A Quantitative Analysis of the Used Car Market*

Alessandro Gavazza¶ Alessandro Lizzeri§ Nikita Roketskiy‖

January 2012

Abstract

We quantitatively investigate the allocative and welfare effects of secondary markets for cars. Gains from trade in these markets arise because of heterogeneity in the willingness to pay for higher-quality (i.e., newer) goods, but transaction costs are an impediment to instantaneous trade. We explore how the income distribution affects this heterogeneity—income is an important determinant of willingness to pay for quality. Calibration of the model matches several aggregate features of U.S. and French used-car markets well. Counterfactual analyses show that transaction costs have a large effect on volume of trade, allocations, and the primary market, but small effects on consumer surplus and welfare.

---

*Preliminary and Incomplete. Thanks to Alistair Wilson for excellent research assistance.

¶Leonard N. Stern School of Business, New York University. 44 West 4th Street, New York, NY 10012. Telephone: (212) 998-0959. Fax: (212) 995-4218. Email: agavazza@stern.nyu.edu.

§Department of Economics, New York University, 19 West 4th Street, New York, NY 10012-1119. Email: alessandro.lizzeri@nyu.edu

‖Department of Economics, New York University, 19 West 4th Street, New York, NY 10012-1119. Email: nroketskiy@nyu.edu

1 Introduction

Secondary markets play an important allocative role for some durable goods. For instance, in the US the number of transactions in used cars are approximately three times as large as the number of transactions of new cars. Furthermore, the dispersion of used car prices is approximately five times as large as the dispersion of new car prices, suggesting that secondary markets play an important role in broadening the spectrum of goods available to consumers.

The amount of activity in secondary markets varies dramatically across goods, with some markets extremely active (e.g., cars, aircraft) and others much less so (e.g., white goods, computers). More surprisingly, the amount of activity also varies substantially across different countries for the same goods. For instance, the American used car market is much more active than the French used car market. What forces are responsible for these differences? What are the consequences for prices and allocations, for producers' profits and consumers' welfare? How do these differences in activity affect the extent of variety available to consumers? Can some of the observed differences in the primary markets across goods and countries be partially due to the underlying causes of the differences in activity in the secondary markets? These are some of the questions this paper attempts to address.[1]

We present a simple model of durable goods markets to tackle these issues. As in all markets, activity in secondary markets arises because of some gains from trade between the counterparties. In the car market, an important source of such gains from trade is heterogeneity in the willingness to pay for quality: high willingness to pay consumers sell used units when they upgrade to a new unit. Transaction costs are an impediment to instantaneous (100 percent) trade. The extent of trade is then affected by the degree of heterogeneity in preferences. We calibrate to the U.S. market for cars an extension of a standard model of trade in secondary markets that allows for transaction costs and for more than one unit per household. The model aims to match the distribution of the number of cars per household as well as some aggregate features of the volume of trade in the used-car market. Despite its simplicity, the model fits the data very well.

We then use the model to perform several counterfactuals with the purpose of understand-

[1] Empirical studies of secondary markets include the following markets: cars (Porter and Sattler, 1999; Adda and Cooper, 2000; Stolyarov, 2002; Esteban and Shum, 2007; Chen, Esteban and Shum, 2011; and Schiraldi, 2011), truck tractors (Bond, 1983), commercial aircraft (Pulvino, 1998; Gavazza 2011a and 2011b), business aircraft (Gilligan, 2004; Gavazza 2011c), capital equipment (Eisfeldt and Rampini 2009).

ing the functioning of secondary markets and their impact on the market for new goods. We first examine the effects of transaction costs by considering two polar cases and contrasting them with the baseline calibrated model: perfectly functioning secondary markets with zero transaction cost and complete shutdown of secondary markets with prohibitive transaction costs. In order to study the effects on the primary market we further break down these into two extreme scenarios concerning the elasticity of supply of new goods. First, we assume perfect elasticity of supply, so that new goods prices are the same in both counterfactual transaction cost scenarios, and new car output adjusts to absorb any increase or reduction in demand for new cars relative to the baseline calibrated scenario. Second, we assume completely inelastic supply, so that output is constant, and prices of new goods must adjust to any change in demand for new goods generated by the change in transaction costs. We find that transaction costs can have large effects on allocations within the secondary market, as well as on the market for new goods. However, the effects on welfare are quite modest, (negligible in some cases). The reason why effects on welfare are small is that there are several margins of adjustment that allow consumers and producers to neutralize the effects of transaction costs. In fact, there is a sense in which the large effects on allocations are exactly the reason why the effects on welfare are small.

Specifically, some of our most interesting findings are the following. We find that new car output is non monotonic in transaction costs, with output going up relative to the baseline case, by four percent when transaction costs are reduced to zero, and by twenty-one percent when transaction costs become prohibitive. This non monotonicity is due to two different forces manifesting themselves for these different levels of transaction costs. When transaction costs are zero, frictionless secondary markets lead to much finer matching of qualities to consumer valuations, which in turn raises high-valuation households' willingness to pay for new cars. Since supply is assumed to be perfectly elastic, the number of cars produced must increase. Instead, when transaction costs are prohibitive, used car markets shut down completely, so the only way for households to upgrade quality is to scrap their used units. Indeed, scrappage increases substantially in this scenario with cars lasting only two thirds as long as in the baseline scenario. This increased scrappage feeds into substantially higher demand for new cars, and hence higher output. The effects on prices when supply is instead assumed to be inelastic is the mirror image of the effects on output when supply is elastic: prices rise by 5 percent when transaction costs fall to zero, and by 25 percent when transaction costs become prohibitive.

We then consider a scrappage policy where we assume that a law specifies that cars must be scrapped at age eleven.[2] Scrappage policies have been introduced in a number of countries. Our policy is closest to the Japanese *shaken* system of tough emission inspections that induces a particularly young fleet of cars in Japan.[3] We see fairly large effects on allocations but very minor effects on welfare, especially in the case of elastic supply where, surprisingly, scrapping cars six years earlier than in the baseline scenario only generates a one percent reduction in welfare. This is partly because of a large output response in the case of elastic supply: output goes up by twenty-five percent. Despite this the overall stock of cars goes down. A surprising finding is that the effect of the reduction in the stock of cars is entirely absorbed by the reduction in the number of households with more than one car.

Our final counterfactual explores the quantitative effects of heterogeneity by considering data from another country: France. The income distribution in France is less unequal than in the U.S., and the model implies that we should see less trade in the French used-car market than in the U.S. This is also what the data says. The magnitude of the difference is also substantial: the average holding duration is approximately 30 percent longer in France than in the U.S. Furthermore, our model matches data from France extremely well. The other important feature of the data is that the average number of cars per household is a lot smaller in France than in the U.S., and our model can match the distribution of cars per households in both countries. Of course, there are many differences between the U.S. and France beyond the differences in the income distribution. However, it is notable that the income distribution alone can account for all the differences in the aggregate car market features that we focus on. One other interesting consequence of reduced heterogeneity is that car prices are flatter, starting with a lower new-car price, in France, and ending with higher used car prices in France for the oldest vintages.

2 Related Literature

This article contributes to two main strands of the literature. First, the theoretical literature on consumer durable goods has investigated the role of secondary markets in allocating new

[2]The reason why we chose age 11 is because it turns out that, with infinite transaction costs the *average* age of scrappage is approximately 11, so this choice facilitates the comparison of these counterfactuals.

[3]As we explain in Section 5.2, our steady state model is less well suited to an analysis of temporary policies such as cash for clunkers. See Adda and Cooper (2000) for such an analysis that does not however take into account the effects of secondary markets.

and used goods (Rust, 1985; Anderson and Ginsburgh, 1994; Waldman 1997, 2003, Hendel and Lizzeri, 1999a,b; Stolyarov, 2002). In this literature, the first part of our paper is close to Stolyarov (2002), that investigates resale rates across different car vintages. The current paper contributes to this strand of the literature by providing a quantitative analysis of the allocative and welfare effects of secondary markets, and by evaluating policies that affect secondary markets.

Second, a series of papers has analyzed car markets. Many influential papers analyze product differentiation and consumers' choices among new cars (Bresnahan, 1981; Berry, Levinsohn and Pakes, 1995; Goldberg, 1995; Petrin, 2002) or manufacturers' pricing (Verboven, 1996; Goldberg and Verboven, 2001), but they do not consider used goods and secondary markets. Wang (2008) incorporates the durability of the good in consumers' choice of new cars and Schiraldi (2011) considers new and used cars in consumers' choice sets, but none of these papers analyzes the equilibrium in the market. Hence, relative to these recent contributions, our equilibrium model is better suited to address the general-equilibrium effects of secondary markets and of policies, such as scrappage policies, that impact them. The closest paper is Chen, Esteban and Shum (2011). The main difference is that they focus on the effects of the secondary market on the primary market: they consider an oligopoly model with forward looking firms, and they compare the effects of secondary markets for both the case of commitment and for the case in which manufacturers lack commitment. Our paper cannot tackle these commitment issues, and we focus on the allocative and welfare role of secondary markets, by allowing for a richer heterogeneity of consumers which is taken from the data.

3 Model

3.1 Assumptions

We modify a model of vertical product differentiation, that has become a standard way to model secondary markets (see, for instance, Rust, 1985, Anderson and Ginsburgh, 1994, Hendel and Lizzeri, 1999a and 1999b). Stolyarov (2002) numerically solved such a model to generate some interesting patterns for secondary markets with transaction costs. We extend Stolyarov's analysis to incorporate some features that are important in the data (e.g., multiple cars per household), and we then evaluate how this simple model can account for some aggregate features of the data, while abstracting from some important features of car markets, such as horizontal product differentiation.

The first step is to obtain equilibrium for any given level of new car output. This is a necessary input for incorporating an analysis of the new car market.[4] In every period, a constant (exogenous) flow x of new cars enters the market. We will infer this output from the data and, as it will become clear, in our baseline model it would be equivalent to assume that the (equilibrium) price p_0 of new cars is exogenous, and any quantity of new cars can be supplied at price p_0, or equivalently, that car supply is infinitely elastic at unit cost of p_0.

New cars are homogeneous, with quality q_0 and deterministic depreciation: a car of age a is of quality q_a, with $q_a > q_{a+1}$. We have also obtained some results for a model with heterogeneous vertical qualities of new goods, but this delivers very similar similar results.[5]

Each car "lives" until it is (endogenously) scrapped at time T. For expositional simplicity, we describe the case in which, in equilibrium, all agents choose to scrap at the same time T^*. This is the relevant case for out baseline calibration and it implies that the steady-state total mass of cars is equal to xT^*.[6]

A majority of households in the U.S. owns more than one car (see Section 4.1). We want the model to capture this feature of the data, partly because, as discussed below, this has consequences for the secondary market, partly because we want to contrast the U.S. with France, where the number of cars per household is much lower. Thus, we must allow households to own more than one car. However, this significantly complicates the numerical computation, so we do not allow for more than two cars: in each period, a household has value for at most two cars. Each household has a preference parameter θ that determines the flow of utility that the household enjoys from their cars. Specifically, a household with preference θ and with two cars enjoys a per-period flow of utility equal to $\theta q_1 - c$ from its first (better) car, and $\alpha\theta q_j - c$ from its second car. The parameter $\alpha \in (0, 1)$ captures the lower valuation for the second car and the parameter c is a per-period holding (maintenance) cost, independent of car quality. The role of the holding cost is to generate a reasonable scrappage age.[7] The preference parameter θ is distributed in the population according to

[4] In our counterfactuals, we consider two opposite scenarios for supply: 1) A perfectly elastic supply, as in a perfectly competitive industry with constant marginal cost equal to p_0; and 2) A perfectly inelastic (per-period) supply equal to x.

[5] Of course, allowing for rich patterns of substitution as in Berry, Levinsohn, and Pakes (1995) would lead to a very different model. It is however very difficult to incorporate secondary markets in such a model.

[6] Some of our counterfactuals require aggregation of heterogeneous scrappage decisions. This is a straightforward extension that we omit from the main analysis to avoid cumbersome notation.

[7] In fact, if we allowed holding costs to increase with age of the car, the only ones that would matter

the non-degenerate c.d.f. F, whereas α is the same for all households in the population.[8]

In order for the model to generate interesting implications on trade in the secondary market, and to match relevant features of the data, we must assume some frictions. We assume that there are transaction costs in the secondary market: if a household sells a car of age a, it pays a transaction cost λ_a proportional to the sale price.[9] The level of transaction costs will be a key variable in some of our counterfactuals.

3.2 Household problem

A household chooses how many cars to own and, for each car, which vintage to buy and how long to keep it. We now formally derive the value functions for the household problem. We proceed by separating the problem into two stages. In the first stage, the household decides whether to have zero, one or two cars. In the second stage, the household decides which vintage(s) to own and how long to keep it (them).

The value V^0 of not owning cars is normalized to zero.

Let $V^1(\theta, a)$ be the value of owning one car of age a for a household with valuation θ. In every period, this household considers whether to keep the q_a car or to replace it, taking as given the (endogenous) vector of prices $p = (p_0, .., p_{T-1})$. Thus, the value $V^1(\theta, a)$ is equal to:

$$V^1(\theta, a) = \theta q_a - c + \beta \max\left\{V^1(\theta, a+1), \max_{a'} V^1(\theta, a') - p_{a'} + (1-\lambda_{a+1}) p_{a+1}\right\}. \tag{1}$$

Equation (1) says that the household enjoys a current-period utility flow equal to $\theta q_a - c$ from owning a car of age a. In the following period, the household decides whether to keep it (obtaining a value equal to $V^1(\theta, a+1)$), or sell it to replace it with a newer one, thereby obtaining a value equal to:

$$\max_{a'} V^1(\theta, a') - p_{a'} + (1-\lambda_a) p_a. \tag{2}$$

would be those for ages close to scrappage time.

[8] We also allowed α to be heterogenous across households. Obviously, adding this heterogeniety allows our model to match the data better. However, since our calibration with homogenous α already matches the data very well (see Table 3), we choose the more parsimonious parametrization.

[9] Two comments on our assumption on transaction costs: 1) Some dependence of transaction costs on prices is realistic. Allowing for a fixed component of transaction costs is straightforward and does not change our qualitative and quantitative results; and 2) The fact that transaction costs are paid by the sellers is immaterial since, as in the analysis of tax incidence, equilibrium allocations are invariant to the "statutory incidence" of transaction costs.

As Stolyarov (2002) shows, for each household θ there is an $a^*(\theta)$ that maximizes equation (2); $a^*(\theta)$ is the vintage that household θ buys whenever it replaces the car. Moreover, since the utility flow $\theta q - c$ is increasing in the quality of the car, and quality depreciates over time, the household θ replaces its car whenever it reaches age $a^{**}(\theta)$. Such age $a^{**}(\theta)$ satisfies the following two inequalities:

$$\begin{aligned} V^1(\theta, a^{**}) &< V^1(\theta, a^*) - p_{a^*} + (1 - \lambda_{a^{**}}) p_{a^{**}}, \\ V^1(\theta, a^{**} - 1) &> V^1(\theta, a^*) - p_{a^*} + (1 - \lambda_{a^{**}-1}) p_{a^{**}-1}. \end{aligned}$$

The first inequality says that the household prefers to simultaneously sell a vintage-a^{**} car and purchase a vintage-a^* car, rather than to keep the vintage-a^{**} car. The second inequality says that the household prefers to keep a vintage-$a^{**}-1$ car, rather than to sell it and purchase a vintage-a^* car.

The previous arguments imply that it is optimal for a household θ to buy a car of age $a^*(\theta)$ and to keep it until it reaches age $a^{**}(\theta)$, for a total of $n^*(\theta) = a^{**}(\theta) - a^*(\theta)$ periods. It easy to show that $a^*(\theta)$ and $a^{**}(\theta)$ are decreasing in θ—i.e., households with stronger preferences for quality choose newer vintages. Thus, we can write the value function $V^1(\theta, a, n)$ of a household with valuation θ buying a car of quality a and keeping it for n periods as:

$$V^1(\theta, a, n) = \frac{\theta \sum_{i=0}^{n-1} \beta^i q_{a+i} - c \sum_{i=0}^{n-1} \beta^i - p_a + \beta^n (1 - \lambda_{a+n}) p_{a+n}}{1 - \beta^n}.$$

The problem of the household is to choose the optimal quality of car q_{a^*} to acquire and the optimal holding time $n^* = a^{**} - a^*$. Hence, the optimal $\{a^*, n^*\}$ solve:

$$\max_{\{a,n\}} V^1(\theta, a, n) = \max_{\{a,n\}} \frac{\theta \sum_{i=0}^{n-1} \beta^i q_{a+i} - c \sum_{i=0}^{n-1} \beta^i - p_a + \beta^n (1 - \lambda_{a+n}) p_{a+n}}{1 - \beta^n}. \tag{3}$$

The value of owning two cars is more complex because a household can choose to follow separate policies for each of its two cars. However, a household can economize on transaction costs for its second car by keeping the depreciated first unit as a second car. Indeed, this "intra-household trade" is an important feature of households' observed behavior, as we will report in more detail in Section 4.1.[10] To simplify the computation of the household decision

[10] More specifically, this "intra-household" trade accounts for the difference between the fractions of cars traded and the fraction of household trading a car reported in the first and the second lines, respectively, of Table 1.

problem, we allow the household to choose only among the following class of policies: the household keeps any car for a total of n periods, but then alternates between acquiring a newer vintage every m and $m-n$ periods. Thus, such policy combines two cycles. In the first cycle, the household keeps a car as its first car for m periods, then the car becomes the second car for the remaining $n-m$ periods. In the second cycle, the household keeps a car as its first car for $n-m$ periods, then the car becomes the second car for the remaining m periods. Obviously, if $n-m=m$, then the household buys a car every $\frac{n}{2}$ periods and keeps it for n periods. This class of (n,m) policies encompasses a large number of possibilities, and it can be shown that, when transaction costs are sufficiently high, the optimal policy belongs to this class.

The value $V^2(\theta,a,n,m)$ of following a (n,m) policy for a household with valuation θ equals:[11]

$$\begin{aligned} &V^2(\theta,a,n,m) = \\ &\frac{\theta\sum_{i=0}^{m-1}\beta^i q_{a+i} + \alpha\theta\sum_{i=m}^{n-1}\beta^i q_{a+i} - c\sum_{i=0}^{n-1}\beta^i - p_a + \beta^n(1-\lambda_{a+n})p_{a+n}}{1-\beta^n} + \\ &\beta^m\frac{\theta\sum_{i=0}^{n-m-1}\beta^i q_{a+i} + \alpha\theta\sum_{i=n-m}^{n-1}\beta^i q_{a+i} - c\sum_{i=0}^{n-1}\beta^i - p_a + \beta^n(1-\lambda_{a+n})p_{a+n}}{1-\beta^n}. \end{aligned} \tag{4}$$

The first term in the right-hand side of equation (4) is the discounted flow of utility provided by a car that is the household's first car for m periods, then is the second car for $n-m$ periods, and then it is sold. Similarly, the second term is the discounted flow of utility provided by a car that is the household's first car for $n-m$ periods, then it becomes the second car for additional m periods, and then it is sold.

Each household θ chooses the optimal number $k^*(\theta)$ of cars to maximize its value function $W(\theta)$, which equals:

$$W(\theta) = \max\left\{V^0, \max_{\{a,n\}} V^1(\theta,a,n), \max_{\{a,n,m\}} V^2(\theta,a,n,m)\right\}. \tag{5}$$

Based on households' choices, the steady state distribution $h_a(\theta)$ of owners of a car of quality q_a is:

$$h_a(\theta) = \begin{cases} \frac{k^*(\theta)f(\theta)}{n^*(\theta)} & \text{if } a^*(\theta) \le a < a^*(\theta) + n^*(\theta) \\ 0 & \text{otherwise.} \end{cases} \tag{6}$$

[11] Equation (4) assumes that for the first m periods the household only has one car, and does not have a second car until it replaces its first car.

Finally, the endogenous scrappage age T^* is determined by the following conditions: 1) No household chooses to keep a car of quality q_{T^*}; 2) No household buys a car of quality q_{T^*}; and 3) A car of quality q_{T^*} has a price p_{T^*} equal to zero.

The market equilibrium is defined by standard competitive conditions. Specifically, an equilibrium is a vector of household decision rules $\{k^*(\theta), a^*(\theta), n^*(\theta), m^*(\theta), T^*\}$ and a vector of prices $p = (p_0, .., p_{T^*-1})$ such that: (i) Decision rules are optimal. (ii) For every vintage a, markets clear:

$$\int h_a(\theta)\, d\theta = x \quad \text{for} \quad a = 0, .., T^* - 1.$$

4 Calibration

4.1 Data

We use data from the *2000 Consumer Expenditure Survey* (CEX), a cross-sectional survey of 7,860 U.S. households. CEX reports detailed information about each of households' vehicles at the time of the interview, such as the model; the age; whether it is owned or leased; whether it has been acquired in the last 12 months; whether it was acquired new or used; and the price paid.[12] CEX also reports households' income, and we will use it to capture households' willingness to pay for car quality in our quantitative analysis of Section 4.

Table 1 reports some aggregate statistics on households' car holdings computed from the CEX that the quantitative analysis of our model will successfully match. Specifically, the first row reports that, on average, one every three U.S. households acquired a car within the last 12 months of the survey interview. The second row reports that one every 4.5 cars was purchased within the last 12 months. The third row reports that, of all cars traded, approximately one every four cars was new. The last three rows report the fraction of households with zero, one and more than one car, respectively. The majority of U.S. households hold more than one car. Overall, these patterns indicate that secondary car markets are very active.

[12] CEX also reports some information on cars provided by the employers (company cars), but this information is less detailed than information about personal cars. In addition, in some cases the decision to replace a company car may not be entirely in the hands of the household. For these reasons, we exclude company cars from our analysis.

Table 1: Secondary Market for Cars, U.S.

$\dfrac{\text{Households with at least one car}}{\text{Households who acquired a car in last 12 months}}$	3.09
$\dfrac{\text{Total stock of cars}}{\text{Cars acquired last 12 months}}$	4.54
$\dfrac{\text{Cars acquired last 12 months}}{\text{New Cars acquired last 12 months}}$	3.55
Households with no car	0.13
Households with one car	0.34
Households with more than one car	0.53

Notes: This table provides aggregate statistics of the U.S. car market computed from the *2000 Consumer Expenditure Survey*.

4.2 Choice of Parameters

We calibrate the model to investigate whether it can quantitatively replicate the aggregate statistics for the U.S. markets reported in Table 1. We report in Table 2 the numerical values of the parameters the we use in our calibration, and we describe below how we choose these numerical values. This description provides intuitive arguments on the "identification" of the parameters.

An important input into our quantitative analysis is the distribution of θ. This is not directly observable. We decided to use the distribution of household gross income as the distribution of θ. This choice can be partially justified theoretically based on the following remark.

Remark 1 *If consumers have logarithmic utilities in income, and there are no borrowing constraints, then θ is equal to total expenditure on all goods except cars. Thus, the distribution of income is a good approximation for the distribution of θ.*

In order to understand this remark, consider the following static problem: A household of type θ faces a distribution of qualities q available at price $p(q)$, and chooses q to maximize $\theta q - p(q)$. The first-order condition for this problem is:

$$p'(q) = \theta.$$

Table 2: Calibration Parameters

Parameter	μ	σ	β	δ	xT^*	T^*	c	α
Numerical Value	10.06	1.32	.95	.08	1.40	17	278	.25

Notes: This table provides the numerical values of the parameters used in the calibration.

Now consider a household with income y and log utility for the outside good. The household solves

$$\max_q \{q + \log(y - p(q))\}.$$

The First Order Condition for this problem is:

$$p'(q) = y - p(q).$$

Thus, if we define $\theta \equiv y - p(q)$, our linear model generates the same choices for consumers. In our model, choosing the age and holding time of a car is the same as choosing its quality, with $p(q)$ replaced by the appropriate equivalent rental price (with transaction costs). The distribution of spending on the outside good $y - p(q)$ is our distribution of θ. In our analysis, we use income y directly.[13] Using the CEX, we find that the distribution of income is fitted well by a lognormal distribution with parameters $\mu = 10.06$ and $\sigma = 1.32$. These parameters match the CEX average household income of $42,100.

We assume that one period in the model is equal to one year and we set the discount rate $\beta = .95$.

We choose the value of the total stock of cars xT^* to match the sum of the fraction of households with one car plus twice the fraction of households with more than one car. Moreover, we choose a value of the per-period holding cost c to match the scrappage age T^* of cars. In Table 1 we report the ratios

$$r_1 = \frac{\text{Total stock of cars}}{\text{Cars acquired last 12 months}}$$

and

$$r_2 = \frac{\text{Cars acquired last 12 months}}{\text{New Cars acquired last 12 months}}.$$

[13] This is a reasonable approximation. Expenditures for Transportation have a weight equal to 17.3 percent in the basket of goods and services that constitutes the Consumer Price Index. New and used motor vehicles have a weight of 6.3 percent. Furthermore, these expenditures have a high correlation with income, so the dispersion of $y - p(q)$ and the dispersion of y are very similar.

In steady state, the total stock of cars is equal to xT^* and the mass of new cars acquired in every period is equal to the flow of new cars x. Thus, we can calculate T^* as $T^* = r_1 r_2$. The calculations imply that $T^* = 16.61$ for the US, which we approximate to the closest integer: $T^* = 17$. We then calibrate the holding cost c to match this scrappage age T^*, and the corresponding value is $c = 272.7$.

The average price of a new car purchase reported in the CEX is equal to \$22,000 and we choose $q_0 = 0.2$ to match this new-car price. We further let $q_a = (1-\delta)^a q_0$, with a value of $\delta = .08$ to match the average annual depreciation of car prices of around 20 percent.[14]

To calculate transaction costs λ_a, we use price data obtained from the Kelley Blue Book for the most popular cars in the U.S.: Toyota Corolla, Toyota Camry, Toyota Previa and Toyota Sienna. As in Porter and Sattler (1999), we estimate transaction costs using the difference between suggested retail and trade-in values. These value evolve from approximately 20 percent for one-year old cars to more than fifty percent for cars older than ten years of age. We then fit a quadratic polynomial regression in age to these data on transaction costs to smooth them and average them across different cars.[15]

Finally, we calibrate the parameter $\alpha = .25$ to match the aggregate statistics reported in Table 1. The key statistic that pins down the value of α is the number of cars per household.

4.3 Computational Algorithm

For any values of the parameters, we take $N = 10,000$ draws of θ from the lognormal income distribution, and we compute the equilibrium using the following steps:

1. We start with a vector of prices $p = (p_0, .., p_{T-1})$;

2. For each household θ, we calculate the optimal $k^*(\theta)$, $a^*(\theta)$, $n^*(\theta)$ and, if $k^*(\theta) = 2$, the optimal $m^*(\theta)$ that maximize equation (3);

3. We calculate the steady state distribution $h_a(\theta)$ as $\frac{k^*(\theta)}{n^*(\theta)N}$ if $a^*(\theta) \leq a < a^*(\theta) + n^*(\theta)$, and 0 otherwise;

[14] We also considered values of $\delta = .09$ and $\delta = .07$. The results (available from the authors upon requests.) are almost identical.

[15] Our estimates of transaction costs do not take into account that transaction costs may be heterogeneous across households. Specifically, for individuals who choose to transact with dealers, the bid-ask spread is a lower bound on their transaction costs. Instead, for households who choose transact with private parties, the bid-ask spread is likely an upper bound on their transaction costs. Unfortunately, allowing for heterogeneous transaction costs is computationally burdensome.

Table 3: Secondary Markets: Model vs. Data

	Data	Model
$\frac{\text{Households with at least one car}}{\text{Households who acquired a car in last 12 months}}$	3.09	2.89
$\frac{\text{Total stock of cars}}{\text{Cars acquired last 12 months}}$	4.54	4.60
$\frac{\text{Cars acquired last 12 months}}{\text{New Cars acquired last 12 months}}$	3.55	3.69
Households with no car	0.13	0.13
Households with one car	0.34	0.34
Households with more than one car	0.53	0.53

Notes: This table reports the moments of the data that the model seeks to match and the corresponding moments computed from the model with the parameters reported in Table 1.

4. We calculate the integral of the steady state distribution (6) of age a as $\sum_{i=1}^{N} h_a(\theta_i)$;

5. We search for the vector of prices p that minimizes the excess demand of all vintages. More formally, we search for the vector of prices p that minimizes the largest absolute value of excess demand across all vintages $\max_{a\in\{0,\ldots,T^*-1\}}\left\{\left|\sum_{i=1}^{N} h_a(\theta_i) - x\right|\right\}$.

4.4 Results

Table 3 reports the numerical results of the calibration of our model, along with the observed values in the data. (In the analysis of the following sections, we refer to the results of Table 3 as the "baseline case.") The model matches well the aggregate features of the U.S. car market. We discuss below in more detail key outcomes of the calibrated model.

Trade. The model matches closely the statistics on aggregate trade in cars and activity in secondary markets, most notably the fraction of households acquiring a car and the fraction of cars traded.

Figure 1 shows the fractions of used cars traded by age generated by the model. The plot shows that the relationship between the fraction of used car traded and the age of the car is non-monotonic. These patters of trade are the focus of Stolyarov (2002). The intuition for

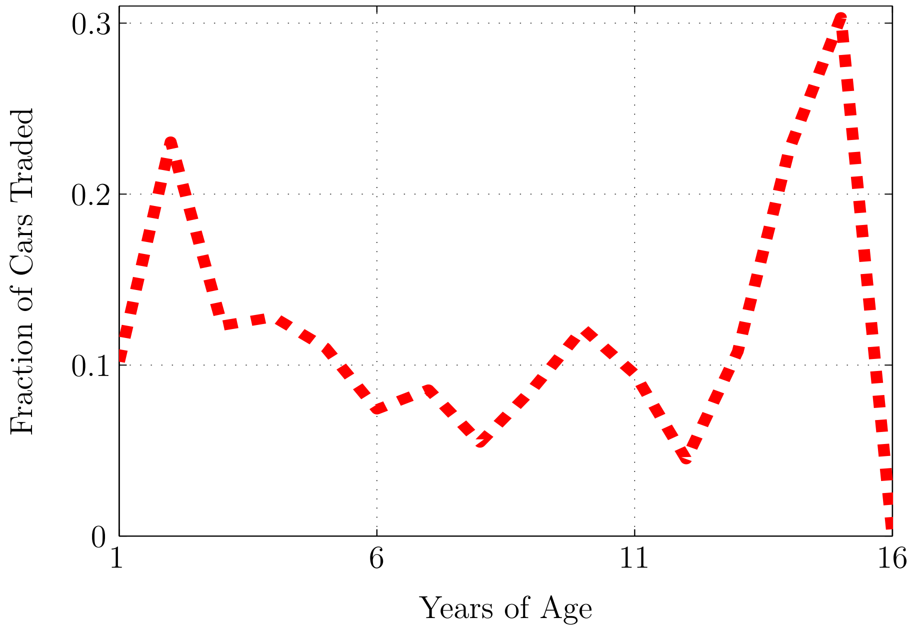

FIG. 1: The figure displays the steady-state fraction of cars traded by vintage.

the spikes of trade is that, because of transaction costs, only a small fraction of households sells their car after one period, so the resale rates are (locally) increasing when cars are relatively new. Moreover, households are unlikely to purchase old cars that they would be scrapping after just one period, so the resale rates are (locally) decreasing when cars are old.

Cars per Household. Table 3 shows that the model matches well the fraction of households with no car, one car, and more than one car. The parameter that allows the model to match these statistics is α, the ratio between the value of the second and the first car.

Car Prices. Equilibrium prices decline at a fast rate—approximately 20 percent per year—because of cars' physical depreciation (assumed to be eight percent per year) and because of the equilibrium sorting of consumers across vintages. The reason for this large price decline is that the U.S. income distribution displays wide dispersion and, thus, the willingness to pay for a marginally better car is high. In Section 5.3, we will see that in France, where the dispersion of the income distribution is lower, the price decline is not as steep.

5 Counterfactual Analyses

We now perform several counterfactuals, with the goal of understanding the allocative and welfare effects of secondary markets. Specifically, we analyze the effects of transaction costs by considering two extreme cases: frictionless secondary markets and no resale markets. We then consider the case of scrappage policies that eliminate the availability of older cars, and the effects of income heterogeneity.

Naturally, we expect any changes in secondary markets to affect primary markets. Thus, the supply response of new-goods producers is an important element determining the welfare consequences of secondary markets frictions. We consider two alternative scenarios that help highlight how primary markets adjust. First, we consider the case of perfectly elastic supply—i.e., the price of new cars does not respond to changes in transaction costs, but the quantity does. Second, we consider the case of perfectly inelastic supply—i.e., the quantity of new cars does not respond to changes in transaction costs, but the price does. These two extreme cases correspond to the case of a perfectly competitive industry with constant marginal costs of production, and to the case of a industry with binding capacity constraints for all producers. Hence, we wish to emphasize that our counterfactuals consider only short-run effects, since the supply-side response to the change in transaction costs is limited. Nonetheless, we believe that these counterfactuals are useful to understand the importance of transaction costs for manufacturers, since they indicate that *either* output *or* prices change when transaction costs change, even in a oligopolistic market for new cars.[16]

In our analysis, we calculate average per-capita flow of consumer surplus as

$$\frac{(1-\beta)\sum_{i=1}^{N} W(\theta_i)}{N}.$$

Moreover, we calculate producers' per-capita flow profits as $(p_0 - mc)\,x$. In the case of a perfectly elastic supply, profits are zero. In the case of an inelastic supply, we impute the marginal cost mc to be equal to the baseline new-car price p_0. Hence, producers' profits are zero in the baseline case, whereas they are equal to the $(p_0' - p_0)\,x$ in counterfactual cases, where p_0' is the counterfactual new-car price.

[16] Our counterfactual analyses do not consider how changes in secondary markets affect the quality of new cars produced. We focus on a single quality of new cars to simplify the way secondary markets expand the array of goods available to consumers, but the forces we discuss still hold when new cars of different qualities are available. Our model can be extended to accommodate multiple qualities on the primary market, along with different durabilities across cars.

The differences in allocations and welfare between our counterfactuals and the baseline case are due to three economic effects.

1. Increasing (decreasing) transaction costs has the partial-equilibrium direct effect of destroying (freeing) resources, thereby affecting households' willingness to pay because they obtain different net resale prices.

2. Lower (higher) transaction costs have the partial-equilibrium indirect effect of allowing a finer (coarser) matching between households preferences and the quality of their cars.

3. Effects (1) and (2) feed into the general-equilibrium effects of changing new- and used-car prices and/or quantities relative to the baseline case.

5.1 The Effects of Transaction Costs

In this Section, we consider the allocative and welfare effects of transaction costs. They are the natural starting point to study the importance of secondary markets. As described in Section 4, in our quantitative analysis we use transaction costs proportional to prices, calculated by fitting dealer bid-ask spreads. We now consider two extreme counterfactual scenarios: frictionless secondary markets and complete shutdown of secondary markets. These cases correspond to $\lambda_a = 0$ and $\lambda_a = 1$ for all a, respectively.

5.1.1 Frictionless Resale Markets

When transaction costs are zero—i.e., $\lambda_a = 0$—the households' maximization problem is static. They hold the same car vintage/quality over time, and their choice is which vintage to hold. The equilibrium displays perfect matching between households' preferences (either θ or $\alpha\theta$) and the qualities of the cars chosen in every period. Market clearing requires that either: 1) All households have at least one car, and the highest-income households own two cars. In this case, there is a threshold value θ' that satisfies $X = F(\theta') + 2(1 - F(\theta')) = 2 - F(\theta')$—i.e., all households with income below θ' own one car (the term $F(\theta')$), and all households with income above θ' own two cars (the term $2(1 - F(\theta'))$); or 2) There are households with zero, one, and two cars. In this case, there are thresholds θ'' and θ''' that satisfy $X = 1 - F(\theta'') + 2(1 - F(\theta'''))$ and $\theta'' = \alpha\theta'''$—i.e., all households with income above θ'' own one car (the term $1 - F(\theta'')$), all households with income above θ''' own two cars (the term $2(1 - F(\theta''')))$, and the lowest willingness-to-pay of one- and two-car households are the same.

Table 4 reports the quantitative results with counterfactual zero transaction costs for the cases of a perfectly elastic supply of new cars—i.e., the price p_0 of new cars is the same as in our baseline case of Section 4—and for the case of a perfectly inelastic supply of new cars—i.e., the quantity x of new cars is the same as in the baseline case of Section 4. Overall, the quantitative effects are similar in these two supply scenarios.

Quantity of cars. Table 4 reports that new-car output increases in the case of elastic supply relative to the baseline case. The reason is that, when $\lambda_a = 0$, both the absence of transaction costs and frictionless matching of qualities to households' valuations raise high-θ households' willingness to pay for cars. Since the supply of new cars is perfectly elastic and, thus, prices are the same as in the baseline case, the number of new cars demanded increases. Clearly, new car output does not change in the case of inelastic supply.

When new-car supply is elastic, the scrappage age decreases relative to the baseline case. The reason is that, if it did not decrease, the new-car increase implies an increase in the total stock of cars. Hence, the marginal owner of a car would have a lower valuation (either θ or $\alpha\theta$) than in the baseline case. However, the holding cost c would imply that the marginal owner's net utility flow (either $\theta q - c$ or $\alpha\theta q - c$) is negative, which is impossible. Thus, some low-valuation consumers scrap their cars at the earlier age of $T = 16$. When new-car supply is inelastic, the scrappage age $T = 17$ is the same in the case when $\lambda_a = 0$ and in the baseline case. The reason is that the total stock of cars does not change and, thus, the optimal scrapping age does not change either, since net prices (i.e., net of transaction costs) are positive in both cases. Overall, the total stock of cars remains constant in both supply scenarios.

Prices. New-car prices are unchanged when the supply of new cars is elastic, whereas new-car prices increase when the supply of new cars is inelastic. The latter happens for the two reasons previously highlighted. First, the absence of transaction costs allows higher-valuation households to capture the full resale value of cars, thereby increasing their willingness to pay. Second, the absence of transaction costs allows a finer matching between the household preferences and cars. In particular, higher-income households own better cars, thereby increasing their willingness to pay.

Table 4: Allocative and Welfare Effects of Secondary Markets, No Transaction Costs

	Baseline	Elastic Supply	Inelastic Supply
$\frac{\text{New Cars}}{\text{New Cars, Baseline Case}}$	1	1.05	1
$\frac{\text{Price of a New Car}}{\text{Price of a New Car, Baseline Case}}$	1	1	1.05
$\frac{\text{Households with at least one car}}{\text{Households who acquired a car last year}}$	2.89	1	1
$\frac{\text{Total stock of cars}}{\text{Cars acquired last year}}$	4.60	1	1
$\frac{\text{Cars acquired last year}}{\text{New Cars acquired last year}}$	3.69	16.2	17
Households with no cars	0.13	0.13	0.13
Households with one car	0.34	0.34	0.34
Households with two cars	0.53	0.53	0.53
$\frac{\text{Consumer Surplus}}{\text{Consumer Surplus, Baseline case}}$	1	1.04	1.03
$\frac{\text{Welfare}}{\text{Welfare, Baseline case}}$	1	1.04	1.04
$\frac{\text{Transaction Costs}}{\text{Consumer Surplus}}$	0.02	NA	NA

Notes: This table reports statistics on allocations and welfare computed from the model with no transaction costs (i.e., $\lambda_a = 0$)and with an elastic or inelastic supply of new cars, respectively.

Interestingly, in both new-car supply scenarios, prices of older cars decline relative to the baseline case—on average by 9.8 percent when supply is elastic and by 8.6 percent when supply is inelastic. The intuition for the decrease is consistent with the new-car price increase. First, as cars age, the expected number of future trades is smaller. Hence, the elimination of transaction costs has a smaller effect on increasing households' willingness to pay for older goods than for newer goods. Second, the finer matching allowed by frictionless trade implies that lowest-valuation households own worse cars relative to the baseline case. Overall, when the supply of new cars is inelastic, the second negative effect dominate the first positive (but small) one for older goods, thereby depressing their prices. In addition, when the supply of cars is elastic, an additional effect further depresses old-car prices. New-car output is higher than in the baseline case. Since only some of the oldest cars are scrapped when transaction costs are zero, the stock of cars of all vintages $a < T$ is higher too. Thus, since the equilibrium displays perfect matching between households preferences and the quality of their cars, the valuation (either θ or $\alpha\theta$) of the owner of each vintage $a < T$ has to drop to equate supply and demand.

Trade. The effect of removing transaction costs on the volume of trade is dramatic, but perhaps unsurprising. When transaction costs are zero, all cars trade in every period, so the volume of trade is equal to 100 percent. This explains the third, fourth and fifth rows of Table 4.

Cars per Household. The distribution of the number of cars per household is exactly the same in the counterfactual scenarios and in the baseline case. This is an interesting feature of our model, as long as there is trade in the oldest vintage. To understand the reason for this feature, note that the price of the oldest vintage must be zero because the identity of the last vintage is determined by the indifference of the lowest-valuation used-car owner between owning a car of that vintage or scrapping it, thereby not owning any car and enjoying a utility flow of zero. Hence, the scrappage age is determined by the equality of the utility flow for the last vintage (either $\theta'' q_T$ or $\alpha\theta''' q_T$) and the holding cost c of the lowest-valuation used-car owner (either θ'' or $\alpha\theta'''$). Since the utility flow is higher with younger vintages, the previous arguments imply that to figure out whether a household with valuation θ owns a car it is enough to determine if its utility flow for the last vintage (either θq_T or $\alpha\theta q_T$) exceeds the holding cost c. Since the total stock of cars is the same in the counterfactual scenarios as in the baseline scenarios, it must also be the case that the marginal θ (and $\alpha\theta$) owning a unit is the same, implying that the distribution of cars per household is also the same. However, lowering transaction costs does change households' distribution of owned vintages.

Welfare. The three economic effects of removing transaction costs—i.e., the direct of freeing resources, the indirect effect of allowing a finer matching between preferences and vintages, and the general-equilibrium effect on prices—have contrasting impacts on consumer surplus and on welfare relative to that of the baseline case. Specifically, when there are no transaction costs, the first two effects increase consumer surplus and welfare relative to the baseline case. Instead, the general-equilibrium effect on prices—lower on old cars, and higher on new cars when the supply is inelastic—has an heterogenous impact on individual households' surplus, depending on their income, and a negative impact on aggregate consumer surplus but a positive impact on producers' profits when the supply is inelastic.

Figure 2 displays the ratio between consumer surplus in the counterfactual case of zero transaction costs and consumer surplus in the baseline case for all households who acquire a car, ranked by the percentile of their income, for the two scenarios of elastic and inelastic supply. Interestingly, the effects are non-monotonic in income.

Table 4 reports that aggregate consumer surplus is higher when transaction costs are zero, indicating that the first two effects dominate the effect of higher new-car prices due to an inelastic new-car supply. The calculations reported in table 4 show that, when secondary markets are frictionless, consumer surplus increases by three or four percent relative to the baseline case, depending on new-car supply. When supply is elastic, producer profits are zero and, thus, welfare increase by four percent When supply is inelastic, producers' profits increase relative to the baseline case, since the new-car prices are higher. Overall, removing transaction costs increases welfare by four percent and, even in the case of an inelastic new-car supply, almost all this increase is due to the increase in consumer surplus.

The magnitudes reported in table 4 allow us to quantify the three economic effects of removing transaction costs. More specifically, the last row of table 4 reports that the direct effect of transaction costs equals two percent of consumer surplus in the baseline case. Since the total effect of removing transaction costs on consumer surplus when new-car supply is elastic equals four percent of consumer surplus, the indirect effect through a finer matching between preferences and vintages is of the same order of magnitude of the direct effect of

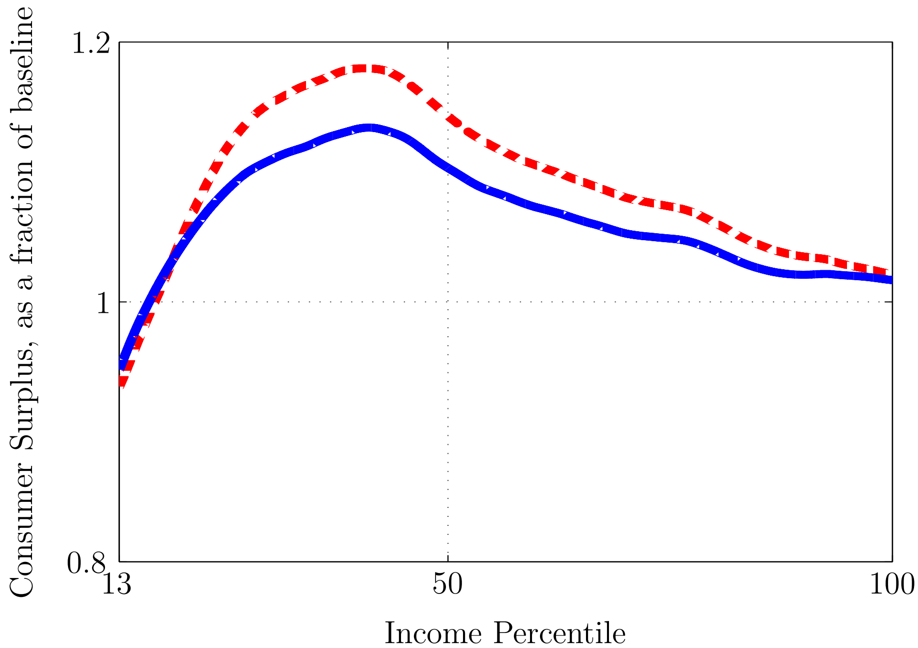

FIG. 2: The figure displays counterfactual consumer surplus with no transaction costs relative to baseline consumer surplus by income percentile, elastic new-car supply (dashed line) and inelastic new-car supply (solid line).

transaction costs, thus approximately equal to two percent of consumer surplus (and welfare). Instead, the difference between aggregate welfare and consumer surplus when new-car supply is inelastic suggests that the general-equilibrium effect on new-car prices—or, alternatively, supply distortions—is approximately equal to one percent of welfare, a smaller magnitude than that the other two effects of transaction costs.

5.1.2 No Resale Markets

When transaction costs are prohibitive (i.e., $\lambda_a = 1$), households optimally purchase only new cars, and their key choice is how long to keep them before scrapping and replacing them. In equilibrium, each household has an optimal scrappage age $T(\theta)$, with households with higher valuation θ scrapping their cars earlier, thereby holding, on average, younger vintages.

Table 5 reports the quantitative results with counterfactual prohibitive transaction costs for the case of a perfectly elastic supply of new cars—i.e., the price p_0 of new cars is the same as in our baseline case of Section 4—and for the case of a perfectly inelastic supply of new cars—i.e., the quantity x of new cars is the same as in the baseline case of Section 4. Overall, as in the previous analysis of no transaction costs, the quantitative effects are similar in the two supply scenarios.

Quantity of cars. When new-car supply is elastic, table 5 reports that new-car output increases by 21 percent relative to the baseline case. Note that this implies that output is non-monotonic in transaction costs, since table 4 showed that new-car output is larger when there are no transaction costs than in the baseline case. However, different forces affect output in the two extreme counterfactual scenarios. The reason of the large increase when transaction costs are prohibitive is that scrappage increases dramatically. This is because the secondary-market shut-down implies that the only way for households to upgrade their quality is to scrap their current cars. From the numbers reported in table 5 it can be verified that, on average, scrappage occurs approximately at age 11, as compared to age 17 in the baseline case.[17] The comparison between the elastic and inelastic case indicates that, on average, households scrap cars slightly later in the case of inelastic supply. The reason is that new-car output does not increase to partially compensate for earlier scrappage, leading to a higher new-car price, thereby dampening the incentive to scrap early. Overall, the total stock of cars decreases substantially relative to the baseline case, in particular in the case of an inelastic new-car supply.

Prices. When new-car supply is inelastic, table 5 reports that new-car prices increase by 25 percent relative to the baseline case. This is a mirror image of the increase in output in the case of a perfectly elastic supply. More precisely, prices of new cars increase relative to the baseline case because the demand of new cars increases. Since households scrap their cars earlier than in the baseline case—the mean scrappage age is 10.63 and the median is 11—the demand of new cars increases, and so does their price.

Trade. The effect of prohibitive transaction costs on the volume of trade is, again, unsurprising. When transaction costs are prohibitive, the volume of trade in used cars is obviously zero.

[17]The median age of scrappage is 9 because the distribution of scrappage ages is asymmetric, with many households scrapping their cars at age 17.

TABLE 5: Allocative and Welfare Effects of Secondary Markets, Prohibitive Transaction Costs

	BASELINE	ELASTIC SUPPLY	INELASTIC SUPPLY
$\frac{\text{NEW CARS}}{\text{NEW CARS, BASELINE CASE}}$	1	1.21	1
$\frac{\text{PRICE OF A NEW CAR}}{\text{PRICE OF A NEW CAR, BASELINE CASE}}$	1	1	1.25
$\frac{\text{HOUSEHOLDS WITH AT LEAST ONE CAR}}{\text{HOUSEHOLDS WHO ACQUIRED A CAR LAST YEAR}}$	2.89	5.99	6.48
$\frac{\text{TOTAL STOCK OF CARS}}{\text{CARS ACQUIRED LAST YEAR}}$	4.60	9.97	10.62
$\frac{\text{CARS ACQUIRED LAST YEAR}}{\text{NEW CARS ACQUIRED LAST YEAR}}$	3.69	1	1
HOUSEHOLDS WITH NO CARS	0.13	0.41	0.47
HOUSEHOLDS WITH ONE CAR	0.34	0.20	0.19
HOUSEHOLDS WITH TWO CARS	0.53	0.40	0.34
$\frac{\text{CONSUMER SURPLUS}}{\text{CONSUMER SURPLUS, BASELINE CASE}}$	1	0.95	0.89
$\frac{\text{WELFARE}}{\text{WELFARE, BASELINE CASE}}$	1	0.95	0.94
$\frac{\text{TRANSACTION COSTS}}{\text{CONSUMER SURPLUS}}$	0.02	NA	NA

Notes: This table reports statistics on allocations and welfare computed from the model with prohibitive transaction costs (i.e., $\lambda_a = 1$) and with an elastic or inelastic supply of new cars, respectively.

Cars per Household. Overall, the inability to resell cars reduce the stock of cars relative to the baseline case. Thus, the fraction of households with no cars increases and the fraction of households with cars decrease relative to the baseline case. However, a natural question arise: Since transaction costs are prohibitive, why do some households hold one car only—i.e., why do they scrap it rather than holding it as a second car? The reason is that households keep cars as second cars (rather than scrap them) as long as they provide positive utility flows. Since households keep their first cars until they are quite old, these cars are, on average, of low quality when the households are deciding between scrapping them or keeping them as second cars. Hence, some households would have negative net utility flow (i.e., negative $\alpha\theta q - c$) and, thus, prefer to scrap them.

Welfare. Figure 3 displays the ratio between consumer surplus with prohibitive transaction costs and consumer surplus in the baseline case for all households who acquire a car in the baseline case, ranked by the percentile of their income, for the two scenarios of elastic and inelastic supply. The figure confirms that surplus is higher for all households when new-car supply is more elastic. Moreover, the figure also shows that households at the bottom of the income distribution suffer the largest surplus decrease relative to the baseline case, because the lower stock of cars imply that these households do not own any car.

Table 5 reports that aggregate consumer surplus is lower when secondary markets are closed by five percent when supply is elastic and by 11 percent when supply is inelastic. Instead, when new-car supply is inelastic, producers profits increase, since new car prices increase by 25 percent, as the first row of Table 5 shows. Overall, the decrease of consumer welfare due to higher new-car prices is approximately equivalent to the increase in producer profits. Thus, the magnitude of the aggregate decrease in welfare due to prohibitive transaction costs relative to the baseline case is similar—five or six percent—in both of new-car supply scenarios.

5.2 Scrappage Policies

In this Section, we investigate how scrappage policies affect equilibrium allocations and welfare. This analysis can be useful to understand the effects of policies that have been implemented in some countries. For example, Japan has a thorough inspection registration system (called *Shaken*) with strict emission standards that induce households to scrap their cars earlier than other countries (Clerides, 2008).

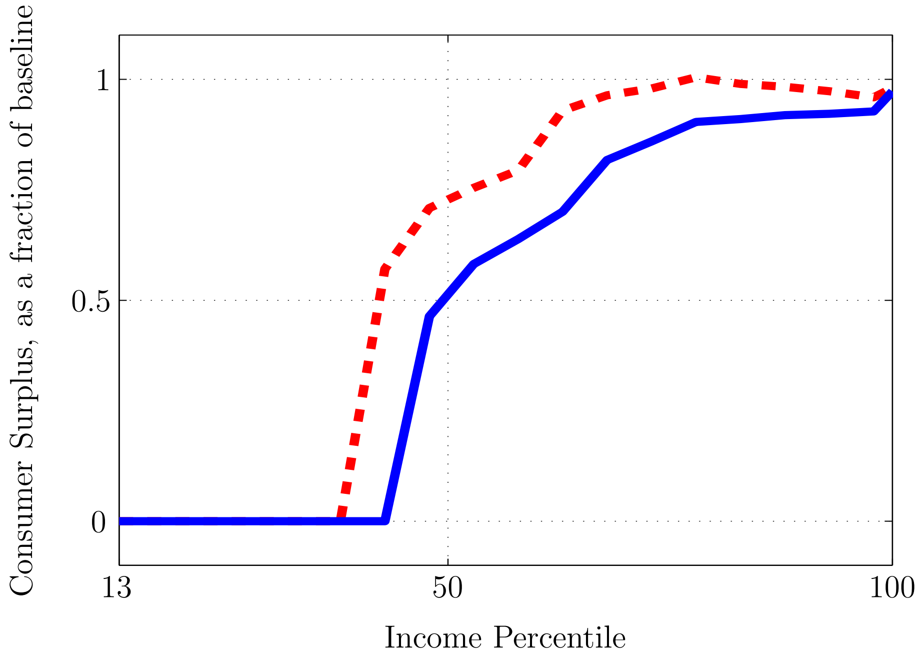

FIG. 3: The figure displays counterfactual consumer surplus with prohibitive transaction costs relative to baseline consumer surplus by income percentile, elastic new-car supply (dashed line) and inelastic new-car supply (solid line).

We consider the following policy: All cars are scrapped when they reach $T = 11$. We choose $T = 11$ since this is approximately the average scrappage age in the counterfactual with prohibitive transaction costs examined in Section 5.1.2. However, two substantive differences arise between the case in which the scrappage age is imposed to be $T = 11$, and the previous case of prohibitive transaction costs in which the *average* scrappage age is endogenously the same. First, the level of transaction costs is different. Specifically, we consider the effects of the scrappage policy with the same level of transaction costs as in the baseline case (i.e., 20 percent of p_1, increasing to approximately 40 percent of p_{10}; see Section 4.2). Therefore, secondary markets are active in the case of a scrappage policy. Second, households' scrappage decisions are very heterogenous when transaction costs are prohibitive, with higher-income households scrapped their cars substantially earlier than lower-income households. Instead, this heterogeneity does not arise under the policy studied in this section, since all cars have positive net resale values and, thus, no households scrap them before they reach $T = 11$. As in previous analyses, we evaluate steady state allocations and welfare. Hence, our analysis complements the evaluation of *temporary* scrappage subsidies that affect

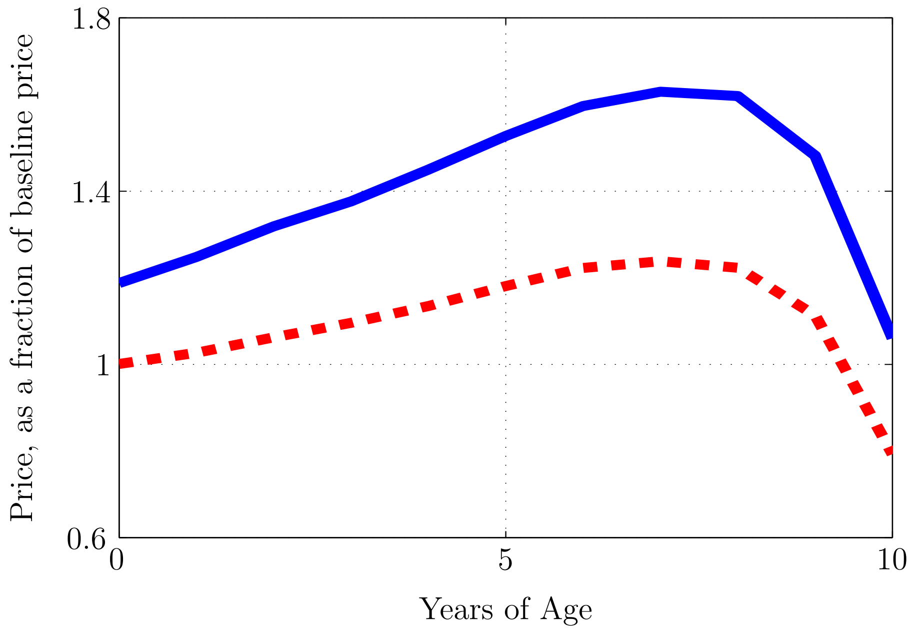

Fig. 4: The figure displays counterfactual car prices relative to baseline car prices when new-car supply is elastic (dashed line) and inelastic (solid line).

the intertemporal incentives to scrap cars, generating a one-off change in the cross-sectional distribution of car vintages (Cooper and Adda, 2000; Copeland and Kahn, 2011; Miravete and Moral, 2011).

Table 6 reports the results of these counterfactual scrappage policies on allocations and welfare in the two scenarios of elastic and inelastic supply, respectively. Overall, as in previous counterfactual analyses, the quantitative effects are similar in these two supply scenarios.

Quantity of Cars. When new-car supply is elastic, Table 6 reports that new-car output increases by 13 percent relative to the baseline case. However, the total stock of cars decreases by 27 percent relative to the baseline case, as the new-car increase does not compensate for the decrease in the scrappage age relative to the baseline case. When new-car supply is inelastic, the total stock of cars decreases by 36 percent relative to the baseline case/

Prices. Figure 4 displays the effect of the scrappage policy on car prices relative to the prices in the baseline case. The dashed line refers to the case of elastic supply and the solid line to the case of inelastic supply. Two contrasting effects are at work. First, the

Table 6: Allocative and Welfare Effects of Scrappage Policies

	Baseline	Elastic Supply	Inelastic Supply
$\frac{\text{New Cars}}{\text{New Cars, Baseline Case}}$	1	1.13	1
$\frac{\text{Price of a New Car}}{\text{Price of a New Car, Baseline Case}}$	1	1	1.19
$\frac{\text{Households with at least one car}}{\text{Households who acquired a car last year}}$	2.89	3.59	3.83
$\frac{\text{Total stock of cars}}{\text{Cars acquired last year}}$	4.60	5.28	5.51
$\frac{\text{Cars acquired last year}}{\text{New Cars acquired last year}}$	3.69	2.08	2.00
Households with no cars	0.13	0.32	0.38
Households with one car	0.34	0.34	0.33
Households with two cars	0.53	0.34	0.29
$\frac{\text{Consumer Surplus}}{\text{Consumer Surplus, Baseline case}}$	1	0.99	0.94
$\frac{\text{Welfare}}{\text{Welfare, Baseline case}}$	1	0.99	0.97

Notes: This table reports statistics on car allocations computed from the equilibrium of the model with a policy that imposes scrappage of all cars older than 11 years of age.

scrappage policy reduces the total stock of cars, thereby raising the valuation of marginal buyers of all vintages and, thus, increasing prices. Second, the scrappage policy decrease cars' "lifetime," thereby decreasing the resale value of cars—of older vintages, in particular—and, thus, their prices. Figure 4 shows that the first effect quantitatively dominates. Interestingly, intermediate vintages experience the highest increase in prices relative to the baseline case. Intuitively, these are the vintages that have more substitutes, since they are in the middle of the vertical distribution of qualities. Thus, the scarcity of cars relative to the benchmark case increases the prices of these vintages relatively more. Finally, prices of older vintages drop rapidly. This is again intuitive, since the scrappage policy reduces the useful lifespan of cars.

Trade. In both supply scenarios, since cars last fewer years, primary markets become more important and the volume of trade in secondary markets relative to primary markets is lower than in the baseline case. Overall, the number of transactions in used goods is approximately twice the number of transaction in new goods in both supply scenarios.

Cars per Household. Table 6 shows that the smaller stock of cars, due to the shorter lifespan of cars, increases the fraction of people without cars relative to the baseline case, and all of this reduction in the stock of cars comes at the expense of the fraction of households with two cars. The reason is that households' willingness-to-pay for their second car $\alpha\theta$ is, on average, low, since α is low. Since the scrappage policy eliminates older cars and increases the prices of younger cars, second cars are too expensive relative to households' willingness-to-pay for them. Moreover, this effect is even stronger when new-car supply is inelastic, since Figure 4 showed that prices increase more in that case. Thus, the decrease in the fraction of households with two cars is larger when new-car supply is inelastic.

Welfare. Figure 5 displays the ratio between consumer surplus with the scrappage policy and consumer surplus in the baseline case for households who acquire a car in the baseline case, ranked by the percentile of their income, for the two scenarios of elastic and inelastic supply. The figure confirms that households at the bottom of the income distribution suffer the largest surplus decrease relative to the baseline case, because the lower stock of cars imply that these households do not own any car. Table 6 reports the aggregate welfare effects. Overall, scrappage policies reduce welfare, but their quantitative effect is small, especially in the case of elastic supply.

Two contrasting economic forces affect the comparison of consumer surplus between the scrappage policies, reported in Table 6, and the case of prohibitive transaction costs, reported in Table 5. First, secondary markets are active in the case of the scrappage policy, but not when transactions costs are prohibitive, thereby allowing households to sell at positive net prices their depreciated cars. This effect leads to higher consumer surplus in the case of the scrappage policy relative to the case of prohibitive transaction costs. Second, consumers can choose when to scrap their cars when transaction costs are prohibitive, but not with the scrappage policy, thereby allowing consumers to keep cars older than $T = 11$. This effect leads to higher consumer surplus in the case of prohibitive transaction costs relative to the case of the scrappage policy. Overall, the comparison between Tables 6 and 5 indicates that the first effect quantitatively dominates. The reason is that consumers with the highest willingness to pay value the first effect and they do not value the second one, whereas the opposite is true for consumers with lower willingness to pay. Since higher-value consumers have greater weights in the welfare calculations, the first effect dominates the overall welfare.

Table 6 further shows that these scrappage policies generate a redistribution of welfare from consumers to producers when supply is inelastic, consistent with the finding of Table 5. In particular, consumer surplus is lower with this scrappage policy because transaction costs are infinite for the oldest vintages. In contrast, producers profits increase, since new car prices increase. The overall effect of the policy is to decrease welfare, although, again, the quantitative effect is small, between one and three percent.[18]

5.3 The Effect of Heterogeneity: A Comparison with France

As we highlighted throughout our analysis, gains from trade in secondary markets for many durable goods arise from heterogeneous valuations for quality. In our quantitative analysis, we use household income to proxy for households' valuation θ. In this section, we calibrate our model using the income distribution of France to investigate the model's quantitative performance on data from a different country.[19] This analysis also allows us to examine how income heterogeneity affects the allocative role of secondary markets and used-car prices.

[18] Note that the positive effect of the scrappage policy on profits, while true for our calibration, is not a general feature of the model, since durability is exogenous. Thus, it could be the case that a reduction of durability, as in the scrappage policy, could hurt the producers.

[19] We also investigated the performance of our model on U.K. data. The model matches qualitative features of the U.K. car market well, and its quantitative performance is reasonably good. Details are available from the authors upon request.

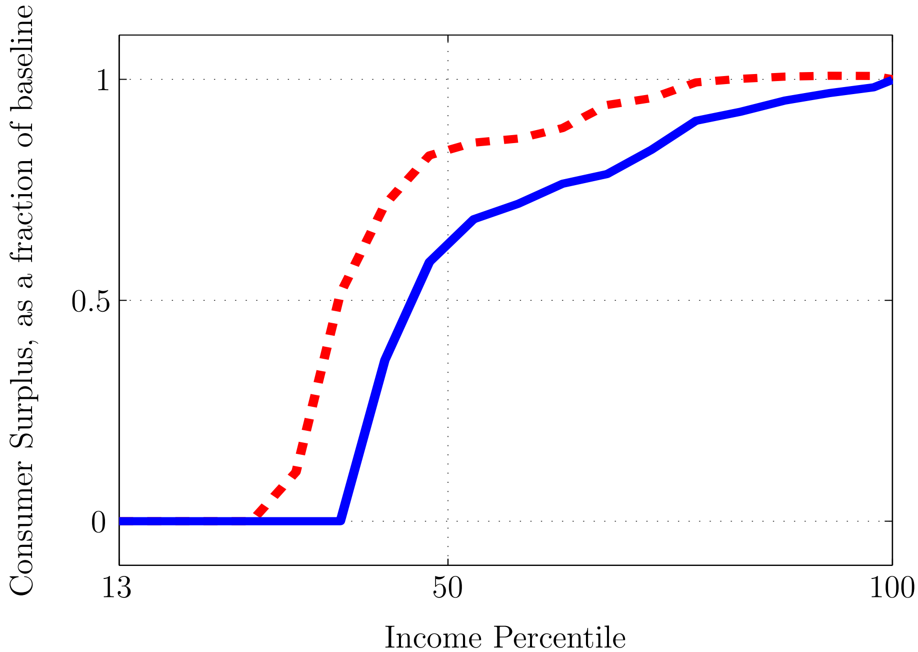

FIG. 5: The figure displays counterfactual consumer surplus with the scrappage policy relative to baseline consumer surplus by income percentile, elastic new-car supply (dashed line) and inelastic new-car supply (solid line).

To this end, we use the *2000-2001 Enquête Budget des familles*, a cross-sectional survey of 10,305 French households. The survey is similar to the U.S. Consumer Expenditure Survey. Most notably, it reports households' income, along with the number of vehicles that each household uses at the time of the interview. For up to two vehicles per household, it reports information about each vehicle, such as whether it has been acquired in the previous 12 months, and whether it was acquired new or used.

From the *Budget des familles*, we recover the French income distribution. Figure 6 plots its histogram along with the histogram of the U.S. income distributions, showing that income heterogeneity is substantially lower in France than in the U.S. Figure 6 also shows that the French income distribution is very well approximated by a lognormal distribution, and we estimate its parameters as $\mu_{FR} = 10.062$ and $\sigma_{FR} = .650$. Moreover, column (1) of Table 7 reports some aggregate statistics on French households' car holdings calculated from the *Budget des familles*. The first row reports that, on average, only one out of every 4.5 households acquired a car in France within the last year (the ratio is equal to three in the U.S.; see Table 1). The second row reports that one every six cars traded during the

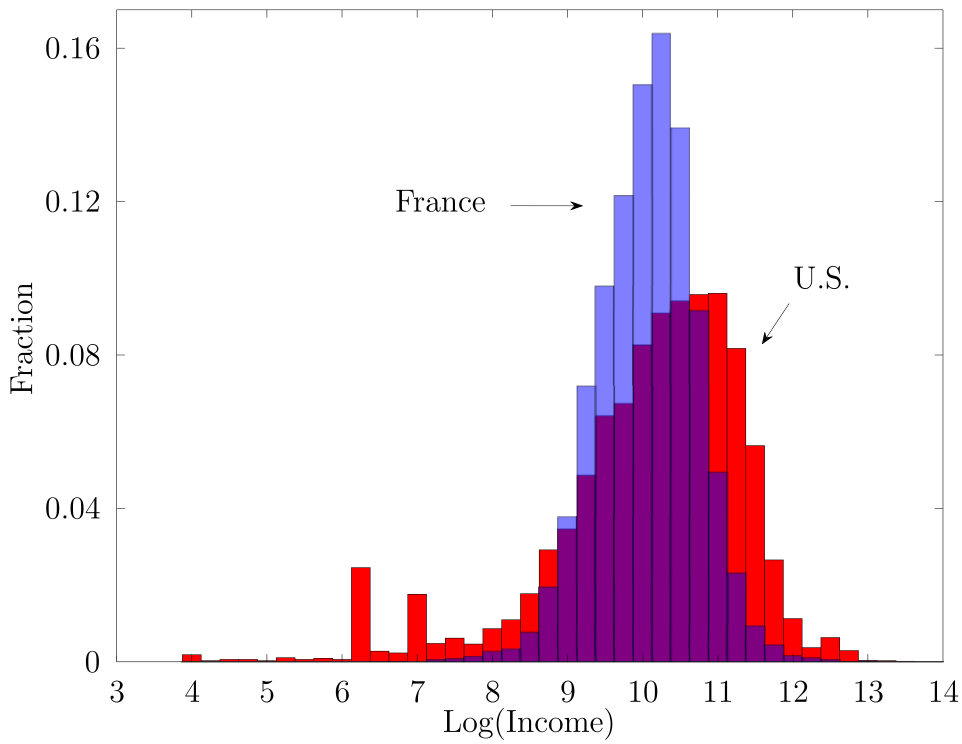

FIG. 6: Histogram of (log) income distribution in France and in the U.S in the year 2000. Income is in Euros for France and in Dollars for the U.S. The average exchange rate during the year 2000 was 1 U.S. Dollar = 1.085 Euro.

year 2000 (one every 4.5 cars in the U.S.). The third row reports that, of all cars traded, approximately one every three cars was new (one every four in the U.S.). Overall, these aggregate statistics imply that secondary markets for cars are less active in France than in the U.S., indicating that our model linking the dispersion of the income distribution with the volume of trade is qualitatively consistent with these cross-market differences. The last three rows of Table 7 report the distribution of cars per household, documenting another important difference with the U.S.: the average number of cars per household is 19 percent higher in the U.S. than in France.

Table 7 reports the results of two calibrations of our model. For expositional purposes, the calibration reported in column (2) uses exactly the same parameters used in the U.S. baseline calibration, with the only exception of the distribution of θ, for which we use the French income distribution. In the calibration reported in column (3), we further allow the parameters α and c to be specific to France, and we choose them to match as closely as

Table 7: Secondary Markets: Model vs. Data, France

	Data (1)	Model (2)	Model (3)
$\frac{\text{Households with at least one car}}{\text{Households who acquired a car last year}}$	4.39	4.88	4.29
$\frac{\text{Total stock of cars}}{\text{Cars acquired last year}}$	5.82	6.31	6.08
$\frac{\text{Cars acquired last year}}{\text{New Cars acquired last year}}$	2.98	2.70	2.80
Households with no cars	0.17	0.08	0.17
Households with one car	0.48	0.65	0.48
Households with two cars	0.35	0.27	0.35

Notes: Column (1) provides aggregate statistics of the French car market computed from the *2000-2001 Budget des familles*. Columns (2) and (3) reports the results of the calibration of the model for different parameter values; see text for more details.

possible the French aggregate statistics of column (1). (More precisely, for any α there is a unique c that equates the aggregate demand of cars with the aggregate supply xT.) The calibrated value of α is equal to .40, and the implied value of c is 531.

Columns (2) and (3) in Table 7 indicate that our model is a quantitative success. More specifically, column (2) shows that the income distribution allows the model to match closely the volume of trade in secondary markets in France. Moreover, allowing for a country-specific parameter α also allows the model to match perfectly the distribution of car holdings.

The model also generates interesting general-equilibrium patterns on the relative decline of car prices between the two countries. This is displayed in Figure 7. New car prices are higher in the U.S. than in France. However, prices decline at a faster rate in the U.S. than in France. Thus, old-car prices in France are higher than in the U.S. The intuition for these patterns is that a less-dispersed income distribution in France relative to the U.S. flattens the depreciation of prices, as the willingness to pay—i.e., income—for a marginally better car is lower when the income distribution is less dispersed.[20]

[20] Thus, our model provides a potential explanation for cross-country difference in car prices, as reported by Verboven (1996) and Goldberg and Verboven (2001, 2005).

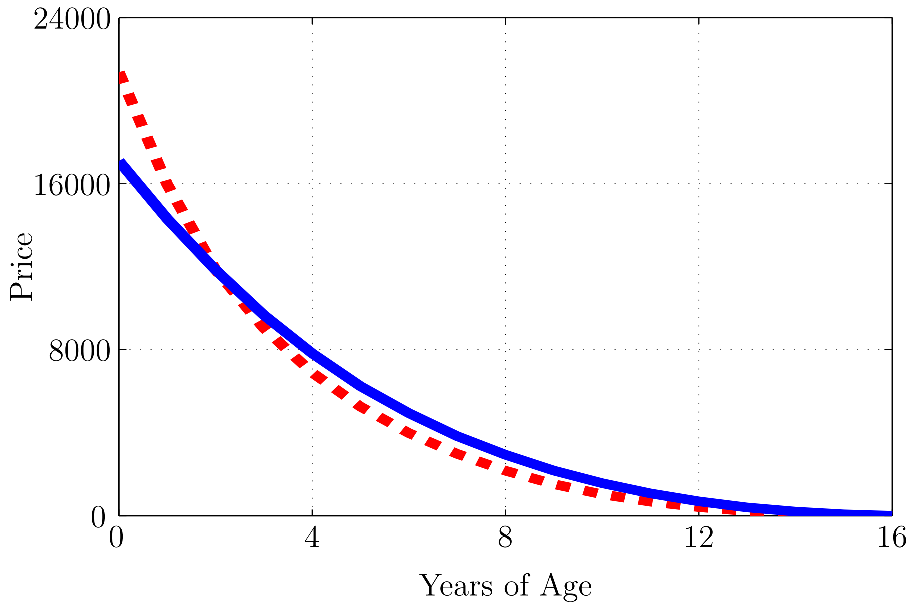

Fig. 7: The figure displays car prices in the U.S. (dashed line) and in France (solid line). Prices are in U.S. dollars. French prices are converted into U.S. dollars using the average exchange rate during the year 2000, 1 U.S. Dollar = 1.085 Euro.

6 Conclusions

Secondary markets play a potentially important role in determining the set of durable goods available to consumers, and how different segments of the income distribution benefit from such goods. We setup a model to understand the allocative and welfare effects of secondary markets. Our analysis highlights that durable goods offer many different margins of adjustments to consumers: which vintage to buy, how long to keep it, whether to sell it or scrap it. These many margins of adjustments imply that any change in secondary markets—because of changes in transaction costs over time or because of policies that directly affect them, such as scrappage policies—have potentially large effects on volume of trade and allocations, but smaller effects on consumers' surplus and welfare.

The ideas of this paper are potentially useful in understanding allocations and welfare in several durable goods markets. An important question, left for future research, is how manufacturers' choice of varieties offered on the primary market respond to changes in secondary markets.

APPENDIX

A Micro-Evidence

The goal of this Appendix is to present microeconomic evidence of the main mechanism of our model—i.e., income heterogeneity drives trade in secondary markets.

We use data from the CEX to investigate the relationship between the dispersion of income and the fraction of cars traded in each State (The CEX does not report any finer geographic information). Thus, one observation corresponds to one State. Unfortunately, the CEX does not disclose the state identifier for some State, so we have only 41 observations. We calculate the dispersion of income in a given State as the standard deviation of the income of all individuals in that State. We then use this explanatory variable in a simple regression in which the dependent variable is the fraction of cars purchased in the 12-month period prior to the CEX interview. Table 8 reports the results of two specifications. Specification (1) is a simple OLS regression, while specification (2) is a WLS regression in which we weight each observation by number of cars in the State. The coefficients of the Standard Deviation of Income is positive and significant in both specifications. This indicates that a larger dispersion of income is positively correlated with the fractions of cars traded, exactly as our model predicts.

Since the State may not be the appropriate level of aggregation, we investigate the role of income dispersion at a finer geographic level. Unfortunately, the CEX does not report MSA identifiers and, thus, we have to use a different data source. However, we are not aware of a data source that report as detailed information on households' car holdings and transactions as the CEX. Thus, our evidence can only be indirect. Specifically, we use data from the County Business Patterns to investigate the relationship between the dispersion of income and the number of car dealers in each MSA. We calculate the dispersion of income as the employment-weighted standard deviation of the per-capita annual payroll between two-digit industries in each MSA. We then use this explanatory variable in a simple regression which the dependent variable is the fraction of employment in car dealers (NAICS 441110 and NAICS 441120) to total MSA employment. Column (1) of Table 9 reports the results of such a regression. The coefficients of the Standard Deviation of Income is positive and

Table 8: The Relationship Between Dispersion of Income and Volume of Trade, U.S. States

	(1)	(2)
Total Number of Cars	-.0011	.0002
	(.0016)	(.0007)
Average per-capita Income ($1,000)	-0.3499	-0.3185
	(0.1212)	(0.1112)
Standard Deviation of Income ($1,000)	0.1954	0.2496
	(0.0983)	(0.0890)
Intercept	26.0632	21.7103
	(3.0509)	(2.3369)
R^2	.12	.15
Number of MSAs	41	41

Notes: The dependent variable is the fractions of cars acquired in the 12-month period prior to the interview in both specifications. Specification (1) is an OLS regression, specification (2) is WLS regression in which the weights are given by the total number of cars in each State. Data from the CEX for the year 2000. Robust standard errors in parentheses.

Table 9: The Relationship Between Dispersion of Income and Selected Retail Trades

	(1)	(2)	(3)
Total Employment	-6.19e-08	-1.38e-07	-4.04e-08
	(7.40e-08)	(1.54e-07)	(1.38e-08)
Average per-capita Income	-0.0434	-0.0341	0.0022
	(0.0128)	(0.0267)	(0.0023)
Standard Deviation of Income	0.0341	0.0193	-0.0006
	(0.0154)	(0.0321)	(0.0028)
Intercept	2.0024	3.1219	0.0280
	(0.2187)	(0.4566)	(0.0408)
R^2	.075	.018	.017
Number of MSAs	318	318	318

Notes: The dependent variable is the share of employment in NAICS 441110 and NAICS 441120 (new and used car dealers, respectively) in specification (1), the share of employment in NAICS 445110 (supermarkets) in specification (2), and the share of employment in NAICS 444130 (hardware stores) in specification (3). Data from the County Business Patterns for the year 2000. Robust standard errors in parentheses.

significant, indicating that a larger dispersion of income is positively correlated with the share of employment in car dealers.

Columns (2) and (3) of Table 9 report the results of two falsification tests. More precisely, the dependent variable in column (2) is the fraction of employment in supermarkets (NAICS 445110) to total MSA employment, while in column (3) is the fraction of employment in hardware stores (NAICS 444130) to total MSA employment. In both cases, the coefficients of the Standard deviation of Income is insignificant. Thus, other important retail trades—for which the mechanism of our model does not operate—do not show a similar relationship to the one we uncover for car dealers.

References

[1] Adda, J. and R. Cooper, "Balladurette and Juppette: A Discrete Analysis of Scrapping Subsidies." *Journal of Political Economy*, Vol. 108, No. 4 (Aug., 2000), pp. 778-806.

[2] Anderson, A. and V Ginsburgh, "Price discrimination via second-hand markets," *European Economic Review*, Vol. 38, Issue 1 (Jan., 1994), pp. 23-44.

[3] Attanasio, O., "Consumer Durables and Inertial Behaviour: Estimation and Aggregation of (S, s) Rules for Automobile Purchases." *The Review of Economic Studies*, Vol. 67, No. 4 (Oct., 2000), pp. 667-696.

[4] Berry, S., J. Levinsohn, and A. Pakes,"Automobile Prices in Market Equilibrium," *Econometrica*, Vol. 63, No. 4 (July, 1995), pp. 841-890.

[5] Bond, E., "Trade in Used Equipment with Heterogeneous Firms", *The Journal of Political Economy,* Vol. 91, No. 4. (Aug., 1983), pp. 688-705.

[6] Bresnahan, T., "Competition and Collusion in the American Automobile Market: The 1955 Price War", *Journal of Industrial Economics*, Vol. XXXV, No. 4 (June, 1987), pp. 457-482.

[7] Caplin, A. and J. Leahy, "Equilibrium in a Durable Goods Market with Lumpy Adjustment", *Journal of Economic Theory,* Vol. 128, Issue 1 (May, 2006), pp. 187-203.

[8] Chen, J., S. Esteban, and M. Shum, "How much Competition is a Secondary Market?" mimeo, California Institute of Technology.

[9] Clerides, S., "Gains from trade in used goods: Evidence from automobiles," *Journal of International Economics,* Vol. 76, Issue 2 (Dec., 2008), pp. 322-336.

[10] Copeland, A. and J. Kahn, "The Production Impact of 'Cash-for-Clunkers': Implications for Stabilization Policy," mimeo, Federal Reserve Bank of New York, (2011).

[11] Eberly, J.C., "Adjustment of Consumers' Durables Stocks: Evidence from Automobile Purchases", *The Journal of Political Economy*, Vol. 102, No. 3 (Jun., 1994), pp. 403-436.

[12] Eisfeldt, A. and A. Rampini, "Capital reallocation and liquidity", *Journal of Monetary Economics,* Vol. 53, Issue 3 (April, 2006), pp. 369-399.

[13] Eisfeldt, A. and A. Rampini, "New or Used? Investment with Credit Constraints", *Journal of Monetary Economics,* Vol. 54, Issue 8, (Nov. 2007), pp. 2656-2681.

[14] Esteban, S. and M. Shum, “Durable Goods Oligopoly with Secondary Markets: the Case of Automobiles”, *RAND Journal of Economics,* Vol. 38, Issue 2, (June, 2007), pp. 332-354.

[15] Gavazza, A., “Leasing and Secondary Markets: Theory and Evidence from Commercial Aircraft,” *Journal of Political Economy*, Vol. 119, No. 2 (April, 2011a), pp. 325-377.

[16] Gavazza, A., “The Role of Trading Frictions in Real Asset Markets,” *American Economic Review*, Vol. 101, No. 4 (June, 2011b), pp. 1106-43.

[17] Gilligan, T., “Lemons and Leases in the Used Business Aircraft Market”, *The Journal of Political Economy,* Vol. 112, No. 5, (Oct., 2004), pp. 1157-1180.

[18] Goldberg, P. and F. Verboven, “The Evolution of Price Dispersion in the European Car Market.” *The Review of Economic Studies*, Vol. 68, No. 4. (Oct., 2001), pp. 811-848.

[19] Goldberg, P. and F. Verboven, “Market Integration and Convergence to the Law of One Price: Evidence from the European Car Market.” *Journal of International Economics*, Vol. 65, Issue 1, (Jan., 2005), pp. 49-73.

[20] Hendel, I. and A. Lizzeri, “Adverse Selection in Durable Goods Markets,” *The American Economic Review*, Vol. 89, No. 5 (Dec., 1999a), pp. 1097-1115.

[21] Hendel, I. and A. Lizzeri, “Interfering with Secondary Markets,” *RAND Journal of Economics*, Vol. 30, No. 1. (Spring, 1999b), pp. 1-21.

[22] House, C. and J. Leahy, “An sS Model with Adverse Selection”, *The Journal of Political Economy,* Vol. 112, No. 3, (Jun., 2004), pp. 581-614.

[23] House, C. and E. Ozdenoren, “Durable Goods and Comformity”, *RAND Journal of Economics,* Vol. 39, Issue 2 (Summer, 2008). pp. 452-468.

[24] Miravete, E. and M. Moral, “Qualitative Effects of ‘Cash for Clunkers’ Programs,” mimeo, University of Texas at Austin, (2011).

[25] Petrin, A. “Quantifying the Benefits of New Products: The Case of the Minivan,” *Journal of Political Economy*, Vol. 110, No. 4. (Aug., 2002), pp. 705-729.

[26] Porter, R. and P. Sattler, “Patterns of Trade in the Market for Used Durables: Theory and Evidence,” NBER Working Paper No. 7149, (1999).

[27] Pulvino, T., "Do Asset Fire Sales Exist? An Empirical Investigation of Commercial Aircraft Transactions", *The Journal of Finance*, Vol. 53, No. 3 (Jun., 1998), pp. 939-978.

[28] Rust, J. "Stationary Equilibrium in a Market for Durable Assets," *Econometrica*, Vol. 53, No. 4. (Jul., 1985), pp. 783-806.

[29] Schiraldi, P., "Automobile Replacement: a Dynamic Structural Approach," *The RAND Journal of Economics,* Vol. 42, Issue 2 (Summer, 2011), pp. 266-291.

[30] Stolyarov, D., "Turnover of Used Durables in a Stationary Equilibrium: Are Older Goods Traded More?" *Journal of Political Economy,* Vol. 110, No. 6, (Dec., 2002), pp. 1390-1413.

[31] Verboven, F., "International Price Discrimination in the European Car Market," *The RAND Journal of Economics*, Vol. 27, No. 2 (Summer, 1996), pp. 240-268.

[32] Waldman, M. "Eliminating the Market for Secondhand Goods: An Alternative Explanation for Leasing ", *The Journal of Law and Economics*, Vol. XL, No. 1, (Apr. 1997), pp. 63-91.

[33] Waldman, M. "Durable Goods Theory for Real World Markets", *The Journal of Economic Perspectives*, Vol. 17, No. 1. (Winter, 2003), pp. 131-154.

[34] Wang, Y. (2008) "Empirical Investigation of Effects of Durability in the US Automobile Market" NYU working paper.