How Much Competition is a Secondary Market?

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Abstract

Do active secondary markets aid or harm durable goods manufacturers? We build a dynamic equilibrium model of durable goods oligopoly, with consumers who incur lumpy costs when transacting in the secondary market, and calibrate it to U.S. automobile industry data. By varying transaction costs, we obtain a direct measure of the competitive pressure that secondary markets create on durable goods manufacturers. For our calibrated parameter values, opening the secondary market decreases the profits of the new car manufacturers by 35%. Additional counterfactuals show, however, that secondary markets can be beneficial when firms are able to commit to future production levels and when the primary market is more concentrated.

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In recent years, the rapid rise of Internet retailing has jump-started a multitude of markets for a wide spectrum of used goods: virtually everything is resold on the Internet, from animals to toys to books, plants, clothing, appliances; even automobiles and housing units. One market observer notes:

> [W]e are beginning to embrace the notion of temporary ownership. We will soon live in a world where the norm is to sell our designer shoes after wearing them twice, where Verizon will automatically send us the newest, best, most high tech mobile phone every six months, and where we'll lease our Rolex watches instead of buying them. The "informed consumer" will soon choose the brand of her next handbag based on how much it will likely fetch on eBay next year—which corresponds to how much it will really cost her to own it up until then.[1]

Has this dramatic expansion in secondary markets (or "temporary ownership", to use the colorful terminology above) helped or hurt new good producers? In determining the gains from secondary markets, we classify various countervailing effects—a substitution, an allocative and a time consistency effect. Therefore, whether secondary markets help or hurt producers is ultimately an empirical question, the answer to which depends on the underlying market features, such as products' characteristics and consumers' preferences. Our main contribution in this paper is to build and calibrate a dynamic equilibrium model of a durable-goods industry, which allows us to address the role that secondary markets play in oligopolistic industries with product depreciation and a heterogeneous consumer population.

In our analysis, transaction costs play a key role in disentangling the effects that secondary markets play. By raising transaction costs, we close down secondary markets to hone in on the effects of durability itself on firms' behavior. In contrast, by decreasing transaction costs, we make transactions frictionless and can evaluate the effects of secondary markets on firms' profitability.

To our knowledge, our model is the first that analyzes a durable goods oligopoly model in a Markov-perfect equilibrium framework whilst allowing for realistic *inertial* behavior ("hysteresis") on the consumer-side due to transaction costs. We calibrate our model's

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[1] From Nissanoff (2006).

parameter values to match aggregate data from the U.S. automobile industry in 1994–2003. To meet the challenge of computing the dynamic equilibrium oligopoly model, we use the MPEC approach (Mathematical Programming with Equilibrium Constraints), recently advocated by Su and Judd (2008).

Using the calibrated parameter values, we show that more active secondary markets lead to lower profits for producers, so that the negative effects of secondary markets appear to outweigh the benefits. We find that opening the secondary market lowers firms' profits (in the steady state) by 35%. Nonetheless, counterfactual simulations show that opening the secondary market is more beneficial (less detrimental) to producers when (1) firms can commit to future production plans; (2) products are less durable; (3) the time-varying component of consumers' preferences becomes less prominent; or (4) the primary market is more concentrated. These findings confirm the importance of accounting for all the effects when evaluating the competitive implications of secondary markets.

The next section describes the various effects that opening secondary markets have on durable goods producers' profits, and summarizes the relevant literature. Section II presents the model. Section III presents the calibration exercise and the model evaluation at the steady state. Section IV runs counterfactual experiments to address our core question, whether secondary markets aid or hurt durable goods manufacturers. Section V concludes.

I Opening secondary markets: A taxonomy of effects

In durable goods markets, consumers typically do not desire to hold onto the same good until it dies; rather, they wish to re-optimize their choices. Absent secondary markets, consumers tend to exhibit inertial behavior and hold onto their depreciated goods; the alternative—scrapping the good and forfeiting its residual value—may only be taken by the few consumers who have very high valuations.

Opening secondary markets modifies the consumers' calculus by both facilitating consumer re-optimization (now they can sell their used goods without forfeiting the residual values) and expanding the set of available products (now they can buy goods of other vintages). Below we discuss how these changes introduced by secondary markets affect new goods' producers.

Multiple effects are at play. First, there is a *substitution effect.* Even if the durable goods producer sells only a single product, it also places many products—all of the used vintages—in the market. Since these products substitute with the new good, they cannibalize its demand in the primary market. The magnitude of this negative effect is largest when the secondary market works without frictions as then it maximizes the substitution opportunities with the used goods stock.

Second, there is an *allocative effect.* Because the price of the new good capitalizes its asset value, a durable goods manufacturer is, in a sense, a multi-product firm that earns revenue not only from selling the new good, but also from (indirectly) selling the older vintages. This durable goods firm, however, is not a standard multi-product firm because it only controls used car sales and prices indirectly through its behavior in the primary market. As in a price discrimination problem, this multi-product firm gains if the efficiency of the allocation of vintages to heterogeneous consumers is improved. Secondary markets improve this allocation; they allocate the lower quality used vintages to the lower valuation consumers, which allows the firm to extract a larger surplus from selling new goods to the high valuation consumers. Closing the secondary market, however, limits these gains: increased transaction costs create frictions in the allocation of goods, which decreases the firm's profitability and the allocative gains.

Lastly, there is a *time consistency effect.* The consumers' value of an asset depends on the expected future prices and quantities. The firm can raise this value, and thus its current earnings, if it can credibly commit to keeping future prices high (by restricting output). Nonetheless, as pointed out by Coase (1972), without a commitment mechanism, such behavior is time inconsistent: once current profits are earned, the firm increases output, jeopardizing its overall profits.

The time consistency effect also interacts with the substitution and allocative effects of secondary markets.[2] On the one hand, the allocative benefits of secondary markets may alleviate the harm from the time consistency problem: the allocative effect reduces firms' incentives to lower prices in the future, since they are able to sell to high valuation consumers instead of having to lower prices to reach lower valuation consumers. The anticipation of higher future prices raises consumers' current valuation, thereby decreasing the magnitude of the time consistency problem. On the other hand, time consistency leads to an increase in output, and correspondingly to an increase in the stock of used goods. This exacerbates the substitution effect, lowering the good's resale value and thus reducing the desirability of secondary markets.

Related literature. Understanding whether secondary markets hurt manufacturers is a long-standing question in the literature. The earliest discussions were motivated by the *United States vs. Alcoa* (1945) monopolization case, in which a key issue was whether Alcoa faced substantial competition from the used (scrap) aluminum sector.[3]

Several papers have investigated whether firms would benefit from closing secondary markets, focusing on the allocative effect. Anderson and Ginsburgh (1994) and Hendel and Lizzeri (1999b) derive the allocative benefits of secondary markets, showing that the firms can benefit from indirect price discrimination when the secondary markets are active. Porter and Sattler (1999) also provide empirical evidence supporting the allocative role that secondary markets play. In all these models, firms can fully commit to future prices (so there is no time consistency effect) and consumers are heterogeneous in the persistent component

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[2] See also Liang (1999). Indeed, Rust (1985), (1986) presents a model of a durable goods monopoly with commitment power in which the secondary market per se has no effect on either consumer or producer behavior.

[3] cf. Areeda and Kaplow (1988, pp. 476ff). Alcoa lost the case on appeal and, decades later, Suslow (1986) showed that Alcoa did indeed retain substantial market power despite the competition from the recyclable aluminum sector.

of their valuation of the good. Recently, Johnson (2010) extends this framework to allow consumers' preferences to change over time, and finds that a two-period time inconsistent monopolist may prefer to close down the secondary market.[4]

We build on the large empirical literature on dynamic demand in durable goods markets (see Erdem, Imai, and Keane (2003), Hendel and Nevo (2006), Melnikov (2000), Gowrisankaran and Rysman (2006), Gordon (2009), Hartmann (2006), Chevalier and Goolsbee (2009), Carranza (2007), Schiraldi (2006), and Copeland (2006)).[5] Following this literature, we assume that consumer heterogeneity has both a *persistent* component, as well as a *time-varying* component which causes consumers to re-optimize their product choices due to stochastic changes in their needs. As we see below, the desirability of secondary markets depends on the relative importance of these two components of consumer heterogeneity.

There is also a much smaller empirical literature on durable-goods markets accomodating dynamics on both the demand and supply sides.[6] Our paper builds on Esteban and Shum (2007), who analyzed a durable-goods oligopoly model with secondary markets under the restrictive assumptions of no transaction costs and limited consumer heterogeneity.[7] Nair (2007) and Goettler and Gordon (2009) are two other papers that estimate dynamic equilibrium models for (respectively) the video game console industry and the PC microprocessors industry. In these two papers, both consumers and firms are forward-looking, but there is no secondary market for used goods.

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[4] In Johnson (2010), a monopolist may prefer to close down the secondary market because doing so induces consumers who obtain a low realization of their willingness to pay to keep the goods even though the firm would never sell to them. Such an effect is also present in our model.

[5] Bresnahan (1981), Berry, Levinsohn, and Pakes (1995), Goldberg (1995), Petrin (2002) estimate static demand-supply models for the automobile industry, where the firms do not internalize the intertemporal linkages between the new and used car markets.

[6] Relatedly, Gul (1987) studies noncooperative collusion in durable goods oligopoly, Carlton and Gertner (1989) examine the effects of mergers in durable goods industries, and Esteban (2002) investigates the equilibrium dynamics in semi-durable goods markets.

[7] J. Chen, S. Esteban, and M. Shum (2008), (2010) study, respectively, estimation bias and tax rate reforms in a similar framework without transaction costs.

Lastly, since transaction costs lead to inertia in consumers' product choices from one period to the next, our paper also relates to studies that model consumers as having (S,s) type replacement problems.[8] Stolyarov (2002) explains the pattern of used car holdings and trade using a model with competitive primary and secondary markets, in which consumers are heterogeneous and replace their goods infrequently due to transaction costs in the used car market. Gavazza and Lizzeri (2009) calibrate a model of secondary markets with heterogeneous consumers, transaction costs, and exogenous new good supply to automobile markets; the model does remarkably well in matching several aggregate features of the U.S. market.

We end this section by noting some limitations of our analysis. First, we abstract away from asymmetric information between buyers and sellers which, as is well-known (Akerlof (1970)), can cause adverse selection in secondary markets.[9] Second, we do not allow firms to choose the durability of their products, as has been done in the planned obsolescence literature.[10] Third, we do not allow firms to make additional dynamic decisions to better compete with its past production.[11] Finally, car manufacturers only sell cars, instead of both selling and leasing them.[12]

II Model

Next, we build a model of a durable goods oligopoly with secondary markets. Consumers incur transaction costs when selling used goods in the secondary market and have heterogeneous valuations. Time is discrete and firms and consumers are infinitely lived, forward-

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[8] cf. Eberly (1994), Adda and Cooper (2000), and Attanasio (2000).

[9] The subsequent empirical and theoretical literature in this area is very large; see Bond (1982) and Hendel and Lizzeri (1999a) for representative papers.

[10] See Swan (1972), Bulow (1986), Hendel and Lizzeri (1999a) , Iizuka (2007), M. Waldman (1993), (1996), among many others, for models of endogenous depreciation.

[11] For instance, Goettler and Gordon (2009) incorporate an innovation decision for the firms.

[12] Table 2 of Aizcorbe, Starr, and Hickman (2003) indicates that between 4.5% and 6.4% of households leased automobiles during our sample period.

looking, and time consistent. For convenience, and foreshadowing our empirical application, we refer to the good as a “car” for the remainder of the paper.

There are two vintages of cars, new and used. New and used cars differ in their characteristics, while cars of the same vintage are homogeneous. After one period of use, new cars become used, and remain in this state until they die, an event that occurs stochastically.[13] We index car vintages by $j = 0, 1, 2$, where $j = 0$ is the outside option of no car, $j = 1$ is a new car, and $j = 2$ is a used car. For each car vintage, we let $\alpha_j \geq 0$ denote its product-characteristics index and normalize $\alpha_0 = 0$.

We next model the vintage transition. We let $\delta_j \in [0, 1]$ denote the probability of stochastic death of a car of vintage j. Accordingly, $1 \geq \delta_2 \geq 0$, while $\delta_0 = \delta_1 = 0$. For convenience, we define $\delta \equiv \delta_2$. We then let $d(j)$ denote the next period’s vintage of a car that is currently vintage j and survives one more period of use. Thus, $d(0) = 0$, $d(1) = 2$, and $d(2) = 2$ if the used car survives. As used cars may not survive, we let $\hat{d}(j)$ denote the next period’s vintage distribution of a car that is currently vintage j. For $j = 2$, $\hat{d}(2)$ equals 2 with probability $1 - \delta$, while it equals 0 with probability δ. For $j = 0, 1$, simply $\hat{d}(j) = d(j)$.

In what follows, we first formulate the consumers’ and firms’ problems in partial equilibrium. Subsequently, we impose equilibrium by clearing all markets and formulating correct expectations by consumers and firms.

A Consumers’ problem

On the demand side, there is a continuum of infinitely-lived consumers with unit mass, with generic consumer i. Consumers are differentiated in two dimensions. On the one hand, consumers differ in their marginal utility of money, γ, of which there are $l = 1, \ldots, L < \infty$ distinct types in proportions $\pi_1, \ldots, \pi_L$, with $\sum_l \pi_l = 1$. We let l_i denote i’s type and γ_i denote his marginal utility of money; this is unchanging across time periods and represents a

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[13] Following Swan (1972).

persistent component of preference heterogeneity across consumers. In addition, consumers also experience preference shocks that vary period-by-period. We let $\vec{\epsilon}_{it} \equiv (\epsilon_{i0t}, \epsilon_{i1t}, \epsilon_{i2t})$ be the vector of preference shocks of consumer i in period t, where the shocks are i.i.d. across (i, j, t).[14] In our specification of the utility function that follows, γ captures vertical differentiation among the new and used cars in the consumers' preferences, while the preference shocks ϵ allow for horizontal differentiation that varies over time.

Each consumer owns (at most) one car in each period. We let $r_{it} \in \{0, 2\}$ denote the index of the car owned by consumer i at the start of period t, and B^l_{2t} denote the measure of consumers who are type l and own a used car at the beginning of period t. Accordingly, $\vec{B}_t$ is the vector of used car holdings by consumer types.

In partial equilibrium, consumers make decisions taking into account current and expected future prices, as well as a transaction cost that is incurred if they sell a used car. We let p_{jt} be the price of car j in period t and $\vec{p}_t = (p_{0t}, p_{1t}, p_{2t})$ be the corresponding price vector. We set $p_{0t} = 0$ for all t. Because of the transaction costs, consumers prefer keeping their car to selling and immediately repurchasing the same car from the secondary market, making their choices depend both on their type as well as on the car vintage they own.[15] We let k_j, for $j = 0, 2$, denote the transaction cost incurred when selling car vintage j. We assume that $k_2 = k$ and $k_0 = 0$.[16]

Consumer i derives the following utility flows in period t. If she keeps her car—car r_{it}—she derives utility of $\alpha_{r_{it}} + \epsilon_{ir_{it}t}$. If she sells it and purchases j as a replacement (which can be the outside option $j = 0$), her utility is $\alpha_j + \gamma_i \cdot (p_{r_{it}t} - k_{r_{it}} - p_{jt}) + \epsilon_{ijt}$, where $k_{r_{it}}$ is the

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[14] In particular, because all of the cars in the same vintage are homogeneous, the preference shock ϵ_{ijt}, for consumer i, is the same for all cars of a given vintage j (even if these cars are produced by different firms).

[15] Without transaction costs, consumers' dynamic optimization problems simplify to static decision problems with prices equal to the implicit rental prices (cf. Esteban and Shum (2007)).

[16] We assume the magnitude of the consumers' transaction costs is exogenous. Hendel and Lizzeri (1999b) note that the producers can effectively "endogenize" transaction costs by limiting the transferability of warranties. However, in the car market, which is the focus of this paper, currently warranties are fully transferrable.

transaction cost in selling r_{it}, as defined above.[17] Finally, if she scraps her car and buys j as a replacement, she obtains utility of $\alpha_j - \gamma_i p_{jt} + \epsilon_{ijt}$. When comparing the utility flows, the consumer only sells her used car if $p_{r_{it}t} \geq k_{r_{it}}$, which makes of the transaction cost a price floor in the secondary market.[18] We can express compactly consumer i's utility flow in t as

$$u(s_{it}, \vec{p}_t, r_{it}, \epsilon_{it}; \gamma_i) = \underbrace{\alpha_{s_{it}} + \mathbf{1}_{s_{it} \neq r_{it}} \cdot \gamma_i \cdot \left(\max\{p_{r_{it}t} - k_{r_{it}}, 0\} - p_{s_{it}t}\right)}_{\equiv\, \tilde{u}(s_{it}, \vec{p}_t, r_{it}; \gamma_i)} + \epsilon_{is_{it}t}.$$

We assume each preference shock ϵ_{ijt} is distributed type I extreme-value, which leads to a number of convenient closed-form expressions in what follows.[19]

We can next derive the dynamic maximization problem of each consumer i. For now, we assume consumers take all prices—current and future—as given. We let $s_{it} \in \{0, 1, 2\}$ denote i's consumption choice in t, and (r_{it}, ϵ_{it}) denote the state variables that affect this choice. Then, using $\hat{\vec{p}}_t$ to denote the vector of prices from t onwards, we write the Bellman equation for consumer i's dynamic decision problem as

$$V(\hat{\vec{p}}_t, r_{it}, \vec{\epsilon}_t; \gamma_i) = \max_{s_{it}} \left[u(s_{it}, \vec{p}_t, r_{it}, \epsilon_{it}; \gamma_i) + (1 - \delta_{s_{it}})\beta \tilde{V}\left(\hat{\vec{p}}_{t+1}, d(s_{it}); \gamma_i\right) + \delta_{s_{it}}\beta \tilde{V}\left(\hat{\vec{p}}_{t+1}, 0; \gamma_i\right)\right], \tag{1}$$

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[17] This lump-sum specification of transaction costs is motivated by numbers in the Kelley Blue Book; there, the implied transaction cost (measured as the difference between the trade-in value and the suggested retail price) is largely constant, even for cars of very different valuations and quality classes. Nevertheless, for completeness, we also calibrate a model where transaction costs are proportional to the car price (see Section V.B of the Online Appendix); the results are qualitatively and quantitatively very similar to those from our baseline specification below.

[18] In our model, a consumer owns only a single car, and must use it. A hybrid model that allows consumers to hold on to a used car, without scrapping it, and yet purchase another car for consumption, would significantly complicate the dynamic behavior of consumers and firms.

[19] With this assumption, our consumer demand model resembles the "dynamic logit" specifications of the dynamic discrete-choice models that started with Miller (1984) and Rust (1987).

where $\beta \in (0,1)$ is the discount factor, common to consumers and firms, and

$$\begin{aligned}\tilde{V}(\hat{\vec{p}}_t, r_{it}; \gamma_i) &\equiv E_{\vec{\epsilon}} V(\hat{\vec{p}}_t, r_{it}, \vec{\epsilon}_t; \gamma_i) \\ &= \log \left\{ \sum_{j=0}^{2} \exp\left(\tilde{u}(j, \vec{p}_t, r_{it}; \gamma_i) + (1-\delta_j)\beta \tilde{V}(\hat{\vec{p}}_{t+1}, d(j); \gamma_i) \right) + \delta_j \beta \tilde{V}(\hat{\vec{p}}_{t+1}, 0; \gamma_i) \right\}\end{aligned} \tag{2}$$

is the expected value function before consumer i's shock is observed, with the latter substitution following from the assumption that the ϵ's are extreme-valued. Accordingly, the choice probability of product j by consumer i who owns a car j' and is of type l takes the multinomial logit form

$$q_j(\vec{p}_t, j', \hat{\vec{p}}_{t+1}; \gamma_l) = \frac{\exp\left(\tilde{u}(j, \vec{p}_t, j'; \gamma_l) + (1-\delta_j)\beta \tilde{V}(\hat{\vec{p}}_{t+1}, d(j); \gamma_l) + \delta_j \beta \tilde{V}(\hat{\vec{p}}_{t+1}, 0; \gamma_l) \right)}{\sum_{h=0}^{2} \exp\left(\tilde{u}(h, \vec{p}_t, j'; \gamma_l) + (1-\delta_h)\beta \tilde{V}(\hat{\vec{p}}_{t+1}, d(h); \gamma_l) + \delta_h \beta \tilde{V}(\hat{\vec{p}}_{t+1}, 0; \gamma_l) \right)}. \tag{3}$$

Remark: Persistent vs. time-varying consumer heterogeneity. In our utility function specification, the γ_i's and the ϵ_{ijt}'s measure, respectively, the persistent and time-varying components to the consumers' preference heterogeneity. The interactions between the two components of heterogeneity have implications for the effects of secondary markets. When the time-varying component becomes more important, the distinction between high- vs. low type-consumers becomes more blurred. Accordingly, the allocative benefits of opening the secondary market arising from the persistent heterogeneity decrease, reducing the desirability of the secondary market for firms. When heterogeneity is primarily persistent, however, the allocative benefits increase, which enhances the desirability of the secondary market. ■

Remark: Two vintages. The assumption that there are only two vintages of cars is made mainly to enable the computation of the model. With more vintages, the different effects of secondary markets will still operate, but their magnitudes may change. For instance, consider the allocative effect. On the one hand, the availability of more vintages increases the allocative benefits of secondary markets. On the other hand, the expanded depreciation schedule brought about by additional vintages may make consumers more likely to scrap used cars even absent secondary markets, which reduces the scope for the allocative gains from opening the secondary market. ■

Aggregate Demand Functions

We next aggregate up the choices for all consumers to obtain the aggregate quantity demanded for each car vintage j in period t. We let $\vec{Q}_t^D$ be the vector of new and used car demand by consumer types, with generic element Q_{jt}^{Dl}. The total demand for car vintage j is given by

$$Q_{jt}^D \equiv \sum_l Q_{jt}^{Dl} = \sum_l \sum_{j', j' \neq j} B_{j't}^l \cdot q_j(\vec{p}_t, j', \hat{\vec{p}}_{t+1}; \gamma_l) \quad \text{for } j = 1, 2. \tag{4}$$

By construction, if j is a used car, its demand excludes those consumers who keep their current car (i.e., the second summation above does not include $j' = j$).

As consumers cannot own more than one car, the supply of used cars in the market is given by the cars owned by those consumers buying into other vintages. That is, for $j' = 2$, it is given by

$$Q_{j't}^S = \begin{cases} \sum_l \sum_{j, j \neq j'} B_{j't}^l \cdot q_j(\vec{p}_t, j', \hat{\vec{p}}_{t+1}; \gamma_l) & \text{if } p_{j't} \geq k, \\ 0 & \text{otherwise.} \end{cases} \tag{5}$$

B Firms' problem

We now turn to the problem of the firms, which, initially, we solve in partial equilibrium by taking as given the inverse demand functions and the law-of-motion determining the next period's consumers' vehicle holdings. We restrict the firms' strategies to be Markov, requiring that the firms' production choices be only functions of the payoff relevant state, which, in our setting, is the vector of used car holdings by consumer types, given by $\vec{B}_t$. Then, in every period, firms choose quantities simultaneously to maximize their discounted sum of current and future profits while accounting for the optimality of the future actions.

Our assumption that the firms choose quantities is supported by several institutional features of the automobile industry. Capacities do not appear to be easily adjustable in the automobile industry (cf., Bresnahan and Ramey (1994)); moreover, it appears common for car manufacturers to adjust prices to clear inventories by offering rebates or other forms of price discounts towards the end of each model year.

There are N firms producing homogeneous new cars. Let $\vec{x}_t = (x_{1t}, \ldots, x_{Nt})$ be the vector of their production choices, and let $\vec{x}_{-nt}$ be the sub-vector containing all elements of $\vec{x}_t$ but excluding x_{nt}, for $n = 1, \ldots, N$. We also assume the marginal cost of production is constant and equal to $c \geq 0$ for all firms.

We let $\vec{B}_{t+1} = L(\vec{x}_t, \vec{B}_t)$ be the law-of-motion of the car holdings' vector, and let $P(\vec{x}_t, \vec{B}_t)$ be the inverse demand function of new cars. For the time being, in partial equilibrium, we assume the inverse demand function is only a function of the current state and choice variables, eliminating its dependence on future output which characterizes durable goods problems with forward-looking consumers. In the next section, we show that an inverse demand function with this structure is consistent with a Markov Perfect Equilibrium, in which the equilibrium decision rules (which depend only on current state variables) are recursively substituted into the consumers' forward-looking decision rules.

Given the inverse demand functions $P(\vec{x}_t, \vec{B}_t)$, the law-of-motion $L(\vec{x}_t, \vec{B}_t)$, and the rival firms' production $\vec{x}_{-nt}$, the maximization problem of each firm is a dynamic programming problem with state $\vec{B}_t$. Then, a Markov-perfect equilibrium consists of decision rules $G_n(\cdot)$ and value functions $W_n(\cdot)$ such that, for all $n = 1, \ldots, N$,

$$G_n(\vec{B}_t) = \arg\max_{x_{nt}} \Big[(P((x_{nt}, \vec{G}_{-n}(\vec{B}_t)), \vec{B}_t) - c)x_{nt} + \beta W_n(L((x_{nt}, \vec{G}_{-n}(\vec{B}_t)), \vec{B}_t)) \Big]; \quad \text{and}$$

$$W_n(\vec{B}_t) = (P((G_n(\vec{B}_t), \vec{G}_{-n}(\vec{B}_t)), \vec{B}_t) - c)G_n(\vec{B}_t) + \beta W_n(L((G_n(\vec{B}_t), \vec{G}_{-n}(\vec{B}_t)), \vec{B}_t)).$$

We focus attention on symmetric equilibrium, that is, equilibrium that involves symmetric strategies for the firms.

C Equilibrium

In equilibrium, we require:

(i) *Primary market clearance:* For new cars, $\sum_{n=1,\ldots,N} G_n(\vec{B}) = Q_1^D$, as defined in the demand equation in (4).

(ii) *Secondary market clearance/free disposal:* For used cars, $Q_2^D = Q_2^S$ if $p_2 > k$, where Q_2^D and Q_2^S are defined in the used car demand and supply equations (4) and (5), respectively. If $p_2 = k$, i.e., if the price floor k binds, then $Q_2^S \geq Q_2^D$, and the measure of used cars scrapped is $Q_2^S - Q_2^D$.[20]

(iii) *Consistency of the inverse demand functions:* $\vec{p} = P(\vec{x}, \vec{B})$ satisfies the aggregate demand and supply equations in (4) and (5), where the next period's price is given by $\vec{p}' = P(\vec{G}(L(\vec{x}, \vec{B})), L(\vec{x}, \vec{B}))$.[21]

(iv) *Consistency of the law of motion for the car holdings vector:* The vector of car holdings evolves as:

$$\begin{aligned}
(B_1^l)' &= 0, \\
(B_2^l)' &= Q_1^{Dl} + (1-\delta)\sum_{j'} B_{j't}^l \cdot q_2(\vec{p}_t, j', \hat{\vec{p}}_{t+1}; \gamma_l), \\
(B_0^l)' &= 1 - (B_2^l)',
\end{aligned} \tag{6}$$

where $Q_{\cdot}^{Dl}$ is defined in the demand equations (4), and the probability $q_{\cdot}(\vec{p}, \cdot, \vec{p}'; \gamma)$ is defined in equation (3). We also require that the updating rule equals the law-of-motion $L(\vec{X}, \vec{B})$ introduced in the firm's problem.

By focusing on a Markov-perfect equilibrium, we require firms to be time consistent—so that they cannot commit to future production levels that are sub-optimal once the future

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[20] When $p_2 = k$, an owner of a used car is indifferent between selling her used car and scrapping it. Therefore, in the model we do not need a rationing rule that specifies, when the quantity supplied is greater than the quantity demanded, which suppliers sell their used cars and which scrap them.

[21] Given $P(.)$, $G(.)$, and $L(.)$, all current and future prices are functions of the current state vector $\vec{B}$. Therefore, in the general equilibrium specification of the consumers' problem, V and $\tilde{V}$ are also functions of $\vec{B}$.

period is reached. To be specific, the requirement of time consistency is established in the restriction that firms' choices are Markov perfect, and also in condition (iii) of the equilibrium definition above, which requires that consumers form rational expectations of prices based on optimal future equilibrium behavior.

III Calibration

In order to quantify the effects of secondary markets, we calibrate our model to aggregate data from the U.S. automobile market. Some of the parameter values are set *a priori* based on data or recent empirical studies, while others are obtained by finding parameter values that give the best fit between the model's steady-state values of endogenous variables and the average aggregate values for the U.S. automobile market during the years 1994–2003.

Table 1 summarizes all the parameters that we fix in the calibration exercise. The model's persistent heterogeneity parameters, the γ's, arise from income differences in the population. To keep our study tractable, we approximate the income distribution with two consumer types ($L = 2$), which we label as types 1 and 2, and let each type represent half of the consumer population. Empirically, these types are identified as those with above- and below-median income. Then, the car holdings' vector in this two-vintage, two-type specification of the model has two elements, B_2^1 and B_2^2, which are the used car stocks held by each of the two consumer types.

On the supply side, we consider an oligopoly of three firms producing homogeneous new cars, corresponding to the Big 3 U.S. automobile producers (General Motors, Ford and Chrysler). As is common in the literature, we assume the interest rate to be 4%, which corresponds to a discount factor of $\beta = 1/1.04$.

Although in our model, cars have only two vintages (new and used), the modeling of stochastic death of used cars allows them to live for more than two years. This modeling plays an important role in allowing us to match the observed expected lifetime of a vehicle. In fact, according to the 2001 US National Household Travel Survey (NHTS), the expected lifetime of a vehicle was 9 years. In the steady state of our model, the average age of existing cars is

$$\phi(\delta) = \frac{1 \cdot 1 + 2 \cdot 1 + 3 \cdot (1-\delta) + 4 \cdot (1-\delta)^2 + ...}{1 + 1 + (1-\delta) + (1-\delta)^2 + ...},$$

where $\delta \in [0,1]$ is the death probability. We therefore solve $\phi(\delta) = 9$ to obtain $\delta = 0.11$, which we fix in our computations.[22]

The remaining model parameters are calibrated; these are: α_1, the new car product-characteristics index; α_2, the used car product-characteristics index; γ_1 (resp. γ_2), the type 1 (resp. 2) consumers' marginal utility of money; c, the marginal cost of production (identical for all firms); and k, the transaction cost parameter. We obtain these values by minimizing the sum of the squared percentage differences between the model's steady-state predictions and the U.S. averages for the following variables: (i) the fraction of above-median income (type 1) and below-median income (type 2) consumers who purchase new and used cars; (ii) the new and used vehicle prices; and (iii) the firms' markup (the difference between the new vehicle price and the marginal cost, divided by the new vehicle price). For (i) and (ii), the U.S. averages are calculated from the owned vehicle component of the Consumer Expenditure Survey for the years 1994–2003, while (iii) is calculated from the annual reports of the Big 3 U.S. automobile producers. All prices are converted to dollars in the year 2003.

Despite having reduced the number of parameters, having dynamics on both the demand and supply sides of the market imposes a heavy computational burden for the calibration exercise. We overcome this hurdle by taking an MPEC approach to calibration. The MPEC approach is a constrained optimization approach to fitting equilibrium models, with constraints that are given by the equilibrium conditions of the consumers' and producers'

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[22] The alternative to modeling stochastic death of used cars would have been to increase the number of vintages, but doing so would make the state space very large, which would result in heavy computational burden and make the calibration exercise infeasible.

dynamic optimization problems (more details are contained in the Appendix).[23] In our calibration exercise, the main advantage of the MPEC approach is to avoid computing the dynamic equilibrium of the model for every candidate set of parameter values, except for the final set. As a result, we reduce the computational burden and associated computing time considerably.

A Calibration results

Table 2 presents the calibrated values of the free parameters, and Table 3 the corresponding simulated steady-state values alongside the U.S. averages. Table 4 reports steady-state results at the calibrated parameter values. Throughout, all the monetary numbers are reported in $10,000 in the year 2003.

Table 2 shows that the product-characteristics index of new cars ($\alpha_1 = 1.67$) is 109% higher than that of used cars ($\alpha_2 = 0.80$). The type 1 consumers have a lower price sensitivity (γ) equal to 1.70 (i.e., a higher taste for quality), while the type 2 consumers have a higher price sensitivity coefficient of 2.28 (a lower taste for quality). Thus, given our calibrated parameter values, gains from trade occur due to the heterogeneity of the product (in the product-characteristics' index and/or the product's stochastic death)[24] and the heterogeneity in the consumers' valuation of the goods, in both the persistent and the time-varying terms.

The marginal cost parameter is calibrated at 1.90 ($19,000), which appears to be in the correct range.[25] The transaction cost parameter k is shown to be calibrated to equal 0.44, corresponding to $4,400. This is corroborated by the Kelley Blue Book, which indicates that, typically, the difference between the trade-in value of a used car (seller's price for

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[23] See also Luo, Pang, and Ralph (1996) for additional details.

[24] It is worth noting that, without transaction costs, heterogeneity in the product's stochastic death alone does not create gains from trade.

[25] Copeland, Dunn, and Hall (2005, pg. 28), for example, reports a lower bound on marginal costs of $17,693 (in the year 2000), which corresponds to $18,905 in the year 2003.

consumers) and its suggested retail value (buyer's price)—which may serve as a proxy for transaction cost—is in the \$3,000-\$4,000 range.

Table 3 reports that in the steady state, in every period, 9.68% of the type 1 consumers purchase new cars and 17.79% purchase used cars, while 4.20% of the type 2 consumers purchase new cars and 19.28% purchase used cars. Thus, type 1 consumers participate more in the primary market than type 2 consumers do and also own a larger fraction of the total car fleet.

This table also reports the markup, which equals 0.17. While our model has a stripped-down specification of consumer heterogeneity relative to other empirical studies of the automobile market (e.g., Goldberg (1995), Berry, Levinsohn, and Pakes (1995)), our markup figure remains in the same ballpark.[26] Lastly, this table also shows that the used car price, which equals 0.90, is greater than the calibrated transaction cost of 0.44, indicating that used cars are not being scrapped in equilibrium.

Table 4 provides further characterization of the behavior of the different consumer types. It reports that, in the steady state, 64.4% of the type 1 consumers and 61.7% of the type 2 ones start next period owning a used car. It also contains the consumers' car ownership transitional probabilities, showing that, unconditionally, the high type consumers (type 1) are more likely to purchase new cars, while the low type consumers are more likely to hold on to their used cars, which is consistent with the observed sorting of the population by income and car vintage in the data.

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[26] For example, Berry, Levinsohn, and Pakes (1995, pg. 882) report markups (in 1990) ranging from 0.155 to 0.328, with an average of 0.239.

IV Counterfactuals: Do secondary markets help or hurt car producers?

The purpose of our counterfactual experiments is to identify when and how secondary markets may be beneficial to durable goods manufacturers and the role that the different effects—substitution, allocative and time consistency—may play. In these experiments, we change the transaction cost parameter k while holding all the other parameters fixed at the calibrated parameter values reported in Table 2, and recompute the equilibrium and the steady state. In all experiments, we vary k between 8, which closes secondary markets, and 0, which makes them frictionless. For expositional convenience, we measure the effect of k on profits by reporting the percentage changes between $k = 8$ and $k = 0$.

The first panel of Table 5 presents the baseline counterfactual steady-state outcomes, measuring the net effect of opening secondary markets. Relative to $k = 8$, opening the secondary market to $k = 0$ lowers profits by 35%, suggesting that at the calibrated parameter values, the negative substitution effect, together with the time consistency effect, outweigh the positive allocative effect.[27]

One additional implication stems from the first panel in this table. Consumer surplus increases from 0.32 to 0.60 as k is decreased from 8 to 0. Although by increasing the total car fleet (from 0.65 to 0.80), closing the secondary market has a positive effect on consumer surplus, this effect is outweighed by the distortions that transaction costs create in the allocation of goods. This finding suggests that the change in the allocative effect from opening secondary markets must be large in relative magnitude, which we explore later.

Better understanding these findings requires that we disentangle each of the effects and identify how they depend on the key parameters and the distributional assumptions. This is the purpose of the counterfactuals that follow. In these counterfactuals, multiple effects

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[27] Section III in the Appendix reports the behavior of the two types of consumers as the secondary market becomes more active.

are at play, and we highlight the first-order ones.

A Disentangling the substitution, allocative and time consistency effects

First, we zero in on the magnitude of the substitution vs. allocative effects. To do so, we compute the full commitment equilibrium of our model, where firms choose simultaneously, once and for all, their entire sequence of output.[28] This equilibrium eliminates the time consistency effect, so that the change in profits from opening secondary markets is completely determined by the substitution and allocative effects.

The second panel of Table 5 reports the results. It shows that in the full commitment solution, opening the secondary market from $k = 8$ to $k = 0$ increases firms' profits by 52%. Therefore, at the calibrated parameter values, the allocative effect of opening the secondary market is sufficiently large to outweigh the negative substitution effect due to the increased availability of used cars.

Comparing these results to the first panel (computed assuming time consistency) illustrates the importance of the time consistency effect in reducing the desirability of secondary markets. First, by increasing output and hence the used car stock, time consistency exacerbates the substitution effect. Moreover, we see that new car prices are almost unchanged in Panel 1 as the secondary market opens, while they increase substantially in Panel 2. This suggests the increase in output arising from time consistency limits the scope of indirect price discrimination. In both of these ways, time consistency reduces the desirability of secondary markets.

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[28] In the Appendix, we also consider the case where firms lease, not sell, new and used cars. As shown in Hendel and Lizzeri (1999b), the leasing and full commitment problems may not be equivalent since the former allows the firm to scrap part of its used car stock. Table A12 in the Appendix shows how, in our calibrated model, the firm effectively uses scrappage to control the stock, obtaining an additional significant gain in profits. Furthermore, comparing the leasing equilibrium to the baseline (sales without commitment), we find that the leasing equilibrium results in lower new car production, more consumers who own no cars, lower consumer surplus, and much higher profits for the firms.

We next explore the substitution effect. The third panel of Table 5 reports the effects of secondary markets when we assume full commitment and reduce preference heterogeneity by making the persistent component (γ) identical between the two types and reducing the variance of the time-varying component (ϵ). By eliminating much of the consumer heterogeneity, we take away the allocative gains and isolate the substitution effect. In this case, opening the secondary market decreases profits by 11%, which we can attribute almost entirely to the substitution effect.

Moreover, by comparing Panels 2 and 3, we can assess the magnitude of the allocative effect. Output is more than halved in moving from closed to open secondary markets in Panel 2 (when both the allocative and substitution effects are present), but output is reduced much more moderately in Panel 3 (from 0.028 to 0.022), when the allocative benefits are "shut off". In addition, the new car price rises sharply (from 2.46 to 3.82) in Panel 2, but is almost unchanged in Panel 3. These patterns illustrate how an active secondary market allows firms to price discriminate by raising prices and focusing on the high-valuation consumers —the crux of the allocative effect.

B Assessing product durability

We next analyze the role of product durability in determining firms' losses or gains from opening secondary markets. Table 6 contains results from counterfactuals where we vary δ, the per-period death probability of a used car. The results in Table 6 show that opening secondary markets hurts firms more severely as the product becomes more durable. In the first panel, durability is increased by reducing the death probability to $\delta = 0.05$. In that case, decreasing transaction costs from 8 to 0 reduces profits by 76%. This shows how an increase in durability increases the stock of used cars against which the firms compete, exacerbating the substitution effect when secondary markets are open. Correspondingly, when durability is reduced by increasing δ to 0.25 (the third panel), each firm's profits actually increase by 11% if transaction costs are reduced from 8 to 0, so the firms would prefer secondary markets to be frictionless.

Remark: Endogenous Durability. The computational complexity of our current model makes it infeasible to endogenize firms' durability choices. Nonetheless, we can use our framework to conduct counterfactuals that shed some light on the problem of planned obsolescence. Using Table 6 and comparing all profits for all values of k, we observe that making cars less durable (by increasing δ) increases firms' profits, and that the magnitude of the increase is larger if the secondary market is more active.[29] For example, increasing δ from 0.11 (the baseline value) to 0.25 increases the firms' profits by 14% when the secondary market is closed ($k = 8$), but it increases the firms' profits by a much more substantial 96% when the secondary market is open ($k = 0$). These results suggest that when the secondary market becomes more active, firms have a stronger incentive to make their cars less durable.

Some anecdotal evidence supports this result. A 2005 report by the US General Accounting Office states that, coincident with the rise in internet retailing of books, textbook publishers "generally agreed that the revision cycle for many books is 3 to 4 years, compared with 4 to 5 years that were standard 10 to 20 years ago [...]"[30] ■

C Assessing consumer heterogeneity

We next analyze the role that the different components of consumer heterogeneity play in our results. We first consider consumers' time-varying preference shocks (ϵ_{ijt}) by modifying the variance of their distribution, with a larger variance implying a more prominent role for the time-varying component of preferences—more volatile preferences, in short. The second panel of Table 7 reports results for the baseline case, in which the scale parameter of the type I extreme value distribution for ϵ_{ijt} is normalized to 1 and hence $Var(\epsilon_{ijt}) = \pi^2/6$.[31] In the first panel, the variance is smaller at $Var(\epsilon_{ijt}) = 3/4 \times \pi^2/6$, and in the third panel,

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[29] We have also computed profits for all the (δ, k) combinations with $\delta \in \{0.05, 0.07, ..., 0.25\}$ and $k \in \{0, 0.5, 1, ..., 8\}$, and these findings are robust.

[30] From GAO (2005), pg. 3.

[31] See Section 2.10.4 in Anderson, de Palma, and Thisse (1992).

the variance is larger at $Var(\epsilon_{ijt}) = 5/4 \times \pi^2/6$ (the mean is normalized to 0 throughout).

We find that as the variance of ϵ_{ijt} is increased, the change in profitability from opening the secondary market becomes more negative. Specifically, from $k = 8$ to $k = 0$, firms' profits decrease by 35% at the baseline variance, compared to a smaller 29% at the decreased variance and a larger 40% at the increased variance. Essentially, as we remarked earlier, when the time-varying heterogeneity becomes more prominent, the distinction between high- vs. low-type consumers becomes more blurred; accordingly, the allocative benefits of secondary markets (which arise from the persistent heterogeneity) decrease, and the detrimental substitution effect dominates.

In the Online Appendix, we further examine the role of consumer heterogeneity by considering alternative specifications of the γ's and the α's. In one of them, we vary consumers' persistent heterogeneity by changing the γ's (reported in Table A7). Consistent with our intuition we find that less persistent heterogeneity limits the gains from price discrimination, decreasing the returns from opening the secondary market, whereas more persistent heterogeneity increases them.

D Assessing market structure

We next consider the interaction between opening the secondary market and market structure (i.e., the number of primary market competitors). As in a static Cournot setting, our oligopolistic firms overproduce relative to the optimal industry level because they do not internalize the negative externality that their own output creates on other firms' profits; as the number of firms increases, this Cournot externality worsens. This increase in aggregate output also implies an increase in the stock of used goods, which magnifies the negative substitution effect of secondary markets.

The results in Table 8 support this intuition, showing that, as the market becomes less concentrated, opening the secondary market decreases firms' profits by a larger amount.

The first panel shows that opening secondary markets decreases profits by 35% in the baseline case (with triopoly), whereas in a duopoly (the second panel), profits decrease by only 23%. If the firm is a monopolist (the third panel), however, opening the secondary market *increases* its profits by 18%: when the oligopolistic externality is eliminated, a monopolist prefers frictionless secondary markets.

The actual number of firms in the automobile industry exceeds three, as assumed in our baseline simulations. An extrapolation of the results here suggests that, all else equal, with more firms, the secondary market becomes less desirable for firms.

E Robustness checks and alternative specifications

In the Online Appendix, we also present results for several robustness checks and alternative specifications, which we briefly summarize below.

Although in Tables 6 and 7 we only report results for three values of δ and three values of $Var(\epsilon)$, respectively, we have extensively varied the parameter values, and our findings are robust. In the Appendix we present figures that plot the counterfactual results as we let δ and $Var(\epsilon)$ take on a broader range of values; the main patterns we observe from Tables 6 and 7 are robust, even at extreme values such as when δ is close to 1 and when $Var(\epsilon)$ is close to 0.

We also consider alternative specifications of key components of the model. First, we make the transaction cost in the secondary market proportional to the used car price rather than fixed. The calibrated parameter values (and accordingly the counterfactuals) are very similar to those in the baseline specification.[32]

Second, we enhance the accounting of persistent heterogeneity of consumer types by approximating the income distribution by three, not two, types. The results show that our main

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[32] For $k = 0$ (resp., $k = 8$), the actual specification of the transaction cost has to be irrelevant because it is equal to zero (resp., secondary market transactions stop taking place).

findings are robust as firms prefer to close secondary markets; nonetheless, the magnitude of the firms' loss due to the secondary market is smaller, which suggests that approximating the distribution with two types may understate the allocative benefits of secondary markets.

Lastly, we replicate all the counterfactual experiments in the context of a monopolistic primary market. Although the reduced output in this case mitigates the substitution effect and enhances the benefits from opening the secondary market, the directions of the remaining first-order effects are unchanged, leading to the same qualitative findings as in the triopoly counterfactuals.

V Summary and conclusions

To investigate how the tradability of durable goods in secondary markets affects firms' behavior and profits, we develop a dynamic equilibrium model of durable goods oligopoly, in which consumers face lumpy costs of transacting in the secondary markets and respond by buying and selling infrequently. Both sides of the market—firms and consumers—are forward-looking. We calibrate the model to match aggregate data from the American automobile industry and obtain a good fit.

In our model, the key element that helps us isolate the effects of secondary markets on durable-goods manufacturers is the transaction cost parameter. Using the calibrated version of the model, we run counterfactuals in which we vary the magnitude of transaction costs, to measure the effects of the secondary market on firms. On the whole, the negative effects of secondary markets dominate: at the preferred parameter values, opening the secondary market from closed to frictionless lowers the profits of the new car manufacturers by 35%. Thus, to answer the question posed in the title of the paper: secondary markets do harm new good producers.

We reiterate the caveat that we have had to make several simplifying assumptions in this paper to facilitate its computation. Because of this, our results should be interpreted with some caution. Nevertheless, one general lesson we learn from our analysis is that effective policy-making in durable goods industries must pay attention to both the dynamic and static effects on both sides of the market, which are oftentimes countervailing.

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Table 1. Fixed parameters

Discount factor (β)	1/1.04
# of distinct persistent consumer types (L)	2
% of type 1 consumers	50%
% of type 2 consumers	50%
Probability of used car quantity depreciation (δ)	0.11
# of firms (N)	3

Table 2. Calibrated parameters[a]

New car product-characteristics index (α_1)	1.67
Used car product-characteristics index (α_2)	0.80
Type 1 consumers' marginal utility of money (γ_1)	1.70
Type 2 consumers' marginal utility of money (γ_2)	2.28
Marginal cost (*c*), $10,000	1.90
Transaction cost (*k*), $10,000	0.44

[a] Throughout the paper, all monetary numbers are reported in $10,000 in the year 2003.

Table 3. Steady-state values at calibrated parameters and U.S. data averages

	Model steady-state values	U.S. data averages (1994-2003)[a]
% of Type 1 consumers:[b]		
who purchase new cars	9.68	9.8
who purchase used cars	17.79	18.7
% of Type 2 consumers:[c]		
who purchase new cars	4.20	4.2
who purchase used cars	19.28	18.6
New vehicle price ($10,000)	2.30	2.3
Used vehicle price ($10,000)	0.90	0.9
Firms' markup	0.17	0.17

[a] Calculated from Consumer Expenditure Survey and annual reports of the Big 3 U.S. automobile producers.

[b] Households with above-median income.

[c] Households with below-median income.

Table 4. Steady-state results at calibrated parameter values

Consumers' transition probabilities $P(s_t\|r_t)$[a]		
	Type 1	Type 2
P(1|2)	0.08	0.03
P(2|2)[b]	0.68	0.73
P(0|2)	0.24	0.23
P(1|0)	0.13	0.06
P(2|0)	0.50	0.50
P(0|0)	0.38	0.44
% consumers who own a used car	64.4	61.7

[a] $P(s_t|r_t)$ is the probability that a consumer who owns r_t at the beginning of t chooses s_t. 1 indicates a new car, 2 indicates a used car, and 0 indicates the outside option of no car.

[b] In the model, all used cars are identical. Therefore, no consumers sell their current used car and buy a different used car in the same period, and P(2|2) in the table corresponds to consumers who keep their current used car. In the U.S. data averages, 5.7% of type 1 consumers and 4.6% of type 2 consumers sell their current used car and buy a different used car in the same year.

Table 5. Effects of opening secondary market: Substitution, allocation, and time consistency

Variable	Transaction cost *k* ($10,000)*			
	8	2	0.44	0
Baseline: Substitution, allocative, and time consistency effects				
New car production per firm[a]	0.046	0.038	0.023	0.021
Used car transactions	0.00	0.04	0.19	0.24
New car price ($10,000)	2.22	2.16	2.30	2.35
Used car price ($10,000)[b]	8.00	2.00	0.90	0.69
Used car scrappage	0.07	0.04	0.00	0.00
Consumers who own no cars	0.20	0.20	0.30	0.35
Consumer surplus ($10,000)[d]	0.32	0.35	0.50	0.60
Profits per firm ($10,000)	0.015	0.010	0.009	0.010 (-35%)[c]
Full commitment: Substitution and allocative effects				
New car production per firm[a]	0.041	0.035	0.020	0.018
Used car transactions	0.00	0.04	0.19	0.25
New car price ($10,000)	2.46	2.25	3.21	3.82
Used car price ($10,000)[b]	8.00	2.00	1.70	2.01
Used car scrappage	0.05	0.03	0.00	0.00
Consumers who own no cars	0.21	0.21	0.39	0.45
Consumer surplus ($10,000)[d]	0.29	0.34	0.46	0.53
Profits per firm ($10,000)	0.023	0.012	0.026	0.035 (+52%)[c]
Full commitment and reduced preference heterogeneity ($\gamma_1 = \gamma_2 = 2.28$, $Var(\varepsilon) = 1/4*\pi^2/6$): Substitution effect				
New car production per firm[a]	0.028	0.027	0.025	0.022
Used car transactions	0.00	0.00	0.12	0.24
New car price ($10,000)	2.61	2.61	2.58	2.71
Used car price ($10,000)[b]	8.13	2.68	1.82	1.67
Used car scrappage	0.00	0.00	0.00	0.00
Consumers who own no cars	0.17	0.17	0.25	0.35
Consumer surplus ($10,000)[d]	0.14	0.15	0.20	0.27
Profits per firm ($10,000)	0.019	0.019	0.017	0.017 (-11%)[c]

* The calibrated transaction cost is $k = 0.44$.

[a] New car production per firm, used car transactions, used car scrappage, and consumers who own no cars are all measured against the consumer population, which is normalized to one.

[b] Because of the type I extreme value distribution of ε, there is a positive, though small, measure of buyers of used cars even at a very high used car price.

[c] Percentage change in profits from $k = 8$ to $k = 0$.

[d] Consumers' utilities are converted to monetary terms using their respective γ's.

Table 6. Effects of opening secondary market: Assessing durability

Variable	Transaction cost k ($10,000)*			
	8	2	0.44	0
More durability: δ = 0.05[a]				
New car production per firm[b]	0.033	0.029	0.013	0.011
Used car transactions	0.00	0.03	0.16	0.23
New car price ($10,000)	2.26	2.16	2.14	2.15
Used car price ($10,000)[c]	8.00	2.00	0.46	0.14
Used car scrappage	0.06	0.05	0.00	0.00
Consumers who own no cars	0.11	0.13	0.23	0.31
Consumer surplus ($10,000)[e]	0.38	0.40	0.53	0.62
Profits per firm ($10,000)	0.011	0.007	0.003	0.003 (-76%)[d]
Baseline: δ = 0.11				
New car production per firm[b]	0.046	0.038	0.023	0.021
Used car transactions	0.00	0.04	0.19	0.24
New car price ($10,000)	2.22	2.16	2.30	2.35
Used car price ($10,000)[c]	8.00	2.00	0.90	0.69
Used car scrappage	0.07	0.04	0.00	0.00
Consumers who own no cars	0.20	0.20	0.30	0.35
Consumer surplus ($10,000)[e]	0.32	0.35	0.50	0.60
Profits per firm ($10,000)	0.015	0.010	0.009	0.010 (-35%)[d]
Less durability: δ = 0.25				
New car production per firm[b]	0.061	0.051	0.041	0.041
Used car transactions	0.00	0.05	0.20	0.25
New car price ($10,000)	2.18	2.16	2.31	2.36
Used car price ($10,000)[c]	8.00	2.00	1.15	0.97
Used car scrappage	0.07	0.03	0.00	0.00
Consumers who own no cars	0.39	0.37	0.38	0.38
Consumer surplus ($10,000)[e]	0.23	0.26	0.43	0.52
Profits per firm ($10,000)	0.017	0.013	0.017	0.019 (+11%)[d]

* The calibrated transaction cost is $k = 0.44$.

[a] δ is the probability of used car depreciation.

[b] New car production per firm, used car transactions, used car scrappage, and consumers who own no cars are all measured against the consumer population, which is normalized to one.

[c] Because of the type I extreme value distribution of ε, there is a positive, though small, measure of buyers of used cars even at a very high used car price.

[d] Percentage change in profits from $k = 8$ to $k = 0$.

[e] Consumers' utilities are converted to monetary terms using their respective γ's.

Table 7. Effects of opening secondary market: Assessing variance of taste shocks

Variable	Transaction cost k (\$10,000)*			
	8	2	0.44	0
Smaller variance: $\mathrm{Var}(\varepsilon) = 3/4*\pi^2/6$[a]				
New car production per firm[b]	0.041	0.034	0.024	0.023
Used car transactions	0.00	0.03	0.17	0.24
New car price (\$10,000)	2.19	2.15	2.24	2.28
Used car price (\$10,000)[c]	8.00	2.00	1.00	0.76
Used car scrappage	0.05	0.02	0.00	0.00
Consumers who own no cars	0.16	0.17	0.26	0.32
Consumer surplus (\$10,000)[e]	0.30	0.32	0.45	0.54
Profits per firm (\$10,000)	0.012	0.008	0.008	0.008 (-29%)[d]
Baseline: $\mathrm{Var}(\varepsilon) = \pi^2/6$				
New car production per firm[b]	0.046	0.038	0.023	0.021
Used car transactions	0.00	0.04	0.19	0.24
New car price (\$10,000)	2.22	2.16	2.30	2.35
Used car price (\$10,000)[c]	8.00	2.00	0.90	0.69
Used car scrappage	0.07	0.04	0.00	0.00
Consumers who own no cars	0.20	0.20	0.30	0.35
Consumer surplus (\$10,000)[e]	0.32	0.35	0.50	0.60
Profits per firm (\$10,000)	0.015	0.010	0.009	0.010 (-35%)[d]
Larger variance: $\mathrm{Var}(\varepsilon) = 5/4*\pi^2/6$				
New car production per firm[b]	0.051	0.042	0.022	0.021
Used car transactions	0.00	0.05	0.19	0.25
New car price (\$10,000)	2.25	2.18	2.36	2.42
Used car price (\$10,000)[c]	8.00	2.00	0.83	0.63
Used car scrappage	0.08	0.05	0.00	0.00
Consumers who own no cars	0.22	0.23	0.33	0.38
Consumer surplus (\$10,000)[e]	0.34	0.39	0.55	0.65
Profits per firm (\$10,000)	0.017	0.011	0.010	0.011 (-40%)[d]

* The calibrated transaction cost is $k = 0.44$.

[a] ε is a consumer's idiosyncratic taste shock.

[b] New car production per firm, used car transactions, used car scrappage, and consumers who own no cars are all measured against the consumer population, which is normalized to one.

[c] Because of the type I extreme value distribution of ε, there is a positive, though small, measure of buyers of used cars even at a very high used car price.

[d] Percentage change in profits from $k = 8$ to $k = 0$.

[e] Consumers' utilities are converted to monetary terms using their respective γ's.

Table 8. Effects of opening secondary market: Assessing market structure

Variable	Transaction cost k ($10,000)*			
	8	2	0.44	0
Baseline: N = 3[a]				
New car production per firm[b]	0.046	0.038	0.023	0.021
Used car transactions	0.00	0.04	0.19	0.24
New car price ($10,000)	2.22	2.16	2.30	2.35
Used car price ($10,000)[c]	8.00	2.00	0.90	0.69
Used car scrappage	0.07	0.04	0.00	0.00
Consumers who own no cars	0.20	0.20	0.30	0.35
Consumer surplus ($10,000)[e]	0.32	0.35	0.50	0.60
Profits per firm ($10,000)	0.015	0.010	0.009	0.010 (-35%)[d]
Duopoly: N = 2				
New car production per firm[b]	0.062	0.048	0.034	0.032
Used car transactions	0.00	0.05	0.19	0.24
New car price ($10,000)	2.43	2.34	2.61	2.70
Used car price ($10,000)[c]	8.00	2.00	1.18	1.00
Used car scrappage	0.05	0.02	0.00	0.00
Consumers who own no cars	0.21	0.21	0.31	0.36
Consumer surplus ($10,000)[e]	0.29	0.33	0.48	0.57
Profits per firm ($10,000)	0.033	0.021	0.024	0.025 (-23%)[d]
Monopoly: N = 1				
New car production per firm[b]	0.085	0.066	0.057	0.053
Used car transactions	0.00	0.06	0.20	0.25
New car price ($10,000)	3.31	3.50	4.07	4.54
Used car price ($10,000)[c]	8.00	2.80	2.46	2.65
Used car scrappage	0.02	0.00	0.00	0.00
Consumers who own no cars	0.29	0.33	0.43	0.46
Consumer surplus ($10,000)[e]	0.20	0.24	0.38	0.45
Profits per firm ($10,000)	0.120	0.106	0.123	0.141 (+18%)[d]

* The calibrated transaction cost is k = 0.44.

[a] N is the number of firms.

[b] New car production per firm, used car transactions, used car scrappage, and consumers who own no cars are all measured against the consumer population, which is normalized to one.

[c] Because of the type I extreme value distribution of ε, there is a positive, though small, measure of buyers of used cars even at a very high used car price.

[d] Percentage change in profits from k = 8 to k = 0.

[e] Consumers' utilities are converted to monetary terms using their respective γ's.