{j,t}^U(\theta,\mu) = \frac{1}{J}$ for any $j$ and $t$. Solving, we obtain $\phi^N(\theta,\mu) = \frac{1}{J}\Gamma\Psi$, $\phi^K(\theta,\mu) = \frac{1}{J}\pi_x^H\Gamma\Psi$ and $\phi^U(\theta,\mu) = \frac{1}{J}(1-\Gamma)\Psi$.

- Finally, for consumers of type $\theta \in \left[\theta_U^U(\mu), \theta_U^K(\mu)\right)$ we have that $\phi_{j,t}^K(\theta,\mu) = \phi_{j,t}^N(\theta,\mu) = 0$, as they all buy used goods every period. Then $\phi^U(\theta,\mu) = \frac{1}{J}$ and $\gamma^U(\theta,\mu) = \frac{1}{J}\Gamma$ in equilibrium, as the case is analogous to the first one.

Observe that the vector $\boldsymbol{\phi} = \left(\phi^N(\theta,\mu), \phi^U(\theta,\mu), \phi^K(\theta,\mu)\right)$ depends on the actual probabilities on getting a good match, not on the consumers' beliefs. Given those values, we can rewrite the equilibrium conditions that demand equals supply in both markets, taking as given the constant supply of $Y$ units of new goods each period, and the actual probabilities of a good match $\boldsymbol{\pi}_x = \left(\pi_x^L, \pi_x^0, \pi_x^H\right)$. The demand for the new vintage is

$D^N(\mathbf{p},\boldsymbol{\pi}_e) = \int_{\underline{\mu}}^{\overline{\mu}} d^N(\mathbf{p},\boldsymbol{\pi}_e,\mu)\cdot dG(\mu)$ , where:

$$\begin{aligned} d^N(\mathbf{p},\boldsymbol{\pi}_e,\mu) \equiv & \frac{1}{J}\Big(\left[1-F\left(\theta_N^N(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)\right] \\ & +\frac{1}{1+\Gamma}\left[F\left(\theta_N^N(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)-F\left(\theta_N^K(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)\right] \\ & +\Gamma\Psi\left[F\left(\theta_N^K(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)-F\left(\theta_U^K(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)\right]\Big). \end{aligned}$$

In turn, the demand for the old vintage is $D^U(\mathbf{p},\boldsymbol{\pi}_e) = \int_{\underline{\mu}}^{\overline{\mu}} d^U(\mathbf{p},\boldsymbol{\pi}_e,\mu)\cdot dG(\mu)$, where:

$$\begin{aligned} d^U(\mathbf{p},\boldsymbol{\pi}_e,\mu) \equiv & \frac{1}{J}\Big((1-\Gamma)\Psi\left[F\left(\theta_N^K(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)-F\left(\theta_U^K(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)\right] \\ & +\left[F\left(\theta_U^K(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)-F\left(\theta_U^U(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)\right]\Big). \end{aligned}$$

Finally, the supply of the old vintage is $S^U(\mathbf{p},\boldsymbol{\pi}_e) = \int_{\underline{\mu}}^{\overline{\mu}} s^U(\mathbf{p},\boldsymbol{\pi}_e,\mu)\cdot dG(\mu)$ , where:

$$\begin{aligned} s^U(\mathbf{p},\boldsymbol{\pi}_e,\mu) \equiv & \frac{1}{J}\Big(\left[1-F\left(\theta_N^N(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)\right] \\ & +\frac{1-\Gamma}{1+\Gamma}\left[F\left(\theta_N^N(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)-F\left(\theta_N^K(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)\right] \\ & +\left(1-\pi_x^H\right)\Gamma\Psi\left[F\left(\theta_N^K(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)-F\left(\theta_U^K(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)\right]\Big) \end{aligned}$$

We also rewrite the equilibrium conditions for consumers' beliefs. Observe first that, for a consumer with pair $(\theta,\mu)$, their average expected experience must be a convex combination of $E\left(z/z^H\right)$ and $E(z)$, representing their beliefs on experience when they stay loyal and when they switch brands, respectively.

For the market-specific equilibrium, we thus need to determine the fraction of buyers of each vintage who actually stay loyal and switch brands. But we have already determined them when found $\boldsymbol{\phi}$. Among buyers of used goods of type $\theta \in \left[\theta_U^U(\mu),\theta_U^K(\mu)\right)$, a fraction $\Gamma$ buys the same brand than last period, while $1-\Gamma$ purchased some other brand. Then $z_e^U(\theta,\mu) = \Gamma E\left(z/z^H\right)+(1-\Gamma)E(z)$. Instead, for consumers with $\theta \in \left[\theta_U^K(\mu),\theta_N^K(\mu)\right)$, all buyers of used goods owned another brand last period, so $z_e^U(\theta,\mu) = E(z)$. As both $E\left(z/z^H\right)$ and $E(z)$ depend on $\boldsymbol{\pi}_e$, then:

$$Z_e^U(\mathbf{p},\boldsymbol{\pi}_e) = \Gamma z^H + (1-\Gamma)z^L + \frac{\pi_e^0\left(1-\pi_x^H\right)-\pi_x^0\left(1-\pi_e^H\right)}{1-\pi_x^H+\pi_x^0}z^{\triangle} - \Gamma\left(\pi_e^H-\pi_e^0\right)\frac{X^U(\mathbf{p},\boldsymbol{\pi}_e)}{D^U(\mathbf{p},\boldsymbol{\pi}_e)}z^{\triangle}$$

where $X^U(\mathbf{p},\boldsymbol{\pi}_e) = \int_{\underline{\mu}}^{\overline{\mu}} \frac{1}{J}(1-\Gamma)\Psi\left[F\left(\theta_N^K(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)-F\left(\theta_U^K(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)\right]dG(\mu)$ is the set of experience-driven consumers that buy used goods. Analogously, we can determine that the actual average experience by all buyers of used goods is $Z_x^U(\mathbf{p},\boldsymbol{\pi}_e) = \Gamma z^H + (1-\Gamma)z^L - \Gamma\left(\pi_x^H-\pi_x^0\right)\frac{X^U(\mathbf{p},\boldsymbol{\pi}_e)}{D^U(\mathbf{p},\boldsymbol{\pi}_e)}z^{\triangle}$. Then, the equilibrium condition for beliefs for buyers of used goods can be written as:

$$\left[\pi_e^0\left(1-\pi_x^H\right)-\pi_x^0\left(1-\pi_e^H\right)\right]D^U(\mathbf{p},\boldsymbol{\pi}_e) = -\left[\left(\pi_x^H-\pi_x^0\right)-\left(\pi_e^H-\pi_e^0\right)\right]\pi_x^0 X^U(\mathbf{p},\boldsymbol{\pi}_e) \tag{26}$$

In turn, observe that $z_e^N(\theta,\mu) = \Gamma E\left(z/z^H\right)+(1-\Gamma)E(z)$ for buyers of new goods with type $\theta \in \left[\theta_N^K(\mu),\theta_N^N(\mu)\right)\cup\left[\theta_N^N(\mu),\overline{\theta}\right]$, because a fraction $\Gamma$ stays loyal, while $1-\Gamma$ switch brands. But $z_e^N(\theta,\mu) = E\left(z/z^H\right)$ for consumers with $\theta \in \left[\theta_U^K(\mu),\theta_N^K(\mu)\right)$ that buy new goods, as they have owned a new good of the same brand last period. Then

$$Z_e^N(\mathbf{p},\boldsymbol{\pi}_e)=\Gamma z^H+(1-\Gamma)\,z^L+\frac{\pi_e^0\left(1-\pi_x^H\right)-\pi_x^0\left(1-\pi_e^H\right)}{1-\pi_x^H+\pi_x^0}z^{\triangle}+(1-\Gamma)\left(\pi_e^H-\pi_e^0\right)\frac{X^N(\mathbf{p},\boldsymbol{\pi}_e)}{D^N(\mathbf{p},\boldsymbol{\pi}_e)}z^{\triangle}$$

where $X^N(\mathbf{p},\boldsymbol{\pi}_e)=\int_{\underline{\mu}}^{\overline{\mu}}\frac{1}{J}\Gamma\Psi\left[F\left(\theta_N^K(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)-F\left(\theta_U^K(\mathbf{p},\boldsymbol{\pi}_e,\mu)\right)\right]dG(\mu)$ is the set of experience-driven consumers that buy new goods. Likewise, the actual average experience that buyers of a new good would enjoy is $Z_x^N(\mathbf{p},\boldsymbol{\pi}_e)=\Gamma z^H+(1-\Gamma)\,z^L+(1-\Gamma)\left(\pi_x^H-\pi_x^0\right)\frac{X^N(\mathbf{p},\boldsymbol{\pi}_e)}{D^U(\mathbf{p},\boldsymbol{\pi}_e)}z^{\triangle}$, so the equilibrium condition for the beliefs for new good buyers is:

$$\left[\pi_e^0\left(1-\pi_x^H\right)-\pi_x^0\left(1-\pi_e^H\right)\right]D^N(\mathbf{p},\boldsymbol{\pi}_e)=\left[\left(\pi_x^H-\pi_x^0\right)-\left(\pi_e^H-\pi_e^0\right)\right]\left(1-\pi_x^H\right)X^N(\mathbf{p},\boldsymbol{\pi}_e). \tag{27}$$

As $\pi_x^0X^U(\mathbf{p},\boldsymbol{\pi}_e)=\left(1-\pi_x^H\right)X^N(\mathbf{p},\boldsymbol{\pi}_e)>0$ for some $\mu$, then both (26) and (27) hold when (i) $\pi_e^0\left(1-\pi_x^H\right)=\pi_x^0\left(1-\pi_e^H\right)$, and (ii) $\left(\pi_x^H-\pi_x^0\right)=\left(\pi_e^H-\pi_e^0\right)$. This occurs only when $\pi_e^0=\pi_x^0$ and $\pi_e^H=\pi_x^H$.

For the industry-wide equilibrium, from the previous analysis we conclude that $z_e(\theta,\mu)=\Gamma E\left(z/z^H\right)+(1-\Gamma)\,E(z)$ for any buyer with pair $(\theta,\mu)$[28]. Then $Z_e(\mathbf{p},\boldsymbol{\pi}_e)=\Gamma z^H+(1-\Gamma)\,z^L+\frac{\pi_e^0\left(1-\pi_x^H\right)-\pi_x^0\left(1-\pi_e^H\right)}{1-\pi_x^H+\pi_x^0}z^{\triangle}$. Analogously, we obtain that the actual average experience is $Z_x(\mathbf{p},\boldsymbol{\pi}_e)=\Gamma z^H+(1-\Gamma)\,z^L$. Then, for $Z_e(\mathbf{p},\boldsymbol{\pi}_e)=Z_x(\mathbf{p},\boldsymbol{\pi}_e)$ to hold we only require that $\pi_e^0\left(1-\pi_x^H\right)=\pi_x^0\left(1-\pi_e^H\right)$.

The proof of existence thus reduces to finding a vector $\mathbf{p}$ that satisfies $D^N(\mathbf{p},\boldsymbol{\pi}_e)=D^S=y$ and $D^U(\mathbf{p},\boldsymbol{\pi}_e)=S^U(\mathbf{p},\boldsymbol{\pi}_e)$, such that $\boldsymbol{\pi}_e$ satisfies either $\pi_e^0=\pi_x^0$ and $\pi_e^H=\pi_x^H$ for a strong, symmetric equilibrium, or $\pi_e^0\left(1-\pi_x^H\right)=\pi_x^0\left(1-\pi_e^H\right)$ for a weak, symmetric equilibrium. Taking the conditions for $\boldsymbol{\pi}_e$ as given, define $e^v(\mathbf{p},\boldsymbol{\pi}_e)$ to be the excess demand function for goods of vintage $v=N,U$, so that $e^N(\mathbf{p},\boldsymbol{\pi}_e)=D^N(\mathbf{p},\boldsymbol{\pi}_e)-y$ and $e^U(\mathbf{p},\boldsymbol{\pi}_e)=D^U(\mathbf{p},\boldsymbol{\pi}_e)-S^U(\mathbf{p},\boldsymbol{\pi}_e)$. Define also the functions $\beta^N(\mathbf{p},\boldsymbol{\pi}_e)=1-\frac{\left|e^N(\mathbf{p},\boldsymbol{\pi}_e)\right|}{\max\{D^N(\mathbf{p},\boldsymbol{\pi}_e),y\}}$ and $\beta^U(\mathbf{p},\boldsymbol{\pi}_e)=1-\frac{\left|e^U(\mathbf{p},\boldsymbol{\pi}_e)\right|}{\max\{D^U(\mathbf{p},\boldsymbol{\pi}_e),S^U(\mathbf{p},\boldsymbol{\pi}_e)\}}$. Finally, define the compact set $\mathcal{S}=\left[\underline{\theta}v^N+\underline{\mu}z^L,\overline{\theta}v^N+\overline{\mu}z^H\right]\times\left[\underline{\theta}v^U+\underline{\mu}z^L,\overline{\theta}v^U+\overline{\mu}z^H\right]$, and the vector valued function $\Psi:\mathcal{S}\to\mathcal{S}=\left[\psi^N,\psi^U\right]$, such that:

$$\begin{aligned}\psi^N(\mathbf{p},\boldsymbol{\pi}_e) &= \beta^N(\mathbf{p},\boldsymbol{\pi}_e)\cdot p^N\\ &\quad+\left(1-\beta^N(\mathbf{p},\boldsymbol{\pi}_e)\right)\left(\mathbf{1}\left(e^N(\mathbf{p},\boldsymbol{\pi}_e)\geq 0\right)\left(\underline{\theta}v^N+\underline{\mu}z^L\right)+\mathbf{1}\left(e^N(\mathbf{p},\boldsymbol{\pi}_e)<0\right)\left(\overline{\theta}v^N+\overline{\mu}z^H\right)\right)\\ \psi^U(\mathbf{p},\boldsymbol{\pi}_e) &= \beta^U(\mathbf{p},\boldsymbol{\pi}_e)\cdot p^U\\ &\quad+\left(1-\beta^U(\mathbf{p},\boldsymbol{\pi}_e)\right)\left(\mathbf{1}\left(e^U(\mathbf{p},\boldsymbol{\pi}_e)\geq 0\right)\left(\underline{\theta}v^U+\underline{\mu}z^L\right)+\mathbf{1}\left(e^U(\mathbf{p},\boldsymbol{\pi}_e)<0\right)\left(\overline{\theta}v^U+\overline{\mu}z^H\right)\right)\end{aligned}$$

Given that $\Psi$ maps $\mathcal{S}$ into itself, and is continuous, then it has a fixed point. We can rewrite both $\psi^N$ and $\psi^U$ as follows:

$$\begin{aligned}\psi^N(\mathbf{p},\boldsymbol{\pi}_e) &= p^N+\left(1-\beta^N(\mathbf{p},\boldsymbol{\pi}_e)\right)\left(\mathbf{1}\left(e^N(\mathbf{p},\boldsymbol{\pi}_e)\geq 0\right)\left(\underline{\theta}v^N+\underline{\mu}z^L\right)+\mathbf{1}\left(e^N(\mathbf{p},\boldsymbol{\pi}_e)<0\right)\left(\overline{\theta}v^N+\overline{\mu}z^H-p^N\right)\right)\\ \psi^U(\mathbf{p},\boldsymbol{\pi}_e) &= p^U+\left(1-\beta^U(\mathbf{p},\boldsymbol{\pi}_e)\right)\left(\mathbf{1}\left(e^U(\mathbf{p},\boldsymbol{\pi}_e)\geq 0\right)\left(\underline{\theta}v^U+\underline{\mu}z^L\right)+\mathbf{1}\left(e^U(\mathbf{p},\boldsymbol{\pi}_e)<0\right)\left(\overline{\theta}v^U+\overline{\mu}z^H-p^U\right)\right)\end{aligned}$$

[28]For experience-driven buyers, notice that a fraction $\frac{\phi^N}{\phi^N+\phi^U}$ buys new goods, so they stay loyal, while $\frac{\phi^U}{\phi^N+\phi^U}=1-\Gamma$ prefers used goods, and thus switch brands.

Therefore, there is a fixed point of $\Psi$ when the following two conditions are satisfied:

$$\begin{aligned}\left(1-\beta^{N}\left(\mathbf{p},\boldsymbol{\pi}_{e}\right)\right)\left(\mathbf{1}\left(e^{N}\left(\mathbf{p},\boldsymbol{\pi}_{e}\right)\geq 0\right)\left(\underline{\theta}v^{N}+\underline{\mu}z^{L}\right)+\mathbf{1}\left(e^{N}\left(\mathbf{p},\boldsymbol{\pi}_{e}\right)<0\right)\left(\overline{\theta}v^{N}+\overline{\mu}z^{H}-p^{N}\right)\right) &= 0\\ \left(1-\beta^{U}\left(\mathbf{p},\boldsymbol{\pi}_{e}\right)\right)\left(\mathbf{1}\left(e^{U}\left(\mathbf{p},\boldsymbol{\pi}_{e}\right)\geq 0\right)\left(\underline{\theta}v^{U}+\underline{\mu}z^{L}\right)+\mathbf{1}\left(e^{U}\left(\mathbf{p},\boldsymbol{\pi}_{e}\right)<0\right)\left(\overline{\theta}v^{U}+\overline{\mu}z^{H}-p^{U}\right)\right) &= 0\end{aligned}$$

In both expressions, the term in braces is never equal to zero. Hence, it must be the case that $\beta^{N}\left(\mathbf{p},\boldsymbol{\pi}_{e}\right)=\beta^{U}\left(\mathbf{p},\boldsymbol{\pi}_{e}\right)=1$. This is only possible when $e^{N}\left(\mathbf{p},\boldsymbol{\pi}_{e}\right)=e^{U}\left(\mathbf{p},\boldsymbol{\pi}_{e}\right)=0$. □

## Proof of Proposition 5

To show that the market of used goods never shuts down, suppose by way of contradiction that in equilibrium $S^{U}=0$. For zero trade, then all buyers must purchase a new good and keep it for two periods, even after a bad experience. Such behavior implies that, for $z'=z^{L},z^{H}$:

$$U_{K}^{K}\left(\theta,\mu/z'\right)=\theta v^{N}+\mu E\left(z/a'\right)-p^{N}+\delta EV^{OWN}\left(\theta,\mu/a'\right)$$

where $E\left(z/a'\right)=\pi_{K}^{K}\left(a'\right)z^{H}+\left(1-\pi_{N}^{K}\left(a'\right)\right)z^{L}$, and

$$EV^{OWN}\left(\theta,\mu/a'\right)=\theta v^{U}+\left(1-\pi_{K}^{K}\left(a'\right)\right)\left(\mu z^{L}+\delta U_{K}^{K}\left(\theta,\mu/z^{L}\right)\right)+\pi_{N}^{K}\left(a'\right)\left(\mu z^{H}+\delta U_{K}^{K}\left(\theta,\mu/z^{H}\right)\right).$$

As $\pi_{K}^{K}\left(a^{H}\right)=\pi_{e}^{H}$ and $\pi_{K}^{K}\left(a^{L}\right)=\pi_{e}^{0}$, the solution to $U_{K}^{K}\left(\theta,\mu/z'\right)$ is

$$\begin{aligned}U_{K}^{K}\left(\theta,\mu/z'\right) &= \frac{1}{1-\delta^{2}}\quad\Big[\alpha_{K}^{K}\left(z'\right)\left(\theta v^{N}+\delta\theta v^{U}-p^{N}+\left(1+\delta\right)\mu E\left(z/z^{H}\right)\right)\\ &\qquad +\left(1-\alpha_{K}^{K}\left(z'\right)\right)\left(\theta v^{N}+\delta\theta v^{U}-p^{N}+\left(1+\delta\right)\mu E\left(z\right)\right)\Big]\end{aligned}\tag{28}$$

where $\alpha_{K}^{K}\left(z^{H}\right)=\frac{1-\delta^{2}\left(1-\pi_{e}^{0}\right)}{1-\delta^{2}\left(\pi_{e}^{H}-\pi_{e}^{0}\right)}$ and $\alpha_{K}^{K}\left(z^{L}\right)=\frac{\delta^{2}\pi_{e}^{0}}{1-\delta^{2}\left(\pi_{e}^{H}-\pi_{e}^{0}\right)}$. This behavior must be preferred to any other possibility. In particular, an owner that got a bad match must prefer keeping the used good than replacing it with either a new good or a used good of an unknown brand, that is, $\theta v^{U}+\mu z^{L}+\delta U_{K}^{K}\left(\theta,\mu/z^{L}\right)\geq p^{U}+\max\left\{U_{N}^{K}\left(\theta,\mu/z'\right),U_{U}^{K}\left(\theta,\mu/z'\right)\right\}$. For this inequality to hold, we require that the difference in prices satisfies:

$$\theta v^{\triangle}+\frac{\left(1+\delta\right)\pi_{e}^{0}}{1-\delta^{2}\left(\pi_{e}^{H}-\pi_{e}^{0}\right)}\mu z^{\triangle}\leq p^{\triangle}\leq\theta v^{\triangle}-\frac{\left(1+\delta\right)\pi_{e}^{0}}{\delta\left(1-\pi_{e}^{0}\right)}\frac{1-\delta\left(1-\pi_{e}^{H}\right)}{1-\delta^{2}\left(\pi_{e}^{H}-\pi_{e}^{0}\right)}\mu z^{\triangle}$$

which is impossible. Then, the volume of trade must be strictly positive.

To show that trade in the secondhand market is never 100%, suppose by way of contradiction that in equilibrium $S^{U}=D^{N}=y^{N}$. For full trade, then every buyer of a new good must sell it as used next period, regardless of experience. As a result, there would be only two optimal purchasing behaviors in equilibrium: (i) consumers who buy a new good and trade their used good every period, and (ii) consumers who buy a used good every period. The expected utilities for both behaviors were found in equations (17) and (16), respectively. Let $\theta^{N}\equiv\dfrac{p^{\triangle}}{v^{\triangle}}$ define the set of marginal consumers who are indifferent between a new and a used good., so that $U_{N}^{N}\left(\theta^{N},\mu/z'\right)=U_{U}^{U}\left(\theta^{N},\mu/z'\right)$. When buying a new good, such consumers must prefer replacing it when used than keeping it, even after a good match. Then we must have $p^{U}+U_{N}^{N}\left(\theta^{N},\mu/z^{H}\right)\geq\theta^{N}v^{U}+\mu z^{H}+\delta U_{N}^{K}\left(\theta^{N},\mu/z^{H}\right)$. Using equations (17) and (18), we obtain:

$$\theta^{N}v^{\triangle}-p^{\triangle}\geq\mu\left(\left[z^{H}-E\left(z\right)\right]-\alpha_{N}^{N}\left(z'\right)\left[E\left(z/z^{H}\right)-E\left(z\right)\right]\right)\tag{29}$$

Thus we arrive at a contradiction as the left hand side equals zero by the definition of $\theta^N$, while the right hand side is always strictly positive for any $\mu > 0$. Then, the volume of trade is always less than 100%. $\square$

## Proof of Proposition 6

For expected experience, we make use of the characterization of consumers' beliefs in the proof of Proposition 4. Under both definitions of equilibrium, we get:

$$\begin{aligned} Z_e^U(\mathbf{p},\boldsymbol{\pi}_e) &= \Gamma z^H + (1-\Gamma) z^L - \Gamma\left(\pi_e^H - \pi_e^0\right) z^{\triangle} \frac{X^U(\mathbf{p},\boldsymbol{\pi}_e)}{D^U(\mathbf{p},\boldsymbol{\pi}_e)} \\ Z_e^N(\mathbf{p},\boldsymbol{\pi}_e) &= \Gamma z^H + (1-\Gamma) z^L + (1-\Gamma)\left(\pi_e^H - \pi_e^0\right) z^{\triangle} \frac{X^N(\mathbf{p},\boldsymbol{\pi}_e)}{D^N(\mathbf{p},\boldsymbol{\pi}_e)} \end{aligned}$$

Direct observation shows that $Z_e^U(\mathbf{p},\boldsymbol{\pi}_e) \leq Z_e^N(\mathbf{p},\boldsymbol{\pi}_e)$, with strict inequality when the set of experience-driven consumers is strictly positive (so that $X^U(\mathbf{p},\boldsymbol{\pi}_e) > 0$ and $X^N(\mathbf{p},\boldsymbol{\pi}_e) > 0$. We can also verify that $Z_e^v \in \left[E(z), E\left(z/z^H\right)\right]$, with the boundaries of the interval open when $X^U(\mathbf{p},\boldsymbol{\pi}_e > 0)$ and $X^U(\mathbf{p},\boldsymbol{\pi}_e) > 0$.

For brand loyalty, we first need to determine the values of $\lambda^N(\theta,\mu)$ and $\lambda^U(\theta,\mu)$ for each of the four optimal purchasing behaviors. But in a stationary equilibrium they actually correspond to the fraction of consumers that stay loyal, which we found as part of the proof of Proposition 4. For $\Lambda^U$, we got that $\lambda^U(\theta,\mu) = \Gamma$ for consumers of type $\theta \in \left[\theta_U^U(\mu), \theta_U^K(\mu)\right)$, and $\lambda^U(\theta,\mu) = 0$ for those of type $\theta \in \left[\theta_U^K(\mu), \theta_N^K(\mu)\right)$. Then:

$$\Lambda^U(\mathbf{p},\boldsymbol{\pi}_e) = \frac{\pi_x^0}{1-\pi_x^H+\pi_x^0}\left(1 - \frac{X^U(\mathbf{p},\boldsymbol{\pi}_e)}{D^U(\mathbf{p},\boldsymbol{\pi}_e)}\right)$$

For $\Lambda^N$, we obtained that $\lambda^N(\theta,\mu) = 1$ for consumers of type $\theta \in \left[\theta_U^K(\mu), \theta_N^K(\mu)\right)$, while $\lambda^N(\theta,\mu) = \Gamma$ for those of type $\theta \in \left[\theta_N^K(\mu), \theta_N^N(\mu)\right) \cup \left[\theta_N^N(\mu), \overline{\theta}\right]$, regardless of whether they keep or replace the used good as owners. Then:

$$\Lambda^N(\mathbf{p},\boldsymbol{\pi}_e) = \frac{\pi_x^0}{1-\pi_x^H+\pi_x^0}\left(1 - \frac{X^N(\mathbf{p},\boldsymbol{\pi}_e)}{D^N(\mathbf{p},\boldsymbol{\pi}_e)}\right) + \frac{X^N(\mathbf{p},\boldsymbol{\pi}_e)}{D^N(\mathbf{p},\boldsymbol{\pi}_e)}.$$

Hence $\Lambda^U(\mathbf{p},\boldsymbol{\pi}_e) \leq \Lambda^N(\mathbf{p},\boldsymbol{\pi}_e)$, with equality only when $X^U(\mathbf{p},\boldsymbol{\pi}_e) = X^N(\mathbf{p},\boldsymbol{\pi}_e) = 0$. $\square$

## Proof of Proposition 7

Suppose that $\boldsymbol{\pi}_A \gg \boldsymbol{\pi}_B$. Without loss of generality, suppose $\mu_A^H \geq \mu_B^H$, which means that high-type consumers with $\mu \in \left[\mu_B^H, \mu_A^H\right]$ that enjoy get a good match decide, as owners, to replace a used good of brand $A$, but to keep a used good of brand $B$. Using the methodology from the proof of proposition 4, we determine that consumers with $\left(\theta^H,\mu\right)$ who want to buy a new good of brand $j$ include (i) those who enjoyed a good match with that brand last period, and (ii) those who bought a new good of the other brand and got a bad match. Consumers with $\mu < \mu_j^N$ who repeat purchase of brand $j$ bought a new good of that brand last period, while those with $\mu > \mu_j^N$ bought it two periods ago. In any case, repeating buyers would get a good match with probability $\pi_j^H$, while switching buyers would get it with probability $\pi_j^0$. Hence, in a steady state equilibrium $\phi_j^N\left(\theta^H,\mu\right) = \gamma_j^N\left(\theta^H,\mu\right) + \left(\phi_k^N\left(\theta^H,\mu\right) - \gamma_k^N\left(\theta^H,\mu\right)\right)$, where $\gamma_j^N\left(\theta^H,\mu\right) = \pi_j^H\gamma_j^N\left(\theta^H,\mu\right) + \pi_j^0\left(\phi_k^N\left(\theta^H,\mu\right) - \gamma_k^N\left(\theta^H,\mu\right)\right)$. Then $\gamma_j^N\left(\theta^H,\mu\right) = \Gamma_j\phi_j^N\left(\theta^H,\mu\right)$, where $\Gamma_j = \frac{\pi_j^0}{1-\pi_j^H+\pi_j^0}$. We thus obtain that, for any $\mu$,

$$(1-\Gamma_A)\,\phi_A^N\left(\theta^H,\mu\right) = (1-\Gamma_B)\,\phi_B^N\left(\theta^H,\mu\right). \tag{30}$$

As $\Gamma_A > \Gamma_B$, then $\phi_A^N(\theta^H,\mu) > \phi_B^N(\theta^H,\mu)$, which in turn implies that $D_A^N > D_B^N$. Hence, for a steady-state equilibrium to exist, we require that $y_A > y_B$. $\square$

**Proof of Proposition 8**

To determine the volume of trade, we first need to define the demand for new goods and the supply of used goods. Observe that $D_j^N = \sigma\left(\phi_j^N(\theta^H,\mu<\mu^N)G(\mu^N) + \phi_j^N(\theta^H,\mu>\mu^N)\left[1-G(\mu^N)\right]\right)$ when $\mu^N = \mu_j^N$ for $j = A, B$[29]. Using the relationship found in (30), we get that $(1-\Gamma_A)D_A^N = (1-\Gamma_B)D_B^N$. To determine $S_j^U$, notice that $\phi_j^K(\theta^H,\mu<\mu^N) = 0$, as all high-type consumers with $\mu < \mu^N$ replace their new goods. In turn, $\phi_j^K(\theta^H,\mu\geq\mu^N) = \Gamma_j\phi_j^N(\theta^H,\mu\geq\mu^N)$ because they prefer keeping a used good after a good match. Then $S_j^U = D_j^N - K_j$, where $K_j$ is the set of high-type consumers that keep a used good, and given by $K_j = \sigma\Gamma_j\phi_j^N(\theta^H,\mu>\mu^N)\left[1-G(\mu^N)\right]$. Observe also that $\Gamma_B(1-\Gamma_A)K_A = \Gamma_A(1-\Gamma_B)K_B$. Then:

$$VoT_A - VoT_B = \frac{D_A^N - K_A}{D_A^N} - \frac{D_B^N - K_B}{D_B^N} = \frac{K_B}{D_B^N} - \frac{K_A}{D_A^N} = \left(\frac{\Gamma_B}{\Gamma_A} - 1\right)\frac{K_A}{D_A^N}.$$

As $\Gamma_A > \Gamma_B$, then $VoT_A - VoT_B \leq 0$, with equality when $K_B = 0$, i.e., when all high-type consumers replace their used goods, so that $\mu^N = \overline{\mu}$.

Regarding brand loyalty and average expected experience in the market of new goods, we obtain that $\Lambda_j^N(\mathbf{p}_j,\boldsymbol{\pi}_j) = \Gamma_j$ and $Z_j^N(\mathbf{p}_j,\boldsymbol{\pi}_j) = \Gamma_j z_j^H + (1-\Gamma_j)z_j^L$. To see this, recall that loyal consumers of brand $j$ include all consumers who enjoyed a good match with that brand last period. Then $\lambda_{j,t}^N(\theta,\mu) = \frac{\gamma_{j,t-1}^N(\theta,\mu)}{\phi_{j,t}^N(\theta,\mu)}$ among those replace their used goods every period, while $\lambda_{j,t}^N(\theta,\mu) = \frac{\phi_{j,t-1}^K(\theta,\mu)}{\phi_{j,t}^N(\theta,\mu)}$ among those who prefer keeping a used good after a good match. As only high-type consumers buy new goods, then $\lambda_j^N(\theta^H,\mu) = \Gamma_j$ for any $\mu$ in a steady-state equilibrium. Also, $z_j^N(\theta^H,\mu) = \Gamma_j E_j(z/z_j^H) + (1-\Gamma_j)E_j(z)$ for any $\mu$ since all buyers who switch to brand $j$ expect $E_j(z)$, while those who stay loyal expect $E_j(z/z_j^H)$. As there is no leapfrogging, then in the market of used goods we also get $\Lambda_j^U(\mathbf{p}_j,\boldsymbol{\pi}_j) = \Gamma_j$ and $Z_j^U(\mathbf{p}_j,\boldsymbol{\pi}_j) = \Gamma_j z_j^H + (1-\Gamma_j)$. More precisely, we get that $\lambda_j^U(\theta^L,\mu) = \Gamma_j$ and $z_j^U(\theta^L,\mu) = \Gamma_j E_j(z/z_j^H) + (1-\Gamma_j)E_j(z)$ for any $\mu > \mu_j^U$. Therefore, $\Lambda_A^v(\mathbf{p}_A,\boldsymbol{\pi}_A) > \Lambda_B^v(\mathbf{p}_B,\boldsymbol{\pi}_B)$ and $Z_A^v(\mathbf{p}_A,\boldsymbol{\pi}_A) = Z_B^v(\mathbf{p}_B,\boldsymbol{\pi}_B)$ for $v = N, U$.

Regarding the prices of used goods, we prove first that $\mu_A^L > \mu_B^L$. Suppose by way of contradiction that $\mu_A^L \leq \mu_B^L$. Then, low-valuation consumers with $\mu \in \left[\mu_A^L,\mu_B^L\right]$ do not have access to used goods of brand $B$. Hence $\phi_A^U\left(\theta^L,\mu\in\left[\mu_A^L,\mu_B^L\right]\right) > \phi_B^U\left(\theta^L,\mu\in\left[\mu_A^L,\mu_B^L\right]\right) = 0$. In turn, consumers with $\left(\theta^L,\mu>\mu_B^L\right)$ behave analogously to consumers that replace a new good every period, so $\phi_j^U\left(\theta^L,\mu>\mu_B^L\right) = \phi_j^N\left(\theta^H,\mu<\mu^N\right)$. Therefore $D_j^U = (1-\sigma)\left(\phi_j^U\left(\theta^L,\mu\in\left[\mu_A^L,\mu_B^L\right]\right)\left[G(\mu_B^L) - G(\mu_A^L)\right] + \phi_j^U\left(\theta^L,\mu\in\left[\mu_A^L,\mu_B^L\right]\right)\left[1-G(\mu_B^L)\right]\right)$. Since in equilibrium $D_j^U = S_j^U$ for $j = A, B$, we can solve for $(1-\sigma)\left[1-G(\mu_B^L)\right]$ in both conditions to obtain:

$$(1-\Gamma_A)S_A^U - (1-\Gamma_B)S_B^U = (1-\sigma)\left[G(\mu_B^L) - G(\mu_A^L)\right]\left[(1-\Gamma_A)\phi_A^U\left(\theta^L,\mu\in\left[\mu_A^L,\mu_B^L\right]\right)\right].$$

We used the fact that $(1-\Gamma_A)\phi_A^U\left(\theta^L,\mu>\mu_B^L\right) = (1-\Gamma_B)\phi_B^U\left(\theta^L,\mu>\mu_B^L\right)$ and $\phi_B^U\left(\theta^L,\mu\in\left[\mu_A^L,\mu_B^L\right]\right) = 0$. Observe that the right hand side is always positive given our assumption that $\mu_A^L \leq \mu_B^L$. As for the left hand side, recall that $S_j^U = D_j^N - K_j$. Using the fact that $(1-\Gamma_A)D_A^N = (1-\Gamma_B)D_B^N$ and $\Gamma_B(1-\Gamma_A)K_A =$

[29]As a reference, we obtain $\phi_j^N(\theta^H,\mu<\mu^N) = \left(1+\frac{(1-\pi_j^H)(1-\pi_k^H+\pi_k^0)}{(1-\pi_k^H)(1-\pi_j^H+\pi_j^0)}\right)^{-1}$ and $\phi_j^N(\theta^H,\mu>\mu^N) = \left(1+\frac{(1-\pi_j^H)(1-\pi_k^H+2\pi_k^0)}{(1-\pi_k^H)(1-\pi_j^H+2\pi_j^0)}\right)^{-1}$, for $k \neq j$

$\Gamma_A (1-\Gamma_B) K_B$, then

$$(1-\Gamma_A) S_A^U - (1-\Gamma_B) S_B^U = (1-\Gamma_A) K_A \left(\frac{\Gamma_B}{\Gamma_A} - 1\right) < 0.$$

As we arrive to a contradiction, then we must have that $\mu_A^L > \mu_B^L$.

Given that $\mu_j^U$ represents the low-type consumer with the lowest valuation of experience that such that her utility is zero, then we obtain $p_j^U = \theta^L v^U + \mu_j^U \widehat{z_j}$, where

$$\widehat{z_j} = \frac{\delta \pi_j^0}{1-\delta\left(\pi_j^H - \pi_j^0\right)} E_j\left(z|z^H\right) + \frac{1-\delta\pi_j^H}{1-\delta\left(\pi_j^H - \pi_j^0\right)} E_j(z).$$

Notice that low-type consumers with $\mu \in \left[\mu_B^L, \mu_A^L\right]$ do not buy used goods of brand $A$ as it is too expensive for them. Hence, a proportion $\phi_{B,t}^U\left(\theta^L, \mu\right)$ of those consumers buys a used good of brand $B$, while the remaining fraction $1-\phi_{B,t}^U\left(\theta^L, \mu\right)$ stays out of the market because they had a bad experience with brand $B$ in $t-1$. If they buy today, their expected experience would be $E_B\left(z/z_B^L\right)$, and as a result their expected utility would negative. As memory lasts only one period, they would buy again in $t+1$, when their expected experience is $E_B(z)$. In any case, we also obtain that the present value of the utility for a consumer with $\left(\theta^L, \mu_B^L\right)$ equals zero when $p_B^U = \theta^L v^U + \mu_B^L \widehat{z_B}$. Simplifying for $\widehat{z_j}$ , we get $\widehat{z_j} = \frac{E_j(z) - \delta\left(\pi_j^H - \pi_j^0\right)}{1-\delta\left(\pi_j^H - \pi_j^0\right)}$. As $\boldsymbol{\pi}_A > \boldsymbol{\pi}_B$, then $\widehat{z_A} > \widehat{z_B}$. Hence, $p_A^U > p_B^U$. $\square$

# Appendix B: Solution with Vintage Differences

Regarding consumers' optimal buying behaviors, observe first that, as $\boldsymbol{\pi}_e^N = \boldsymbol{\pi}_e$, then both $U_N^N(\theta, \mu/z')$ and $U_N^K(\theta, \mu/z')$ remain unchanged, so $\theta_N^N(\mu)$ is as defined in Proposition 2. Also, $U_U^U(\theta, \mu/z')$ is as determined in (16), but now $\alpha_U^U\left(z^H\right)$ and $\alpha_U^U\left(z^L\right)$ change because $\boldsymbol{\pi}_e^N = \beta\boldsymbol{\pi}_e$. Then, the definition of $\theta_U^U(\mu)$ also remains unaltered, although now $\widehat{z} = \frac{\delta\beta\pi_e^0}{1-\delta\beta(\pi_e^H - \pi_e^0)} E^U\left(z/z^H\right) + \frac{1-\delta\beta\pi_e^H}{1-\delta\beta(\pi_e^H - \pi_e^0)} E^U(z)$.

Using the proof of Proposition 3, we solve again for $U_U^K(\theta, \mu/z')$ when $\boldsymbol{\pi}_e^U = \beta\boldsymbol{\pi}_e^N$ , and use the solution to determine the new values for $\theta_N^K(\mu)$ and $\theta_U^K(\mu)$. We obtain:

$$\begin{aligned}
\theta_N^K(\mu) &= \frac{p^\triangle}{v^\triangle} - \frac{\pi_e^0\left[(1-\beta) + \delta\left(1-\beta\pi_e^H\right)\right]}{1-\delta^2\left(1-\beta\pi_e^0\right)\left(\pi_e^H - \pi_e^0\right)} \mu \frac{z^\triangle}{v^\triangle}, \\
\theta_U^K(\mu) &= \frac{p^\triangle}{v^\triangle} - \frac{\pi_e^H\left[(1-\beta) + \delta\left(1-\beta\pi_e^H\right)\right]}{1-\delta\beta\left(\pi_e^H - \pi_e^0\right)} \mu \frac{z^\triangle}{v^\triangle}.
\end{aligned}$$

Observe that $\theta_N^K(\mu) \geq \theta_U^K(\mu)$ as long as $(1-\beta) + \delta\left(1-\beta\pi_e^H\right) \geq 0$. Hence, $\beta^* = \frac{1+\delta}{1+\delta\pi_e^H}$. Notice that both cutoff functions are strictly decreasing as long as $\beta < \beta^*$.

Instead, when $\boldsymbol{\pi}_e^U > \beta^*\boldsymbol{\pi}_e$, we find that the optimal behavior for experience-driven buyers was characterized by $U_K^U(\theta, \mu/z')$ in equation (25). Solving again for $U_U^K(\theta, \mu/z')$ when $\boldsymbol{\pi}_e^U = \beta\boldsymbol{\pi}_e^N$, and comparing it to $U_N^K(\theta, \mu/z')$ and $U_U^U(\theta, \mu/z')$, respectively, we obtain the following cutoff functions:

$$\begin{aligned}
\theta_K^N(\mu) &= \frac{p^\triangle}{v^\triangle} - \frac{\pi_e^H\left[(1-\beta) + \delta\left(1-\beta\pi_e^H\right)\right]}{1-\delta\left(\pi_e^H - \pi_e^0\right)\left(1+\delta\left(1-\beta\pi_e^H\right)\right)} \mu \frac{z^\triangle}{v^\triangle} \\
\theta_K^U(\mu) &= \frac{p^\triangle}{v^\triangle} - \frac{\pi_e^0\left[(1-\beta) + \delta\left(1-\beta\pi_e^H\right)\right]}{1-\delta\beta\left(\pi_e^H - \pi_e^0\right)} \mu \frac{z^\triangle}{v^\triangle}
\end{aligned}$$

Observe that $\theta_N^K(\mu) = \theta_U^K(\mu)$ when $\beta = \beta^*$. Further, they are both increasing functions when $\beta > \beta^*$, such that $\theta_K^N(\mu) > \theta_K^U(\mu)$.

As the methodology to prove the existence of an equilibrium is the same described in the proof of proposition 4, here we only characterize the conditions for consumers' beliefs. For the market-specific equilibrium, the conditions for the old and new vintages when $\beta < \beta^*$are respectively:

$$\begin{aligned} \left[\beta\pi_e^0\left(1-\pi_x^{H,U}\right)-\pi_x^{0,U}\left(1-\beta\pi_e^H\right)\right]D^U(\mathbf{p},\boldsymbol{\pi}_e) &= -\left[\left(\pi_x^{H,U}-\pi_x^{0,U}\right)-\beta\left(\pi_e^H-\pi_e^0\right)\right]\pi_x^{0,U}X^U(\mathbf{p},\boldsymbol{\pi}_e) \\ \left[\pi_e^0\left(1-\pi_x^{H,N}\right)-\pi_x^{0,N}\left(1-\pi_e^H\right)\right]D^N(\mathbf{p},\boldsymbol{\pi}_e) &= \left[\left(\pi_x^{H,N}-\pi_x^{0,N}\right)-\left(\pi_e^H-\pi_e^0\right)\right]\left(1-\pi_x^{H,N}\right)X^N(\mathbf{p},\boldsymbol{\pi}_e). \end{aligned}$$

Then the two conditions hold if and only if the four brackets equal zero. This can only be satisfied if and only if $\boldsymbol{\pi}_e = \boldsymbol{\pi}_x$ with $\boldsymbol{\pi}_x^U = \beta\boldsymbol{\pi}_x$ and $\boldsymbol{\pi}_x^N = \boldsymbol{\pi}_x$

Instead, the condition for beliefs required for the industry-specific equilibria can be written as:

$$\begin{aligned} &\int_{\underline{\mu}}^{\overline{\mu}}\left(\left[\frac{\pi_e^0\left(1-\pi_x^{H,N}\right)-\pi_x^{0,N}\left(1-\pi_e^H\right)}{1-\left(\pi_x^{H,N}-\pi_x^{0,N}\right)}\right]\int_{\theta_N^N(\mu)}^{\overline{\theta}}dF(\theta)\right)dG(\mu) \\ &+\int_{\underline{\mu}}^{\overline{\mu}}\left(\left[\frac{\pi_e^0\left(1-\pi_x^{H,N}\right)-\pi_x^{0,N}\left(1-\pi_e^H\right)}{1-\left(\pi_x^{H,N}-\pi_x^{0,N}\right)}\right]\left(\frac{1-\pi_x^{H,N}+\pi_x^{0,N}}{1-\pi_x^{H,N}+2\pi_x^{0,N}}\right)\int_{\theta_N^K(\mu)}^{\theta_N^N(\mu)}dF(\theta)\right)dG(\mu) \\ &+\int_{\underline{\mu}}^{\overline{\mu}}\left(\left[\frac{\beta\pi_e^0\left(1-\pi_x^{H,N}\right)-\pi_x^{0,U}\left(1-\pi_e^H\right)}{1-\left(\pi_x^{H,N}-\pi_x^{0,U}\right)}\right]\left(\frac{1-\pi_x^{H,N}+\pi_x^{0,U}}{1-\pi_x^{H,N}+\pi_x^{0,U}+\pi_x^{H,N}\pi_x^{0,U}}\right)\int_{\theta_U^K(\mu)}^{\theta_N^K(\mu)}dF(\theta)\right)dG(\mu) \\ &+\int_{\underline{\mu}}^{\overline{\mu}}\left(\left[\frac{\beta\pi_e^0\left(1-\pi_x^{H,U}\right)-\pi_x^{0,U}\left(1-\beta\pi_e^H\right)}{1-\left(\pi_x^{H,U}-\pi_x^{0,U}\right)}\right]\int_{\theta_U^U(\mu)}^{\theta_U^K(\mu)}dF(\theta)\right)dG(\mu) = 0 \qquad (31) \end{aligned}$$

The sign of each term depends on the sign of its bracket. One possible solution is when all brackets equal zero. We are left with three conditions: (i) $\pi_e^0\left(1-\pi_x^{H,N}\right) = \pi_x^{0,N}\left(1-\pi_e^H\right)$, (ii) $\beta\pi_e^0\left(1-\pi_x^{H,N}\right) = \pi_x^{0,U}\left(1-\pi_e^H\right)$, and (iii) $\beta\pi_e^0\left(1-\pi_x^{H,U}\right) = \pi_x^{0,U}\left(1-\beta\pi_e^H\right)$. The three conditions are satisfied when $\boldsymbol{\pi}_x^U = \beta\boldsymbol{\pi}_x$ and $\boldsymbol{\pi}_x^N = \boldsymbol{\pi}_x$ so that $\boldsymbol{\pi}_e = \boldsymbol{\pi}_x$ (i.e., when consumers are rational) but there are other values of $\pi_e^0$ and $\pi_e^H$ that also satisfy those conditions. Further, when some of the brackets in equation (31) are not equal to zero, the solution depends on the proportion of consumers that buys a good for each of the four optimal buying behaviors. We omit the conditions for $\beta > \beta^*$as the intuition is essentially the same.

Regarding volume of trade, recall that the secondhand market shuts down when all consumers buy a new good and keep it for two periods, getting utility $U_K^K(\theta,\mu/z')$, which is the same for all $\beta$. Again, this cannot be the only optimal behavior, as all owners prefer to replace a used good after a bad match. Concretely, we get that $\theta v^U + \mu z^L + \delta U_K^K\left(\theta,\mu/z^L\right) < p^U + \max\left\{U_N^K(\theta,\mu/z'), U_U^K(\theta,\mu/z')\right\}$ when $\beta \leq \beta^*$, and $\theta v^U + \mu z^L + \delta U_K^K\left(\theta,\mu/z^L\right) < p^U + \max\left\{U_N^K(\theta,\mu/z'), U_K^U(\theta,\mu/z')\right\}$ when $\beta \geq \beta^*$.

In turn, recall that there is full trade in the secondhand market when all buyers of new goods replace them when used, so that every period consumers either buy a new or a used good. In this case, the set of marginal consumers who are indifferent between a new and a used good is given by

$$\theta^N(\mu,\beta) = \frac{p^\triangle}{v^\triangle} - (1-\beta)\frac{\delta\pi_e^0 + (1-\delta)\pi_e^H}{(1-\delta(\pi_e^H-\pi_e^0))(1-\delta\beta(\pi_e^H-\pi_e^0))}\mu\frac{z^\triangle}{v^\triangle}$$

Observe that $\theta^N(\mu,\beta)$ decreases with $\mu$ when $\beta < 1$. Replacing $\theta^N(\mu,\beta)$ into equation (29), then buyers of new goods prefer replacing the used good after a good match, rather than keeping it, whenever $\left(\beta\pi_e^H - 1\right)\left(1 + \delta\pi_e^o - \delta^2\left(\pi_e^H - \pi_e^0\right)\right) > 0$. This leads to a contradiction as $\pi_e^{H,U} = \beta\pi_e^H < 1$..

For brand loyalty, observe that, regardless of $\beta$, we always get $\lambda^N(\theta,\mu)=\frac{\pi_x^H}{1-\pi_x^H+\pi_x^0}$ and $\lambda^U(\theta,\mu)=0$ for consumers who only buy new goods, while $\lambda^N(\theta,\mu)=0$ and $\lambda^U(\theta,\mu)=\frac{\beta\pi_x^H}{1-\beta(\pi_x^H-\pi_x^0)}$ for those who only purchase used goods. When $\beta\le\beta^*$, experience-driven buyers choose a new good after a good match, and a used good after a bad match, so $\lambda^N(\theta,\mu)=1$ and $\lambda^U(\theta,\mu)=0$. Then:

$$
\begin{aligned}
\Lambda^N(\mathbf{p},\boldsymbol{\pi}_e) &= \frac{\pi_x^0}{1-(\pi_x^H-\pi_x^0)}+\left(1-\frac{\pi_x^0}{1-(\pi_x^H-\pi_x^0)}\right)\frac{X^N(\mathbf{p},\boldsymbol{\pi}_e)}{D^N(\mathbf{p},\boldsymbol{\pi}_e)}\\
\Lambda^U(\mathbf{p},\boldsymbol{\pi}_e) &= \frac{\beta\pi_x^0}{1-\beta(\pi_x^H-\pi_x^0)}\left(1-\frac{X^U(\mathbf{p},\boldsymbol{\pi}_e)}{D^U(\mathbf{p},\boldsymbol{\pi}_e)}\right)
\end{aligned}
$$

where $\left(1-\pi_x^H\right)X^N(\mathbf{p},\boldsymbol{\pi}_e)=\pi_x^0X^U(\mathbf{p},\boldsymbol{\pi}_e)$. It is immediate to see that $\Lambda^N(\mathbf{p},\boldsymbol{\pi}_e)>\Lambda^U(\mathbf{p},\boldsymbol{\pi}_e)$ when $\beta\le 1$. Also, if $\beta=\beta^*$ then $X^N(\mathbf{p},\boldsymbol{\pi}_e)=X^U(\mathbf{p},\boldsymbol{\pi}_e)=0$, so $\Lambda^N(\mathbf{p},\boldsymbol{\pi}_e)<\Lambda^U(\mathbf{p},\boldsymbol{\pi}_e)$. Then, there must exist a $\widehat{\beta}\in(1,\beta^*)$ such that $\Lambda^N(\mathbf{p},\boldsymbol{\pi}_e)=\Lambda^U(\mathbf{p},\boldsymbol{\pi}_e)$, with some $\beta<\widehat{\beta}$ holding $\Lambda^N(\mathbf{p},\boldsymbol{\pi}_e)>\Lambda^U(\mathbf{p},\boldsymbol{\pi}_e)$. If $X^N(\cdot)$ and $X^U(\cdot)$ are strictly decreasing in $\beta$, then $\widehat{\beta}$ is unique.

Instead, when $\beta>\beta^*$, experience-driven buyers choose a new good after a bad match, and a used good after a good match, so $\lambda^N(\theta,\mu)=0$ and $\lambda^U(\theta,\mu)=1$. Then:

$$
\begin{aligned}
\Lambda^N(\mathbf{p},\boldsymbol{\pi}_e) &= \frac{\pi_x^0}{1-(\pi_x^H-\pi_x^0)}\left(1-\frac{X^N(\mathbf{p},\boldsymbol{\pi}_e)}{D^N(\mathbf{p},\boldsymbol{\pi}_e)}\right)\\
\Lambda^U(\mathbf{p},\boldsymbol{\pi}_e) &= \frac{\beta\pi_x^0}{1-\beta(\pi_x^H-\pi_x^0)}+\left(1-\frac{\beta\pi_x^0}{1-\beta(\pi_x^H-\pi_x^0)}\right)\frac{X^U(\mathbf{p},\boldsymbol{\pi}_e)}{D^U(\mathbf{p},\boldsymbol{\pi}_e)}
\end{aligned}
$$

As $X^N(\mathbf{p},\boldsymbol{\pi}_e)\ge 0$ and $X^U(\mathbf{p},\boldsymbol{\pi}_e)\ge 0$, then $\Lambda^N(\mathbf{p},\boldsymbol{\pi}_e)<\Lambda^U(\mathbf{p},\boldsymbol{\pi}_e)$.