Durable Goods Markets in Heterogenous Agents Economies

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Durable Goods Markets in Heterogenous Agents Economies*

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Abstract

I provide a theoretical framework of optimal purchases of new and used consumer durables in an economy with heterogenous agents, idiosyncratic income risk and incomplete financial markets. Agents choose optimally between consuming nondurable and durable goods and accumulating a risk-free asset. The price of durable goods in the secondary market is determined endogenously, through market clearing. The model is used to study the impact of idiosyncratic unemployment risk and incomplete financial markets on market outcomes, and especially on the resale price of durables. I find that an unexpected shock to unemployment probabilities has the effect of lowering this price on impact. The mechanism behind this result is that following the increase in risk, the non-ownership option becomes more attractive to households, which rebalance their portfolio from durables towards liquid asset holdings. This decreases the demand for durable goods and exerts a downward pressure on their price.

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1 Introduction

Durable goods are an important component of households' balance sheets. According to the 2013 Survey of Consumer Finances, for more than 70% of U.S car owners the total value of their vehicles is higher than their holdings of liquid assets. Following a negative income shock (for example a job loss), these households may find it optimal to sell durable goods, in order to smooth consumption. However, as used goods are sold on the secondary market, agents are likely to incur a loss if the price is low when they wish to sell.

Figure 1 shows the cyclical properties of 'used vehicle prices' and the unemployment rate, in quarterly U.S data covering the period 1982-2016. The two series are negatively correlated (the correlation coefficient is -0.56). Therefore in US data, periods of high unemployment are usually associated with a lower resale price of used vehicles. This negative correlation shows that durable goods are a poor hedge against labor income risks.

This paper sets up a model where labor income risks and household investments in durable goods coexist, and identifies the forces which explain the negative correlation between unemployment and the resale price of durable goods. The model assumes that agents are heterogeneous, labor income risks cannot be warded off because financial markets are incomplete: agents can accumulate wealth investing in a riskless asset, and they can run down their wealth endowments when labor income drops in unemployment. Moreover, agents can invest in a durable good which they can sell when they are unemployed; however to access the secondary market for durables, they have to pay transaction costs and also the resale price is lower, meaning that households experience a capital loss when they sell their goods. These modelling assumptions are in line with recent work on heterogeneous agents models with durable goods (e.g. Berger and Vavra, 2015, Guerrieri and Lorenzoni, 2017). The key innovation here is that resale prices are endogenized, determined in equilibrium by household optimal decisions, along with the distribution of wealth. This allows me to use my model in order to identify the forces that explain the strong negative correlation between resale prices and aggregate unemployment.

[Figure 1 approximately here]

I study the impact of higher unemployment studying the transition from a low unemployment steady state, to a high unemployment steady state. In the high unemployment calibration of the model, the job finding probability drops sharply and the likelihood of a job loss is higher. The mechanisms through which unemployment risks affect the price of durables in the model are the following: First, an increase in risk makes more households not willing to hold any durable goods at all. A stronger 'precautionary savings motive' induces agents to accumulate more riskless assets, since this is also a liquid asset, which enables households to effectively smooth consumption if they become unemployed. As durable goods are less liquid (due to transaction costs), households rebalance their portfolio away from them and postpone their purchases of durables. This decreases the demand for durable goods and exerts a downward pressure on the resale price. Second, in the high unemployment case, more durable good owners that become unemployed desire to sell their goods to free up resources, this increases the supply of used goods, adding another negative impact on the resale price.

Third, higher risk overall makes used durable goods more attractive than new goods, and wealthier households shift their portfolios towards used goods. This property also reflects a stronger precautionary savings motive; the fact that households have to sell their goods in the secondary market, even the ones that they recently purchased, makes 'new' goods sales subject to the same transaction costs and lower resale price as older used good sales.[1] Because of this property, agents prefer to hold on to their used durables rather than to sell them and buy new goods. This decreases the supply in the secondary market and tends to increase the resale price.

Accounting for all of the above forces, I find that an unexpected shock to unemployment lowers the equilibrium resale price. Thus the first and second channels dominate the third channel in the microfounded model.

A sizeable literature has studied the behaviour of household spending in durable markets. The well known failures of the lifecycle-permanent income hypothesis to match the behaviour of durable spending (see for example Mankiw, 1982; Bernanke, 1984 and Caballero, 1990 among others) has led to the development of (s,S) type of models of durable stock adjustments (Grossman and Laroque, 1990; Caballero, 1993; Eberly, 1994). In these models, the presence of non-convex adjustment costs gives rise to 'inactivity regions' in which agents find it optimal not to adjust their stocks of durables. The framework proposed in this paper can be seen partly endogenizes these non-convexities; even without exogenous transaction costs, agents in my model would still avoid continuously adjusting their durable stock because selling a old good and replacing it with a new one entails a capital loss as the resale price is endogenously lower.[2] Moreover, since the resale price is endogenous and responds to unemployment risks, the model predicts that shocks to the economy lead to variations in the size of non-convexities. The types of shocks considered in this paper, lead to countercyclical adjustment costs. This feature of my model can be seen as complementary to other sources of endonegous potentially time varying adjustment costs, for example adverse selection (Hendel and Lizzeri, 1999; House and Leahy, 2004) and search frictions (Caplin and Leahy, 2011).

[1]This is an empirically motivated assumption. In the data the price of a new good drops discretely immediately after its bought.

[2] To see how nonconvexities appear from the price gap between new and used goods, consider the following. Assume for simplicity that durable goods never depreciate and that the only way for an agent to adjust her durable stock is to sell her current good on the secondary market at the price p_t^u, and buy new goods at the price p_t^n. Denote z_t the total market resources spent in period t on durable investment. The part of an agent's budget constraint related to durable spending can therefore be written as:

$$z_t = \begin{cases} p_t^n d_t - p_t^u d_{t-1} & \text{if the agent adjusts its stock of durables} \\ 0 & \text{otherwise} \end{cases}$$

This equation can be rewritten as $z_t = p_t^n \Delta d_t + (p_t^n - p_t^u) d_{t-1} \mathbf{1}_{(\Delta d_t \neq 0)}$. From this we see clearly that there is a discontinuity at $\Delta d_t = 0$, provided that $p_t^n - p_t^u \neq 0$.

Several papers have used frameworks similar to one employed in this paper, to study durable adjustments with heterogeneous agents and precautionary savings. An early reference is the work of Carroll and Dunn (1997), who show that an increase in unemployment risk extends the region where it is optimal for households not to adjust their durable stock. More recently, Berger and Vavra (2015) estimate a model where individual durable adjustments are subject to non-convexities and show that the response of durable spending to exogenous shocks is strongly procyclical. Harmenberg and Öberg (2016) use a similar framework to study the impact of time-varying labor income risk and show that their model can generate a volatility and procyclicality of durable spending similar to what is observed in the data. Gruber and Martin (2003) introduce durable goods to the Aiyagari (1994) model and look at the implications of the framework on the long-run distribution of wealth. Luengo-Prado (2006) uses a buffer-stock model with convex adjustment costs and down-payment requirements when borrowing to accumulate durables, in order to study how changes in credit market conditions influence the behaviour of nondurable consumption. Guerrieri and Lorenzoni (2017) look at the implications of a credit crunch in a general equilibrium model with nominal rigidities and look at the transition between two long-run steady states. All the above mentioned papers assume that the price of durables is exogenous and constant over time. In the framework proposed here, this assumption is relaxed, and the price of goods in the secondary market is determined endogenously through a market-clearing condition. This provides an additional channel of adjustment for durable spending, which is seen as complementary to the ones that have been emphasized in the previous literature.

The treatment of secondary markets in my model is similar to Stolyarov (2002) and Gavazza, Lizzeri, and Roketskiy (2014). These papers use models with different vintages of durable goods and impose market clearing in the market for each vintage. They show that the presence of transaction costs (and income inequality in Gavazza et al., 2014) in durable markets allows to explain the resale patterns of durable goods over their lifetime. However, while these papers have a thorough treatment of the durable market, they assign no role to precautionary savings and the interaction between liquid assets and durable goods. The model presented here extends these papers through introducing curved utility, jointly modeling durable and nondurable consumption, and allowing for portfolio decisions through the inclusion of a riskless asset to the model.

The remainder of the paper is structured as follows. Section 2 provides a description of the model economy and defines its competitive equilibrium. Section 3 provides the results obtained from numerical simulations of the model, and analyzes the main mechanisms at work through the lens of households' policy functions. The last section concludes.

2 The model economy

I consider a model where agents face uninsurable income risks and choose optimally between consuming nondurable and durable goods and accumulating a risk-free asset. Trades in the risk free asset are restricted through assuming an ad hoc borrowing constraint. Moreover, the model distinguishes between new and used goods. Agents can choose to buy new durable goods, or used goods, through accessing the secondary market. The supply of new goods is perfectly elastic at an exogenously given price, whereas in the case of used goods, the price in the secondary market is determined endogenously, through market clearing.

2.1 The baseline model

Preferences There is a continuum of infinitely-lived agents that derive utility from nondurable consumption, and from the services provided by the stock of durable goods they hold. Let c_t denote the nondurable consumption level of a generic agent and d_t her durable stock. Preferences are time-additive and all agents discount the future at rate β. Individual lifetime utility can be written as:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, d_t)$$

where $u(\cdot, \cdot)$ is the period utility function.

Individual Income and Aggregate Uncertainty Individuals face uncertainty in income which is formalized as follows: First, each individual can be in any period t either employed or unemployed. If the agent is employed, she earns income $\overline{y}$, whereas in unemployment she earns 0. Second, transitions across employment and unemployment are governed by a first order Markov process with transition matrix Π whose elements vary depending on whether the economy is in recession or in expansion. More specifically, let $\epsilon_t \in \{0, 1\}$ denote the employment status, taking the value 1 if the agent is employed and 0 otherwise. Let $j \in \{G, B\}$ denote the aggregate state, with G representing 'good times'- i.e. expansions and B 'bad times' - recessions. Transition probabilities are given by

$$\Pi^j(\epsilon_{t+1}|\epsilon_t) = \begin{pmatrix} \pi^j_{ee} & 1 - \pi^j_{ee} \\ 1 - \pi^j_{uu} & \pi^j_{uu} \end{pmatrix}$$

where $1 - \pi^j_{ee}$ is the job separation rate in state j and $1 - \pi^j_{uu}$ is the job finding probability. Naturally, it is easier to find a job during an expansion than it is in a recession and also agents experience transitions from employment to unemployment at higher rate in recessions. The elements of Π^j vary accordingly across j.

The main focus of this paper will be to study how changes in unemployment risks, that is changes in the aggregate state j, influence the equilibrium in the durable good markets.

Liquid assets Agents can save in a one-period, risk-free asset, subject to an ad hoc borrowing limit. a denotes the quantity of the asset. r is the real return and so an agent who saved a_t units of income in period $t-1$ (brings forward a_t units in t) has financial wealth from her investment equal to $a_t(1+r)$. I assume that r is exogenous; since the focus here is to study the equilibrium in the market of durable goods, this assumption can be seen as a simplification.

Finally, in every period t it must hold that

$$a_t \geqslant 0$$

. Ruling out negative savings (debt) is a standard friction in the heterogeneous agents literature.

Durable goods Durable goods enter in the model as a discrete choice. An agent can purchase/hold $\overline{d}$ units of a durable good or hold 0 units of the good. As discussed previously, durable goods can be either old or new. New goods are in perfectly elastic supply: The price of a new durable always equals 1, and the quantity is demand determined through the agents's optimal decisions which I describe below.

New durables are subject to a depreciation shock; I assume that with probability $1-\pi_1$, the good becomes *used* (old). Used goods differ from new goods in terms of the utility services that they provide to their owners. In particular, $\overline{d}$ units of a used good enter in the agent's utility function as $(1-\delta)\overline{d}$. Since u is monotonically increasing in its arguments, individuals derive lower utility from a used good than they do from a new good. Moreover, used goods are subject to a risk of becoming scrapped, in which case their utility services are zero. This occurs at rate $1-\pi_2$ in the model. The above can be summarized as follows: Let the set $\{n, u, o\}$ denote the 'vintage' of a durable good, (where n stands for a new good, u for a used one, and o for a scrapped good) and let Ω denote the matrix of transition probabilities across n, u and o. We have:

$$\Omega = \begin{pmatrix} \pi_1 & 1-\pi_1 & 0 \\ 0 & \pi_2 & 1-\pi_2 \\ 0 & 0 & 1 \end{pmatrix}$$

Ω is not the only object that influences the 'ownership status' of a household (whether it holds a new, or a used good for example) in a given period. Ownership is also influenced by agents' choices. In particular, at any point in time, agents can choose (i) whether or not to hold a durable good, and (ii) if they decide to hold a good, the type of the good (new or used) they wish to hold. Agents can adjust their stocks of durables by selling them in the secondary market; new goods that are sold automatically depreciate and become used goods. The owners are therefore not able to sell them at price equal to 1. Notice that basically this assumption aims at capturing the fact that resale prices of durable goods drop significantly right after their purchase.[3] This also holds in the model; an agent can purchase a new good at price 1, and if they sell after one model period, the price is p^u (the price of a used good in the secondary market)

[3] According to Kelly Blue Books, a website that provides information on car prices in the U.S, the resale value of cars drops by about 20% one year after they are bought. Clearly, the price drop can be explained through many channels, including incomplete information about the quality of the good, but also preferences for new goods over used goods, which is what I assume here.

Finally, it is assumed agents face proportional transaction costs χ when they sell their goods; sellers receive $(1-\chi)p^u\overline{d}$ when they sell $\overline{d}$ units of a durable in the market.

[Figure 2 approximately here]

2.2 Recursive formulation

I now state the agent's program recursively. Let

$$(a_{t-1}, \epsilon_t, h_t) \subset (\mathbb{R}^+, \{0,1\}, \{n,u,o\})$$

denote the vector of state variables where a_{t-1} is asset holdings at the beginning of t, ϵ_t is the employment status and h_t is the 'ownership status' of the durable good. Based on these states variables (h_t and ϵ_t are revealed at the beginning of t) individuals will make optimal consumption and savings decisions. The timing of these decisions is represented in Figure 2: At the beginning of the period, agents draw ϵ_t and h_t. Subsequently, they have to decide their 'ownership' status. Owners of goods (new and old) decide wether to sell or not and conditional on selling, they receive amount $(1-\chi)p^u\overline{d}$ and choose a new ownership status. They can buy a new good at price equal to 1, or a used good in the secondary market, or no good at all. Agents who at the beginning of t are non-owners simply choose whether or not to be owners in t. The optimal ownership decision is denoted by $\tilde{h}_t$.

Finally, agents choose asset holdings a_t and nondurable consumption c_t.

Formally let $V^{\tilde{h}_t}$ denote the lifetime utility of an agent who chooses status $\tilde{h}$ in period t. Then

$$V(a_{t-1}, \epsilon_t, h_t) = \max_{\tilde{h}_t \in \{n,u,o\}} V^{\tilde{h}_t}(a_{t-1}, \epsilon_t, h_t) \tag{1}$$

is the envelope which gives the lifetime utility at the beginning of t after observing $(a_{t-1}, \epsilon_t, h_t)$ and before the 'ownership status' $\tilde{h}$ decision.

After the choice of $\tilde{h}$ the agent's program can be described through the following functional equation:

$$\begin{aligned} V^{\tilde{h}_t}(a_{t-1}, \epsilon_t, h_t) &= \max_{c_t, a_t} u(c_t, d^{\tilde{h}_t}) + \beta \sum_{h'} \sum_{\epsilon'} \Pi(\epsilon'|\epsilon_t)\ \Omega(h'|\tilde{h}_t) V(a_t, \epsilon', h') \\ \text{s.t} \qquad & a_t = (1+r)\big(x(a_{t-1}, \epsilon_t, h_t, \tilde{h}) - c_t - p^{\tilde{h}_t} d^{\tilde{h}_t}\big) \\ & a_t \geqslant 0 \\ & x(a_{t-1}, \epsilon_t, h_t, \tilde{h}_t) = \begin{cases} a_{t-1} + \epsilon_t \bar{y} + \big(1 - \mathbf{1}[\tilde{h}_t = h_t]\big)(1-\chi) p^u \bar{d} & \text{if } h_t = n, u \\ a_{t-1} + \epsilon_t \bar{y} & \text{if } h_t = o \end{cases} \\ & d^{\tilde{h}} = \begin{cases} \bar{d} & \text{if } \tilde{h} = n \\ (1-\delta)\bar{d} & \text{if } \tilde{h} = u \\ 0 & \text{if } \tilde{h} = o \end{cases} \end{aligned} \tag{2}$$

for $\tilde{h} \in \{n, u, o\}$. $x(a_{t-1}, \epsilon_t, h_t, \tilde{h}_t)$ defines the available resources of the agent given her status h at the beginning of t and her choice $\tilde{h}$ in t.

2.3 The competitive equilibrium

This section defines the competitive equilibrium. As discussed previously in the model, the return on the liquid asset a and the price of new goods are exogenous. The competitive equilibrium therefore determines the market clearing price p^u as a function of the agents' optimal decisions and the distribution of agents across the state space.

Definition The competitive equilibrium is objects $V^{\tilde{h}_t}$ and V described above, optimal policies $\tilde{h}(a_{t-1}, \epsilon_t, h_t)$ (mapping state variables to 'ownership status'), $a_{\tilde{h}_t}(a_{t-1}, \epsilon_t, h_t)$ and $c_{\tilde{h}_t}(a_{t-1}, \epsilon_t, h_t)$ (mapping states to liquid asset holdings and consumption of non-durable goods), a resale price of durables p^u and a measure F of agents across the state space such that:

1. Optimal policies $\tilde{h}(a_{t-1}, \epsilon_t, h_t)$ $a_{\tilde{h}_t}(a_{t-1}, \epsilon_t, h_t)$ and $c_{\tilde{h}_t}(a_{t-1}, \epsilon_t, h_t)$ derive from the solution of the functional equations V and $V^{\tilde{h}_t}$.

2. The secondary market for durables clears:

$$\begin{aligned} &\sum_{h_t = n,o} \sum_{\epsilon_t = 0,1} \int_{a_{t-1} \in \mathbb{R}^+} \mathbf{1}\big(\tilde{h}(a_{t-1}, \epsilon_t, h_t) = u\big) dF(a_{t-1}, \epsilon_t, h_t) \\ &\qquad = \sum_{h_t = n,u} \sum_{\epsilon_t = 0,1} \int_{a_{t-1} \in \mathbb{R}^+} \big(1 - \mathbf{1}\big[\tilde{h}(a_{t-1}, \epsilon_t, h_t) = h_t\big]\big) dF(a_{t-1}, \epsilon_t, h_t) \end{aligned}$$

3. The measure F is consistent. In particular, it obeys the following law of motion:

$$F^{(t)}(\mathcal{A}, \epsilon', h') = \int_{a \in \mathbb{R}^+} \sum_{\epsilon \in \{0,1\}} \sum_{h \in \{n,u,o\}} \Pi\big(\epsilon'|\epsilon\big) \Omega\big(h'|\tilde{h}(a, \epsilon, h)\big) \mathbf{1}\big[a_{\tilde{h}(a,\epsilon,h)}(a, \epsilon, h) \in \mathcal{A}\big] dF^{(t-1)}(a, \epsilon, h)$$

3 Quantitative Analysis

In this section, I use numerical simulations of the model to tease out the effect of unemployment shocks to the secondary market of durables. I first describe the properties of the optimal policies over durable goods and liquid assets, in order to show the working of the model. I focus on an equilibrium where the resale price is equal to it steady state value and the economy is permanently in the expansion phase. Then I consider a change in the aggregate state assuming that following an unexpected (essentially zero probability) shock, the economy permanently enters in recession. Looking at the transition path after this shock occurs, I can characterize the short run effect of an increase in unemployment risks on the durable goods market.

The nonconvexities present in households' optimization programs make my model difficult to solve. To approximate households' optimal policies, I use the method proposed in Fella (2014). Details about the solution method are provided in Appendix B.

3.1 Calibration

Preferences The model period is one quarter and the discount factor is set to $\beta = 0.99$. The period utility function is of the following form:

$$u(c_t, d_t) = \frac{\left(c_t^{\alpha}(\underline{d} + d_t)^{1-\alpha}\right)^{1-\gamma}}{1-\gamma} \quad \text{, where } d_t = \begin{cases} \overline{d} & \text{if the good is new} \\ (1-\delta)\overline{d} & \text{if the good is used} \\ 0 & \text{otherwise} \end{cases}$$

The coefficient of risk aversion, γ, is set to 2, a standard value in the macro literature. The parameter α, which represents the relative share of nondurable goods in utility is set to 0.78, which is the average share of nondurable goods observed in U.S data over the period 1992-2016.[4] This follows Guerrieri and Lorenzoni (2017).

$\underline{d}$ is introduced in utility to allow for the 'non-ownership' state. If $\underline{d} = 0$ then obviously, given the curvature of utility, no agent would be a non-owner. I set $\underline{d} = 3.875$ to match the non-ownership rate for cars in the 2013 Survey of Consumer Finances, which equals 0.15.

Individual income process and employment status Conditional on employment ($\epsilon_t = 1$) individual income is constant and equal to $\bar{y}$. I normalize this value to 1. For the aggregate state G I choose the elements of Π so that in the long run, the unemployment rate is equal to 4 percent and the average duration of an unemployment spell is 1.5 quarters. In aggregate state B the long run unemployment is at 10 percent and the duration of unemployment 2.5 quarters. These values are taken from Krusell and Smith (1998). The transition probabilities are summarized in Table 1.

[4] This share was computed using data from the U.S Bureau of Economic Analysis. The share is $\frac{ND}{ND+D}$, where ND stands for personal consumption expenditures on nondurable goods and services, except spending for health care and financial services expenses. D stands for expenditures on durable goods.

[Table 1 approximately here]

Liquid assets I set $r = 0.025/4$ which gives an annualized interest rate to 2.5%. Notice that it holds that $\beta(1+r) < 1$ which is a necessary condition under incomplete financial markets for assets to not diverge (see e.g. Deaton, 1991).

Durable goods The transition probabilities between vintages, $1-\pi_1$ and $1-\pi_2$, determine both the relative share of new and used goods in the long-run equilibrium, and the average life of durable goods. I set the average life to 12 years (or 48 quarters), which gives me the restriction $\frac{1}{1-\pi_1} + \frac{1}{1-\pi_2} = 48$. The steady-state ratio of used to new goods, $\frac{1-\pi_1}{\pi_2}$ in the model, is assumed to be equal to 3. I thus obtain $\pi_1 = 2/3$ and $\pi_2 = 35/36$ to satisfy both targets. With these numbers the expected duration of a new good is 3 years.

The depreciation rate δ is chosen in order to match the depreciation of average used good. Since on average a good becomes used after 3 years and scrapped after 12, the average age of used goods is 7.5 years. I set $\delta = 7.5 \times \delta^A$, where δ_A is an annual depreciation rate for durable goods. Following Stolyarov (2002) I set $\delta_A = 0.085$. Then $\delta = 0.638$.

According to Kelly Blue Books, the average value of new cars bought in the U.S was around \$30,000 in 2015. This is roughly equivalent to 3/4 of average annual disposable income. To match this ratio, the size of goods $\overline{d}$ is set to 3. Finally, the proportional transaction cost χ incurred by agents who sell a used good is 0.05. This value is standard in the literature (see e.g. Eberly, 1994).

3.2 Inspecting individual policy functions: the role of prices

This section describes the agents' policy functions. I investigate the impact of varying the price p^u in the secondary market and the impact of a change in the unemployment risks. The analysis presented here is necessary to understand how unemployment and the resale price are jointly determined in equilibrium, which I analyze in a subsequent section. Here the focus is on partial equilibrium; this enables me to identify separately the forces at work.

[Figure 3 approximately here]

In Figure 3, I consider the low unemployment risk economy (aggregate state G). The figure shows the optimal choices of new, used and no goods as functions of individual resources (variable z_t in the figure). z_t is defined as follows:

$$z_t \equiv a_{t-1} + \epsilon_t \bar{y} \tag{3}$$

and so it represents 'cash in hand' (the sum of liquid wealth and current labor income) in the beginning of t.

The left panel of Figure 3 represents non-owners' policy functions, which is basically the demand side of the durables market; the right panel displays the policies for used goods owners, the supply side of the market.[5]) This figure shows how reservation prices on the secondary market (defined as the highest price at which agents want to buy a used good - in the case of non owners, and the lowest price at which they are willing to sell - in the case of owners) vary with individual wealth.

The first noteworthy feature is that poor agents never wish to purchase durable goods, no matter what the price is. These households prefer to accumulate a buffer stock of liquid assets in order to insure their nondurable consumption against idiosyncratic income shocks. Once this buffer stock is built, then households start buying durable goods. The counterpart of this property on the selling side of the market (panel b) is that very poor agents always sell their durable good to free up market resources and finance nondurable consumption or the accumulation of liquid assets.

The second key property shown in the figure is that, beyond a certain threshold, reservation prices drop with the wealth level. Richer agents prefer new durable goods since the marginal utility services these yield is higher. Therefore, the richer the agent, the higher the relative price she accepts to pay for a new good, and since prices of new goods are normalized to unity, this translates into a lower reservation price for used goods. The same intuition applies to owners of used (panel b). Even at relatively low resale prices, agents with high wealth desire to sell their used goods in order to buy new ones.

[Figure 4 approximately here]

To study the impact of unemployment risk on reservation prices, in Figure 4 I plot households' polices under low (state G) and high (state B) risk. The left panel depicts areas where non-owners buy used goods (this coincides with the black triangles in Figure 3), and the right panel shows regions where used goods owners decide to keep their goods.

The following properties emerge from the figure: First, the response to unemployment risk is different at low and high levels of wealth. Agents with low wealth now prefer the outside option of non-ownership and as a result, their reservation prices drop when the unemployment risk is higher. On the other hand, agents with high wealth optimize at the margin new/used goods and as can be seen from the figure, the reservation price increases (in the sense that agents are willing to pay a higher price to buy them). This can be explained by the fact that new goods are a worse hedge against unemployment risks. If agents become unemployed and are forced to sell, they suffer a capital loss, since their new goods automatically become used. Hence, many agents prefer to hold used goods which can be liquidated at lower costs χ.

[5] Notice that in Section 2 the value functions allowed owners of new goods to sell them in the secondary market. Clearly, agents would never wish to sell a new good and buy a used good and they would never sell to buy a new good (recall that new goods' prices depreciate when they are offered in the secondary market). However, they can sell a new good (as a used good) and become non-owners. Though this policy emerges from the value functions because it is costly, it is not included in the part of the state space considered in the figure. Moreover, in equilibrium, the measure of agents in the region where this policy is active is basically zero.

From the above findings we can identify key forces which will influence the response of the price of used goods to a change in unemployment risks. On the one hand, more low wealth agents are less willing to buy durables and prefer to hold no good, since focusing on the accumulation of liquid assets is better, in terms of hedging against the higher income risk. So the demand for used goods weakens. On the other hand, used goods become relatively more attractive to wealthier agents, and this will give a potent portfolio rebalancing effect which will increase demand. The balance of these forces determines the impact of unemployment on p^u. In the case where the first effect dominates p^u will be procyclical, like in the data. Otherwise, p^u will be counterfactually positively correlated with unemployment.

3.3 Long-run steady states

[Table 2 approximately here]

[Figure 5 approximately here]

Before studying the transition, following a shock to unemployment, I consider here the properties of the long-run equilibrium, comparing steady states with high and low unemployment risks. Table 2 presents the results for each of the models; the results can be summarized as follows. First, in the high risk economy, liquid asset holdings are more than twice as high as in the low-risk economy. Panel b of Figure 5 plots the distribution of agents over liquid wealth. From the figure we can see that in the high risk case there is an upward shift in the distribution of wealth. This property may seem surprising, because aggregate income is lower in this case where a larger fraction of the population is unemployed. However, this shift can be explained by standard precautionary savings arguments and the fact that the model features two types of assets- liquid and illiquid: Notice that when individuals face an uncertain income stream they are willing to accumulate wealth to finance consumption in unemployment; moreover, as discussed previously, agents are now less willing to buy durable goods and thus rebalance their portfolios towards liquid wealth. The non-ownership rate increases in the high risk steady state to 19 percent, compared to 15 percent in the low-risk case. To show how this leads to higher assets holdings in equilibrium, in panel a of Figure 5 I show the policy functions of liquid assets for each ownership status separately. From the figure it can be clearly seen that optimal asset holdings jump when a used good is bought, and also jump when the agent decides to hold no good at all. This is the portfolio rebalancing effect: as overall household wealth (including the value of durables) decreases households substitute towards liquid assets. A stronger precautionary savings motive is clearly consistent with the graphs since the asset policy functions are shifted upwards in the high risk scenario (dotted red lines v.s. blue solid lines).

Another noteworthy result is that in the long run equilibrium, durable good prices are not at all sensitive to the change in the unemployment risks. This is shown in Table 2; the steady state price is basically the same across the two models. As discussed previously, higher unemployment risk makes less wealthy agents rebalance their portfolios towards liquid assets, but also wealthier agents value used durables more than new goods. In the long-run, these two forces therefore, balance each other. The next section will revisit this result, to show that changes in unemployment risks impart large effects on p^u in the transition.

3.4 Transitional dynamics

I now investigate the effects of changes in unemployment risk in the transition. The structure is the following. The economy has settled in the steady state with low unemployment risk when an unanticipated (zero probability) shock is realized. Households perceive this shock as permanent and therefore anticipate that the economy will eventually reach a new steady state with high unemployment. However, after 6 quarters, there is another unanticipated shock which changes the aggregate state back to G.[6]

[Figure 6 approximately here]

Figure 6 presents the path followed by model variables from $t = 0$ to 50. In each panel, the red circle represents the initial steady-state value, and the black solid line shows the behaviour of the variable of interest under the baseline specification. Shaded areas represent periods in which the aggregate state is B.

Panel a shows the response of the resale price of durables p^u_t. As can be seen, there is a huge drop in the price on impact: it drops to 0.434 in $t = 1$, when the first shock occurs and so its value is 20% lower than in the initial steady state.

Recall that the model imparts two separate forces which determine the equilibrium outcome in the secondary market. On the one hand high unemployment induces agents to rebalance their portfolios towards liquid assets and away from used goods. On the other, wealthier households rebalance away from new durables and towards used goods. The behavior of the price reveals that the first force is the dominant one.

[Figure 7 approximately here]

[Figure 8 approximately here]

[6]Modelling unanticipated permanent shocks is very common in the literature. Here, I put one shock on top of the other to also consider the adjustment back to the original steady state, before the economy has time to settle to the high unemployment steady state. In other words, the economy will be on the 'saddle path' which leads to the high risk steady state after the first shock, but when the second shock arrives it jumps on the old saddle path which leads to the low risk steady state. Clearly, the behavior of model quantities during the first 6 periods (after the first shock occurs) is not impacted by the second shock, since this is not anticipated.

In order to show explicitly the above using individual policy functions, in Figure 7 I plot optimal policies under aggregate states G (regions denoted A_1, A_2, A_3) and B (regions denoted B_1, B_2, B_3) at the *initial* price level (i.e. the steady state price in the low-unemployment economy). Panels a and b show the regions where owners of used goods optimally keep their goods and therefore do not participate in the market. The shaded areas in panel c represents the values of z_t at which non-owners are happy to buy. The solid blue line represents the distribution of agents over liquid wealth. The last panel shows the relative populations (densities) of the types of agents considered in panels a to c. Figure 8 compares policies at the initial price p_0^u (the regions B_1, B_2, B_3, also depicted in Figure 7) and at the *equilibirum* price in $t = 1$, p_1^u (regions C_1, C_2, C_3, C_4).

At the initial steady-state, most of the goods sold in the secondary market are supplied by unemployed owners, as can be seen from panel b of Figure 7, where the lower end of the distribution of agents lies outside the region A_2. The richest employed owners also sell their used goods (the part of the distribution in panel a which is on the right hand side of region A_1). These are the agents that have accumulated enough liquid assets to find it optimal to upgrade their holdings of durable goods; they therefore choose to sell used goods in order to buy new ones. The durables sold on the market are all bought by employed non-owners. These agents find it optimal to buy used durable at levels of z_t in the region A_3; it can be observed from the distribution that this region is occupied by the richest agents among non-owners. Only a negligible share of agents are on the right of this region and buy new goods.

When the aggregate shock hits, the inaction region of owners moves towards higher wealth levels (from A_1 to B_1 and A_2 to B_2). It becomes optimal for agents with low wealth to sell their goods, and at higher wealth levels used goods become more attractive than new goods. However, only the first effect matters in the determination of equilibrium prices, because the mass of agents in the right part of regions B_1 and B_2 is zero. At the initial price level, the supply of used goods is therefore higher under aggregate state B. Notice that under high unemployment risk most of the unemployed owners want to sell their goods: an important part of the line depicting the distribution of agents in panel b lies outside the region B_2.

On the demand side, panel c shows that higher unemployment risk moves the region where non owners want to buy used goods towards higher levels of wealth (from A_3 to B_3 for employed agents[7]). It reflects the fact that the non-ownership option is more attractive when uncertainty increases. Because the mass of agents in the new region is zero, there is no demand for used goods at price p_0^u.

The impact of the change in prices on policy functions can be observed from Figure 8. Regions denoted C correspond to the policies when the equilibrium price goes down to p_1^u. On the supply side (where the change in price moves the inaction regions from B_1 and B_2 to C_1 and C_2), the price drop has the effect of extending the levels of z_t at which owners find it optimal to keep their used durables instead of selling them. This is especially the case for employed agents (panel a), for which

[7] Unemployed non-owners never want to buy used goods at the price p_0^u, both under low and high unemployment risk.

the inaction region C_1 includes levels such that there is almost no agent that wish to sell goods, as can be seen from the plotted density. Therefore, in the new equilibrium most of the goods in the market are sold by unemployed owners who want to finance nondurable consumption and accumulate liquid assets (there is still a significant share of agents at level of z_t outside the region C_2 in panel b).

For employed non owners, panel c of Figure 8 shows that the region where it is optimal to buy used durables also extends on both sides (from B_3 to C_3). The price decline makes agents in the right tail of the distribution buy used goods, which accommodates the supply coming from unemployed owners. Concerning unemployed non-owners (panel d), the price drop makes it optimal for them to buy used goods at high levels of z_t (the region C_4 is nonempty, as compared to regions A_4 and B_4). However, the mass of agents at such levels of wealth is zero; they therefore do not participate to the durable market, both in the initial steady-state and in the new equilibrium.

Notice that at the equilibrium price p_1^u, at all levels of cash-in-hand z_t depicted in the Figure agents prefer used goods to new ones. This can be observed from the fact that in Figure 8, above a certain level, regions C_1, C_2, C_3, C_4 cover all the levels of z_t included in the figure. Agents therefore never find it optimal to buy goods in the primary market and only decide to be either non-owner or to own used goods. As a result, the demand for new durables becomes zero in the first period of the transition, and the ratio of new-to-used goods in the economy decreases.

Let us now turn back to the analysis Figure 6 and look at the response of other model variables to the recessionary shock. Panel b plots aggregate holdings of liquid assets during the transition. For reasons identical to the ones given in the steady-state analysis (see previous section), households start accumulating more liquid assets when the economy turns to its bad aggregate state. This is the result of higher precautionary savings, and the portfolio rebalancing from durables towards holdings of financial assets. The model predicts that asset holdings increase during recessions for all employed agents. The mechanisms at work behind higher asset accumulation is much stronger than the negative effect implied by the higher share of agents getting unemployed and running down their buffer-stock of savings. More on this below.

Panel c represents the behaviour of aggregate nondurable spending. A significant drop is observed on impact, as nondurable consumption drops by 17%. This outcome is the result of higher precautionary savings. On impact, agents prefer to reduce consumption to accumulate assets faster and be able to cope with possible future unemployment spells, which are more likely and last longer in aggregate state B. Once their buffer-stock of savings becomes high enough, households start consuming more again.

Finally, panels d and e represent respectively the share of new-to-used good owners and the share of non-owners in the economy. It can be seen that the non-ownership ratio increases up to 10 percentage points above its steady-state level, reaching 0.26 in the last period of the recession. Then, when the economy turns back to aggregate state G, the ratio starts decreasing and goes as low as 0.09 in $t = 10$. Therefore, when the economy goes back to normal, many agents start accumulating durables and the ownership rate overshoots its steady state level. The same type of behaviour is observed for the ratio of new-to-used owners. On impact, the ratio falls as used goods start to become more attractive, both because they are a better hedge against labor income shocks, and from the fact that their relative price falls. When unemployment risk becomes low again, the ratio starts rising and reaches a level more than 50% above its long-run value. The main intuition behind the impact response of these quantities has already been discussed above. Higher unemployment risk makes households less willing to accumulate durables. The non-ownership option therefore becomes more attractive to households and, conditional on durable ownership, used goods become more attractive than new goods, for their better hedging properties against shock, and also because they become cheaper. Concerning the strong reversal in the behaviour of these variables after $t = 6$, the main explanation goes as follows. Having accumulated a lot of liquid assets, many agents (mostly employed households) have become wealthier in recessionary times. As a result, when the economy reverts back to the good aggregate state, many agents find it useless to keep high levels of assets, and durable ownership becomes more attractive to them. As a result, the ownership ratio increases significantly. As there is not enough supply of used goods to accommodate the overall increase in durables' demand, many agents start buying goods on the primary market. The ratio of new-to-used goods in the economy therefore increases.

In order to distinguish the effect of the shock coming from the behavioural response of agents to increasing risk and the response coming mechanically from the higher share of agents getting unemployed, the transition path of the model was also simulated for the following cases: (i) with changes in 'perceived' unemployment risk only and (ii) with only 'realized' unemployment risk. More precisely, in case (i) during the recessionary period the model was run using the same households' policy functions as in the baseline case, but the true realizations of unemployment status continued to be set according to the transition matrix of the good state, Π^G. In case (ii) the realized labor market status are the same as in the baseline (i.e. from $t = 1$ to 6, the transition matrix of the bad state Π^B is used, and otherwise the matrix of Π^G), but the policy functions under the good aggregate state have been used throughout the entire transition period. Results are also presented in Figure 6. The blue dashed lines presents model outcomes from exercise (i), and the cyan dashed-dotted lines results from case (ii). It can be observed that under case (ii) there is almost no price change in the durable market. Therefore, most of the price response comes from the precautionary behaviour and the portfolio rebalancing towards liquid assets described above. For all the other variables present in the figure, it is also the case that most of the variation comes from changes in households' policies, and not from the mechanical response due to the higher share of unemployed agents. Overall, the two mechanisms have an opposite effect, but the response under case (i) is always stronger in absolute value. Therefore, changes in actual unemployment realizations only contribute marginally to the model outcomes implied by the optimal response of agents to higher unemployment risk.

3.5 Robustness to separable preferences

As a robustness check, the model was solved with an alternative specification for households' preferences, with separability between nondurable and durable consumption. The following utility function was used:

$$u(c_t, d_t) = \frac{c_t^{1-\gamma_c}}{1-\gamma_c} + \theta \frac{(\underline{d} + d_t)^{1-\gamma_d}}{1-\gamma_d}$$

It was assumed that $\gamma_c = \gamma_d \equiv \gamma$. The parameter γ was set to 2, as in the baseline case with non-separable preferences. The parameter θ was set to $\theta = \frac{1-\alpha}{\alpha}$, where α is the non-durable utility share in the non-separable specification. This implies that if γ is equal to 1 (log-utility), the separable and non-separable cases are equivalent. The parameter $\underline{d}$ was also changed in order to keep the non-ownership ratio at 0.15 in the steady-state of the low unemployment economy. This implied $\underline{d} = 1.306$.

The steady state quantities and the figure depicting the transitional path of model variables obtained under this model specification are provided in Appendix C. The only changes in model outcomes when using separable preferences are level changes for the equilibrium resale price and the aggregate stock of assets. In the initial equilibrium, the resale price of durables is equal to 0.65, as compared to 0.55 in the non-separable case. The aggregate stock of liquid assets is 2.89 instead of 2.66. The behaviour of variables following the recessionary shock, as well as the steady-state differences between the model versions with low and high unemployment risk, are similar under the two specifications, and the analysis provided above therefore also applies to the case of non-separable preferences.

4 Conclusions

The impact of idiosyncratic unemployment risk and incomplete financial markets on the resale price of durable goods is investigated in this paper. I develop a macroeconomic framework where individual households face uninsurable income risks and choose optimally between consuming nondurable and durable goods and accumulating a risk-free asset. The model distinguishes between new and used durables, and the price in the secondary market is determined endogenously, through market clearing.

The mechanisms through which unemployment risk affects the price of durables are the following. First, an increase in risk makes the non-ownership option more attractive to households. Therefore, they rebalance their portfolio from durables to liquid asset holdings. This decreases the demand for used durable goods and exerts a downward pressure on their price. Second, increasing risk makes used durable goods more attractive than new goods, because new goods cannot be sold at their true value (reflecting the empirical observation that the resale value of new durables drops discretely after purchase). Therefore, agents prefer to keep their used durables rather than selling them to buy new goods, which decreases the supply in the secondary market and impacts the price positively. The main finding is that, starting from a steady-state with relatively low risk, an unexpected shock to unemployment probabilities has the effect of lowering the resale price of durables on impact, giving more weight to the first channel.

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Appendix

A Tables and Figures

Parameter	Description	Target	Value
β	discount factor	standard	0.99
γ	risk aversion	standard	2
α	non durable share in utility	nondurable-to-durable spending	0.78
$\underline{d}$	minimum durable services	share of non owners = 0.15	3.875
r	interest rate on asset holdings	annual rate = 2.5%	0.025/4
$\overline{d}$	size of a durable unit	av. value of new cars = 2/3 yearly income	3
$1-\pi_1$	transition prob new→used	share of new-to-used goods = 1/3	0.917
$1-\pi_2$	transition prob used→scrap	average lifetime of durables = 12 years	0.972
δ	depreciation rate	av. annualized rate = 0.085	0.638
χ	transaction cost	standard	0.05
$\bar{y}$	income of employed	normalization	1
$1-\pi^g_{ee}$	job separation rate, normal times	steady-state unemployment = 0.04	0.028
$1-\pi^g_{uu}$	job finding rate, normal times	av. unemployment spell of 1.5 quarters	0.67
$1-\pi^b_{ee}$	job separation rate, recession	steady-state unemployment = 0.10	0.044
$1-\pi^b_{uu}$	job finding rate, recession	av. unemployment spell of 2.5 quarters	0.40

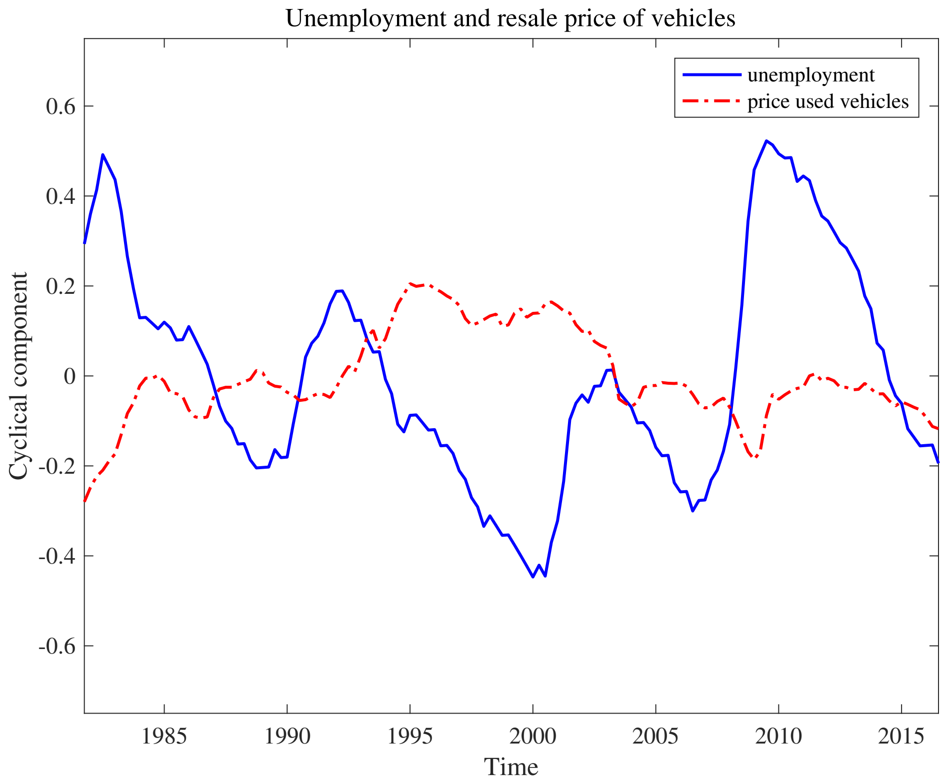
Notes: The model period is one quarter. Parameters $\alpha, \underline{d}, \overline{d}, \pi_1, \pi_2, \delta$ are the ones linked to durable goods. They are set in order to match non durable-to-durables sending, the average value of new cars as a ratio of yearly income, the non-ownership ratio observed in the U.S, and a share of new-to-used goods of 1/3, an average lifetime of 12 years for durables, and an average annual depreciation of 0.085 for used goods.

TABLE 1: **Baseline calibration**

	Low unemployment risk	High unemployment risk
Price of used durables	0.549	0.549
Owners of new goods	0.20	0.19
Owners of used goods	0.65	0.62
Non-owners	0.15	0.19
Nondurable consumption	0.92	0.89
Liquid asset holdings	2.66	6.30

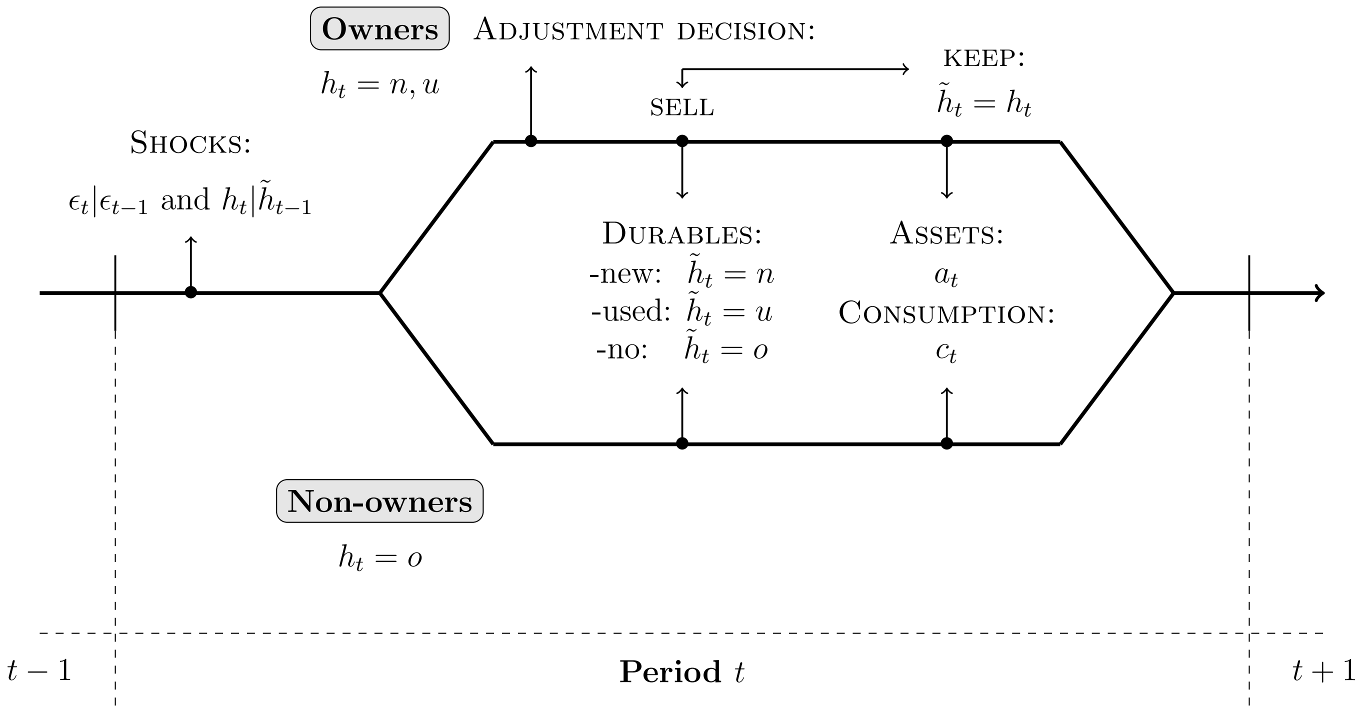
Notes: Steady-state results. The first column shows results for the economy that is permanently in state G (the low-risk economy). The second column is the equivalent for aggregate state B (the high-risk, recessionary economy).

TABLE 2: **Steady state results**



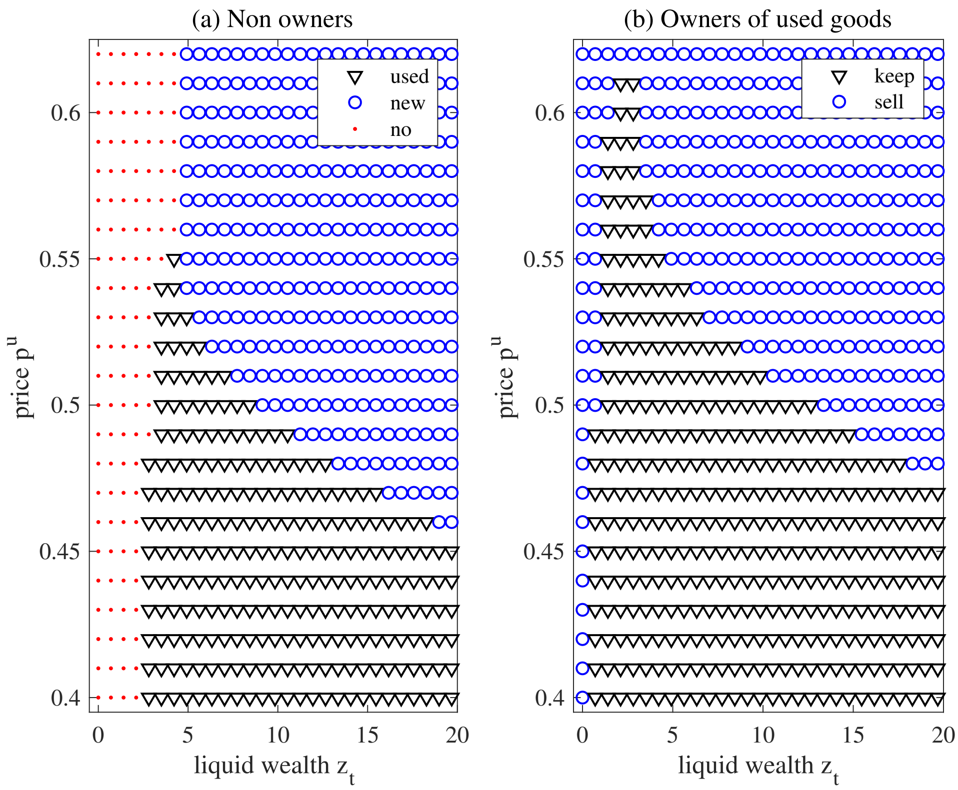
Notes: Cyclical components of quarterly U.S data. Solid blue line: Civilian Unemployment Rate. Dash-dotted red line: Consumer Price Index for All Urban Consumers: Used cars and trucks. Both series are seasonally-adjusted. The series are logged and detrended using a linear filter. The correlation coefficient of the two series is -0.559.
The data series have been extracted from the *FRED database*

FIGURE 1: **Unemployment rate and resale price of durables in U.S data**



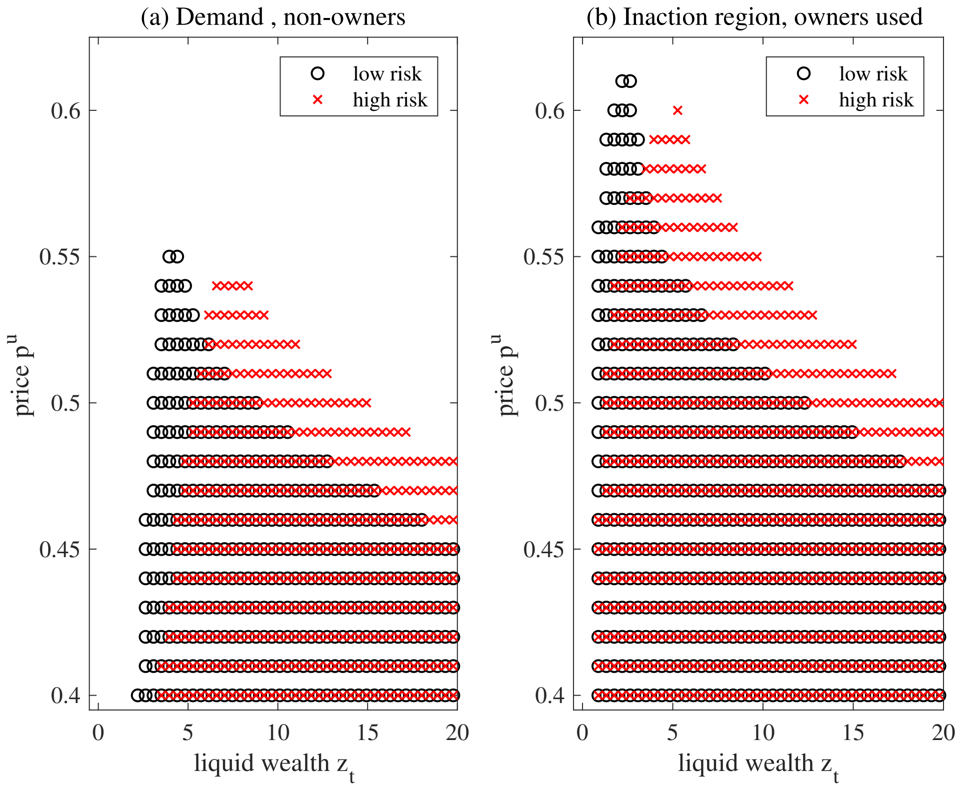
Notes: Timing convention adopted in the model: at the beginning of period t, durable and employment status are updated. Then, durable market adjustment takes place. Owners ($h_t \in \{n, u\}$) choose whether to sell their good or not. If yes, they join the pool of non-owners ($h_t = o$) and freely choose their new status $\tilde{h}_t$. Finally, holdings of liquid assets a_t and nondurable consumption levels c_t are chosen.

FIGURE 2: **Timing of events in the model**



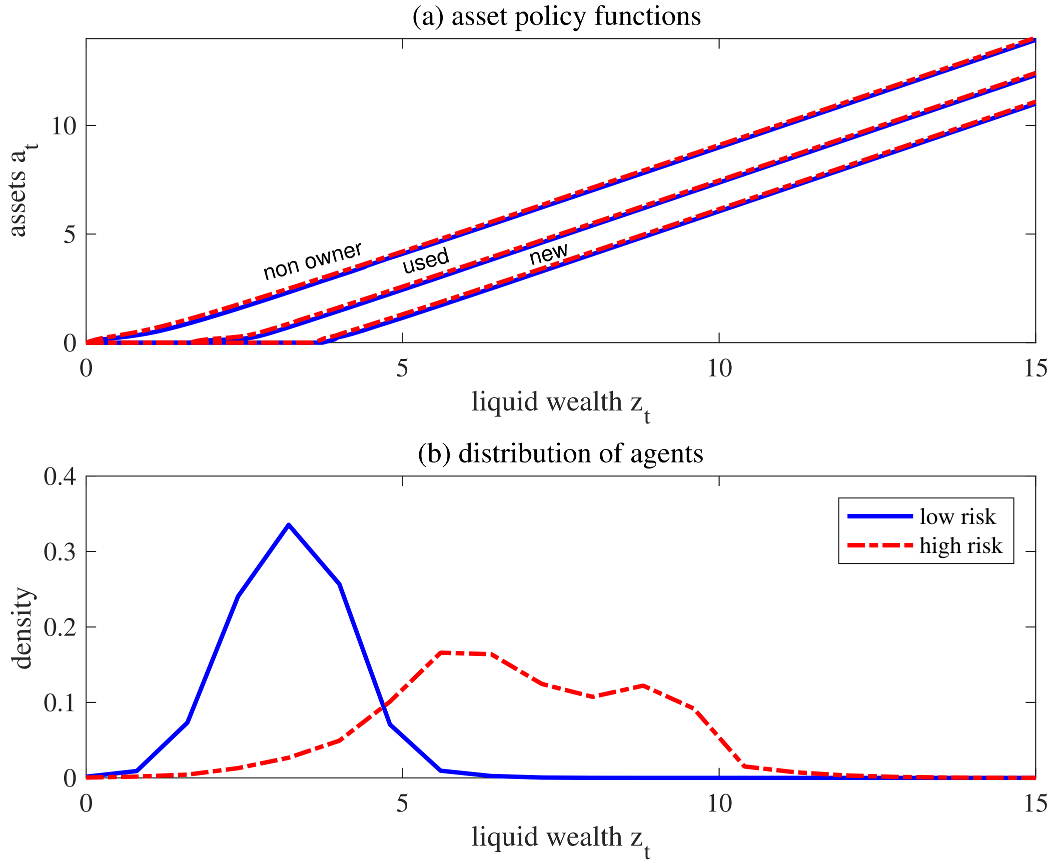
Notes: Optimal durable policies $\tilde{h}(a_{t-1}, \epsilon_t, h_t)$ over different values of the resale price of durables p^u, and aggregate state G. Optimal policies for employed agents ($\epsilon_t = 1$). Panel a: policies of non-owners ($h_t = o$). Panel b: policies of owners of used goods ($h_t = u$). For the latter, only the decision between adjusting ($\tilde{h}(a_{t-1}, \epsilon_t, h_t) \neq h_t$, the 'sell' region) or not ($\tilde{h}(a_{t-1}, \epsilon_t, h_t) = h_t$, the 'keep' region) is displayed. The x-axis denotes liquid wealth $z_t = a_{t-1} + \bar{y}$, and the y-axis the resale price p^u.

FIGURE 3: **Optimal durable policies in the low unemployment economy**



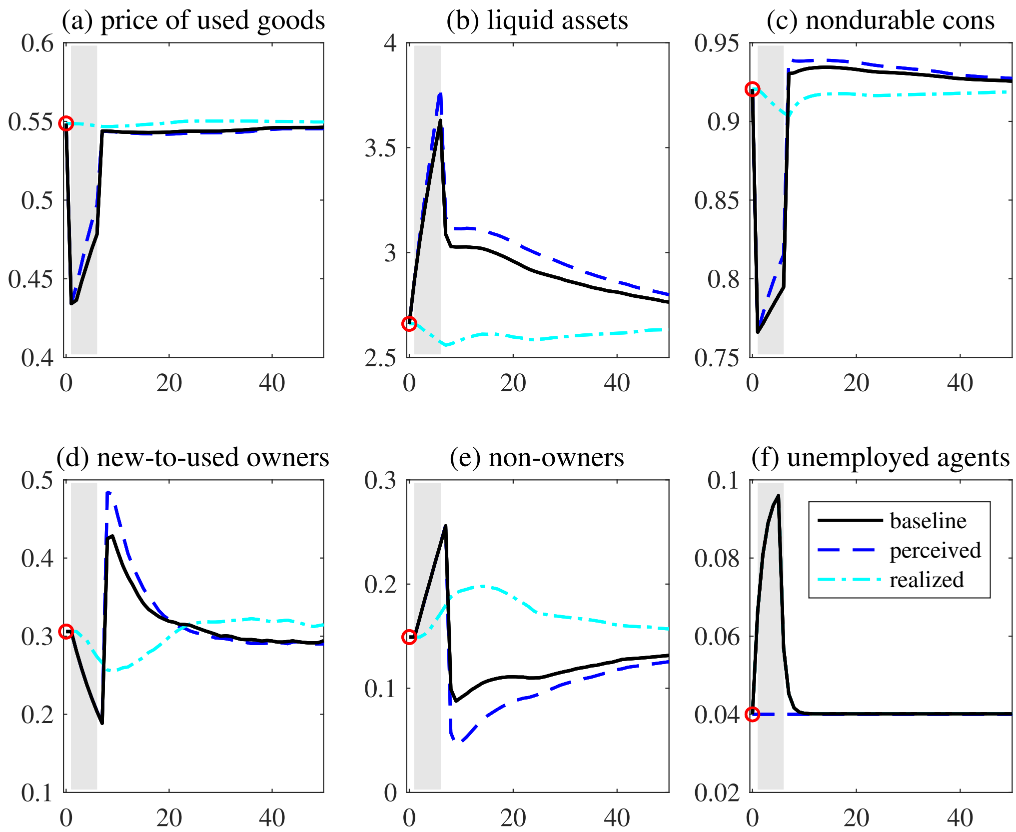
Notes: Optimal durable policies $\tilde{h}(a_{t-1}, \epsilon_t, h_t)$ as a function of liquid wealth z_t and resale price p^u, for employed agents ($\epsilon_t = 1$) under low and high unemployment risk (respectively aggregate state G, black circles - and B, red crosses). The left panel represents the region where non-owners ($h_t = o$) find it optimal to buy a used good ($\tilde{h}(a_{t-1}, \epsilon_t = 1, h_t = o) = u$). The right panel represents the region where owners of used goods ($h_t = u$) choose to be inactive in the resale market and keep their good.

FIGURE 4: **Optimal policies under low and high unemployment risk**



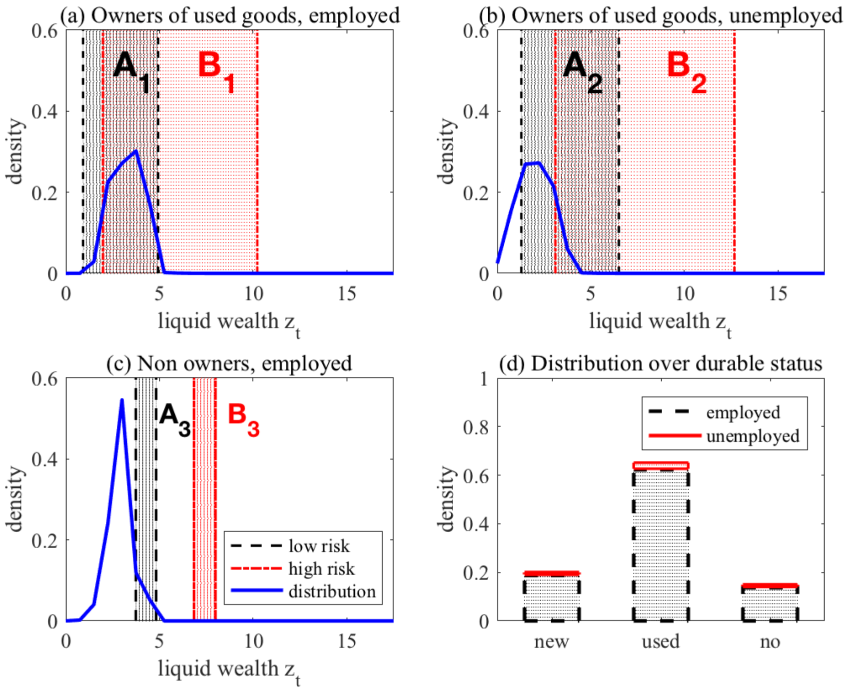
Notes: Solid blue lines are associated to quantities in the low-risk economy (aggregate state G). Dotted red lines concern aggregate state B. Panel a represents asset policies $a(a_{t-1}, \epsilon_t, h_t)$ as a function of liquid wealth z_t, conditional on the current choice $\tilde{h}_t$. The policies depicted are for non-owners ($h_t = o$) that are currently employed ($\epsilon_t = 1$). The text above policies described current durable policy $\tilde{h}_t$. Panel b depicts the distribution of agents over liquid wealth holdings z_t.

FIGURE 5: **Liquid asset policy functions over durable ownership status**



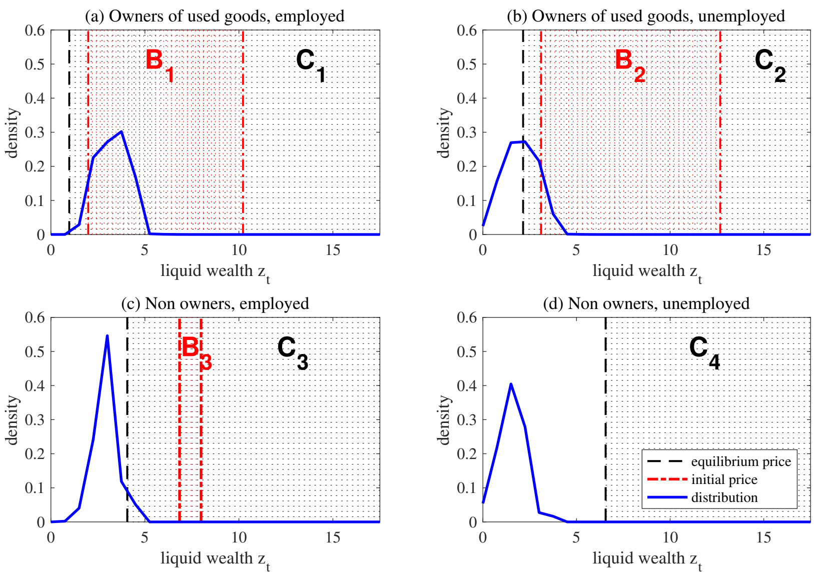
Notes: Path of model variables following a transitory shock to unemployment probabilities. In $t = 0$, the economy is assumed to be in the long-run equilibrium under aggregate state G. Then, from $t = 1$ to 6 (the shaded areas) the aggregate state switches to B, before returning indefinitely to G. Solid black lines represent the behaviour of variables in the baseline specification. The dashed blue lines depict the response of variables when only the policy functions switch to the bad aggregate state (and not the realized unemployment status). The dash-dotted cyan lines represent the response when only the realized unemployment status switches to state B.

FIGURE 6: **Transition dynamics**



Notes: The three first panels represent optimal durable policies $\tilde{h}(a_{t-1}, \epsilon_t, h_t)$ as a function of liquid wealth z_t, at the initial equilibrium price p_0^u. Regions A_1, A_2, A_3 are associated to policies under aggregate state G, whereas the regions B_1, B_2, B_3 are associated to state B. Panels a and b represent the levels of liquid wealth z_t at which it is optimal for owners of used goods ($h_t = u$) to keep their good for employed agents ($\epsilon_t = 1$, panel a) and unemployed agents ($\epsilon_t = 0$, panel b). Panel c represents the regions where employed non-owners ($h_t = o$, $\epsilon_t = 1$) decide to buy a good on the secondary market. In all panels, the solid blue lines represent the conditional distributions of agents over levels of z_t. Finally, panel d depicts the distribution of agents across durable holdings and employment status.

FIGURE 7: **Durable policies at initial equilibrium price**



Notes: Durable policies $\tilde{h}(a_{t-1}, \epsilon_t, h_t)$ as a function of liquid wealth z_t, at the equilibrium prices p_0^u (regions B_1, B_2, B_3) and p_1^u (regions C_1, C_2, C_3, C_4). Panels a and b represent the levels of z_t for which it is optimal for used good owners ($h_t = u$) to be inactive in the durable market, for respectively employed ($\epsilon_t = 1$) and unemployed agents ($\epsilon_t = 0$). Panels c and d represent the regions where it is optimal for non-owners to buy a used good. The solid blue lines represent the conditional distributions of agents over levels of z_t.

FIGURE 8: **Durable policies at prices in $t = 0$ and $t = 1$**

B Solution method

B.1 The household's problem

The household's problem, as described by equations (1) and (2), has been solved using the algorithm developed in Fella (2014). The method deals with the non-convexities present in the model efficiently, combining the endogenous gridpoint method (EGM) of **?**, and value function iteration in the region where the value function is identified as non-concave.

The EGM step makes use of the first order conditions of the household's problem. To derive them, let us rewrite the intensive margin problem of households for given choice in the durable market $\tilde{h}_t$, stated in equation (2), as follows:

$$
\begin{aligned}
V^{\tilde{h}_t}(a_{t-1}, \epsilon_t, h_t) \quad &= \quad \max_{c_t, a_t} u(c_t, d^{\tilde{h}_t}) + \beta \tilde{V}(a_t, \epsilon_t, \tilde{h}_t) \\
\text{s.t} \quad & \quad a_t = (1+r)\big(\hat{x}(a_{t-1}, \epsilon_t, h_t, \tilde{h}_t) - c_t\big) \\
& \quad a_t \geqslant 0
\end{aligned}
$$

where the objects $\tilde{V}$ and $\hat{x}$ are defined as follows:

$$
\tilde{V}(a_t, \epsilon_t, \tilde{h}_t) \equiv \sum_{\epsilon} \sum_{h'} \Pi(\epsilon'|\epsilon_t) \Omega(h'|\tilde{h}_t) V(a_t, \epsilon_{t+1}, h_{t+1}) \tag{A.1}
$$

and

$$
\hat{x}(a_{t-1}, \epsilon_t, h_t, \tilde{h}_t) \equiv x(a_{t-1}, \epsilon_t, h_t, \tilde{h}_t) - p_t^{\tilde{h}_t} d^{\tilde{h}_t} \tag{A.2}
$$

The first order condition with respect to a_t, for given $\hat{x}_t$, can be written as:

$$u_{c,t}\Big(\hat{x}_t - \frac{a_t}{1+r},\ d^{\tilde{h}_t}\Big) \geqslant \beta(1+r)\tilde{V}_a(a_t, \epsilon_t, \tilde{h}_t)$$

with strict inequality if the borrowing constraint is not binding, and where

$$u_{c,t}(c_t, d_t) \equiv \frac{\partial}{\partial c_t} u(c_t, d_t)$$

and

$$\tilde{V}_a(a_t, \epsilon_t, \tilde{h}_t) \equiv \frac{\partial}{\partial a_t}\tilde{V}(a_t, \epsilon_t, \tilde{h}_t) = \frac{\partial}{\partial a_t}\sum_{\epsilon}\sum_{h'} \Pi(\epsilon'|\epsilon_t)\Omega(h'|\tilde{h}_t)V^{\tilde{h}(a_t,\epsilon',h')}(a_t, \epsilon', h') \tag{A.3}$$

where the last equality makes use (1), optimal extensive marginal policies $\tilde{h}(a_t, \epsilon_{t+1}, h_{t+1})$, and the fact that at the optimum the extensive margin value function $V(a_{t-1}, \epsilon_t, h_t)$ is never at a kink and is therefore differentiable (see ?). Defining $u_{c,t}^{-1}$ as the inverse of $u_{c,t}$ with respect to its first argument, we have:

$$\hat{x}_t = u_{c,t}^{-1}\Big[\beta(1+r)\tilde{V}_a(a_t, \epsilon_t, \tilde{h}_t)\ , d^{\tilde{h}_t}\Big] + \frac{a_t}{1+r} \tag{A.4}$$

Equation (A.4) allows us to get the current level of $\hat{x}_t$, for a given value of next period's assets a_t. This constitutes the EGM step of the solution method: a grid for next period's assets is defined, and for each gridpoint the above equation is used to know what is the current value of $\hat{x}_t$ associated with it. In what follows, I describe the entire algorithm used to solve the optimization problem faced by individual households in the model.

Algorithm I: Approximating households' policy functions

Preliminaries:

- Create a grid of size n_a for asset levels a_{t-1} and a_t: $\mathcal{A} = \{a^i\}_{i=1}^{n_a}$.
- Provide an initial guess for intensive margin value functions $V^{\tilde{h}_t}(a^j, \epsilon_t, h_t)$ and associated durable policies $\tilde{h}(a^j, \epsilon_t, h_t)$, for all $a^j \in \mathcal{A}$

Algorithm:

1. Compute $\tilde{V}(a_t, \epsilon_t, \tilde{h}_t)$ and its derivative $\tilde{V}_a(a_t, \epsilon_t, \tilde{h}_t)$ given previous guesses of and $V^{\tilde{h}_t}(a_{t-1}, \epsilon_t, h_t)$, using (A.1) and (A.3). A finite difference method is used to compute the derivatives of $V^{\tilde{h}_t}(a_t, \epsilon_{t+1}, h_{t+1})$ w.r.t a_t.
2. For every $(\epsilon_t, \tilde{h}_t)$ pair:
   (a) Find the region of the state space where the value function is non-concave. For details on how it is done, see Fella (2014, sec 3.2).
   (b) For each level of next period assets on the grid $\mathcal{A}$, use (A.4) to get the associated value of $\hat{x}_t$, that I denote $\hat{x}_t^{end,i}(\epsilon_t, \tilde{h}_t)$. Complement this with value function iteration in the non-concave region to discard the local maxima that are not global maxima.
   (c) Deal with the borrowing constraint in the case where the pair $(\hat{x}^{end,1}, a^1)$ is discarded, i.e. find the value of $\hat{x}_t$ below which the household is credit constrained. A root-finding method is used to do it.

(d) Store the pairs $\left(\hat{x}_t^{end,i}(\epsilon_t, \tilde{h}_t), a^i\right)_{i=1}^{n_a}$, and the associated value for the intensive margin value function $V^{int}(\hat{x}_t^{endo,i}, \epsilon_t, \tilde{h}_t)$.

3. For every (a^j, ϵ_t, h_t) (where the gridpoints $a^j \in \mathcal{A}$ are now associated to a_{t-1} levels)

   (a) Compute $\hat{x}_t = \hat{x}(a^j, \epsilon_t, h_t, \tilde{h}_t)$ for each $\tilde{h}_t$ and use interpolation schemes on the objects obtained in the previous step to recover $V^{\tilde{h}_t}(a^j, \epsilon_t, h_t)$

   (b) Use the extensive margin value function (1) to choose the optimal $\tilde{h}_t$ and set $V^{new}(a^j, \epsilon_t, h_t) = \max_{\tilde{h}_t}\{V^{\tilde{h}_t}(a^j, \epsilon_t, h_t)\}$

4. Compute the convergence criterion $crit = \max\left(\left|\frac{V^{new}(a^j,\epsilon_t,h_t) - V(a^j,\epsilon_t,h_t)}{V(a^j,\epsilon_t,h_t)}\right|\right)$

   (a) If $crit < tol$, stop

   (b) Otherwise, set $V = V^{new}$ and go back to step 1

B.2 Distribution of agents and market clearing

To get the steady-state distribution of agents over values of $(a_{t-1}, \epsilon_t, h_t)$, I follow the method of **?**, which makes use of non-stochastic simulations. The algorithm is described in what follows.

Algorithm II: Steady state distribution

Preliminaries:

- Create an equidistant grid for assets of size n_a^d (with $n_a^d > n_a$): $\mathcal{A}^d = \{a^i\}_{i=1}^{n_a^d}$
- Recover policy functions $a(a^i, \epsilon_t, h_t)$, $\tilde{h}(a^i, \epsilon_t, h_t)$ for all $a^i \in \mathcal{A}^d$ on the new grid from the ones obtained in Algorithm I.
- Set $k = 0$ and initialize the distribution: $F^{(0)}(a^i, \epsilon_t, h_t)$

Algorithm:

1. Set $F^{(k+1)}(a^i, \epsilon_t, h_t) = 0$ for all (a^i, ϵ_t, h_t) triples

2. For every (a^i, ϵ_t, h_t) combination:

   (a) Get $a' = a(a^i, \epsilon_t, h_t)$ and $\tilde{h}' = \tilde{h}(a^i, \epsilon_t, h_t)$

   (b) Find j such that $a^j \leqslant a' \leqslant a^{j+1}$ and compute $\omega = 1 - \frac{a'-a^j}{a^{j+1}-a^j}$

   (c) For every $(\epsilon_{t+1}, h_{t+1})$ pair, store:

$$\begin{aligned} F^{(k+1)}(a^j, \epsilon_{t+1}, h_{t+1}) &= F^{(k+1)}(a^j, \epsilon_{t+1}, h_{t+1}) \quad + \omega\ \Pi(\epsilon_{t+1}|\epsilon_t)\Omega(h_{t+1}|\tilde{h}')F^{(k)}(a^i, \epsilon_t, h_t) \\ F^{(k+1)}(a^{j+1}, \epsilon_{t+1}, h_{t+1}) &= F^{(k+1)}(a^{j+1}, \epsilon_{t+1}, h_{t+1}) + (1-\omega)\ \Pi(\epsilon_{t+1}|\epsilon_t)\Omega(h_{t+1}|\tilde{h}')F^{(k)}(a^i, \epsilon_t, h_t) \end{aligned}$$

3. Compute $conv = \max\left(\left|F^{(k+1)}(a^i, \epsilon_t, h_t) - F^{(k)}(a^i, \epsilon_t, h_t)\right|\right)$

   (a) if $conv < tol$, stop and store $F(a^i, \epsilon_t, h_t) = F^{(k+1)}(a^i, \epsilon_t, h_t)$ as the steady state distribution

   (b) Otherwise, set $k = k + 1$ and go back to step 1

Algorithm III: Equilibrium price

To compute the equilibrium steady-state resale price of durables p^u, I use a bisection search algorithm to find the price at which the excess demand for used durables is zero:

Preliminaries:

- Initialize P_l and P_r to loose enough levels in order to make sure that $p^u \in [P_l, P_r]$
- Set $k = 0$ and initialize $P^{(0)} = \frac{P_l + P_r}{2}$

Algorithm:

1. Use Algorithm I and Algorithm II to get household policy functions and steady-state distribution of agents given $p^u = P^{(k)}$
2. Compute excess demand for durables, denoted Z:

$$Z = \sum_{i=1}^{n_a^d} \sum_{\epsilon_t=0,1} \sum_{h_t=n,o} \mathbf{1}\big(\tilde{h}(a^i, \epsilon_t, h_t) = u\big) F(a^i, \epsilon_t, h_t) - \sum_{i=1}^{n_a^d} \sum_{\epsilon_t=0,1} \sum_{h_t=n,u} \mathbf{1}\big(\tilde{h}(a^i, \epsilon_t, h_t) \neq h_t\big) F(a^i, \epsilon_t, h_t)$$

3. If $Z < 0$, set $P_r = P^{(k)}$. Otherwise if $Z > 0$, set $P_l = P^{(k)}$
4. Set $P^{(k+1)} = \frac{P_l + P_r}{2}$
   - If $|Z| < tol_z$ or $|P^{k+1} - P^k| < tol_p$, stop and store $p^u = P^k$
   - Otherwise, go back to step 1

Algorithm IV: Transition path

To get the transition path of equilibrium prices and quantities (which is analyzed in section 3.4), the following algorithm is used:

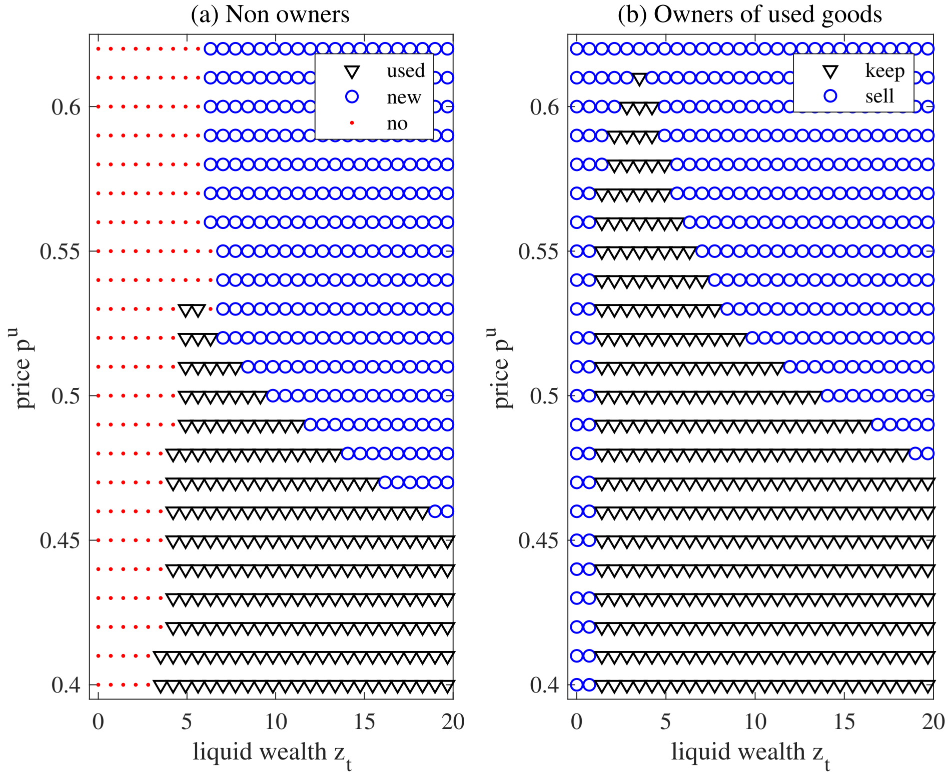
Preliminaries:

- Set $t = 1$
- Initialize the distribution at the one obtained for the steady-state in Algorithm II: $F^{(0)}(a^i, \epsilon_t, h_t) = F(a^i, \epsilon_t, h_t)$
- Initialize p_0^u to the steady-state equilibrium price p^u
- Guess initial P_l, P_r, and p_t^u for all t (similarly to Algorithm III).

Algorithm:

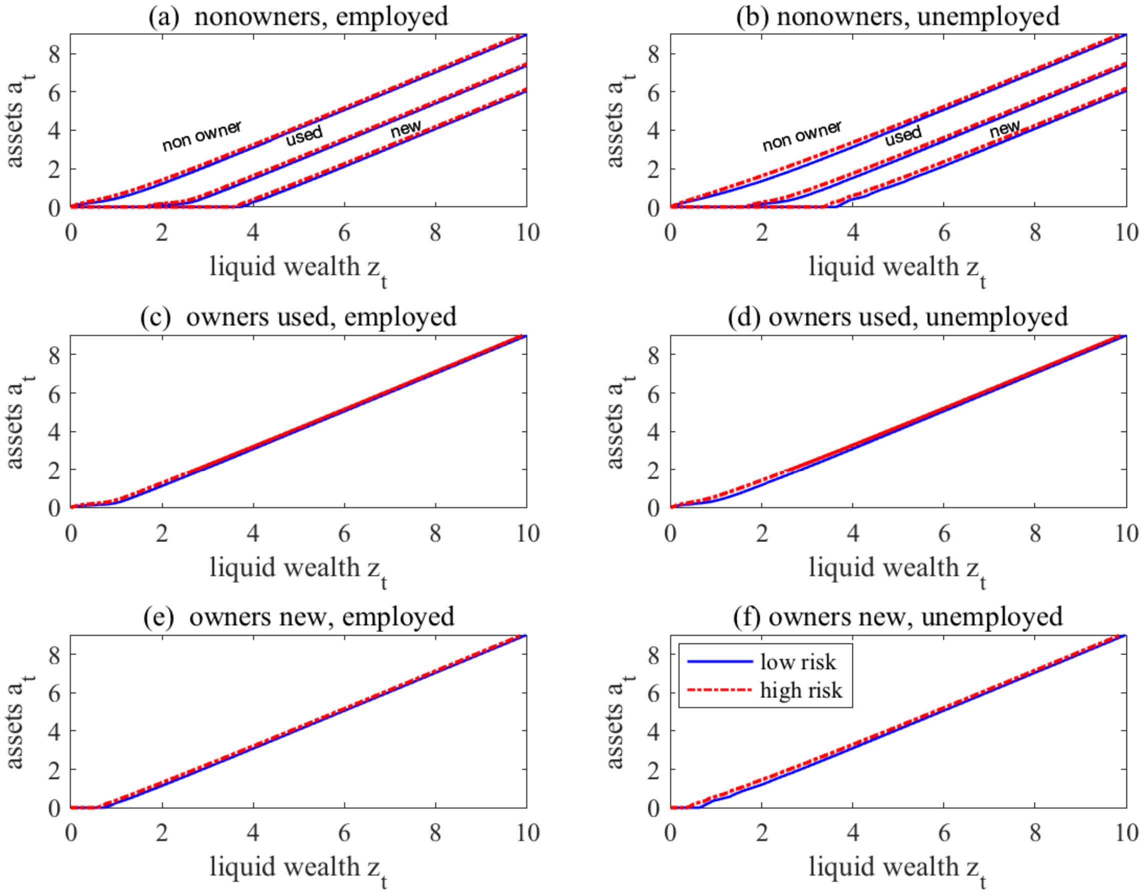
1. Compute households' policies using Algorithm I
2. Use steps 1 to 2 of Algorithm II (replacing $k + 1$ by t) to update the distribution of agents
3. Use steps 2 to 5 of Algorithm III to update the price p_t^u. If convergence, store the distribution $F^{(t)}(a^i, \epsilon_t, h_t)$, and set $t = t+1$. Otherwise, keep the same t and iterate until the excess demand Z_t is close to zero.

C Additional figures and tables



Notes: Optimal durable policies $\tilde{h}(a_{t-1}, \epsilon_t, h_t)$ over different values of the resale price of durables p^u, and aggregate state G. Optimal policies for **unemployed** agents ($\epsilon_t = 1$). Panel a: policies of non-owners ($h_t = o$). Panel b: policies of owners of used goods ($h_t = u$). For the latter, only the decision between adjusting ($\tilde{h}(a_{t-1}, \epsilon_t, h_t) \neq h_t$, the 'sell' region) or not ($\tilde{h}(a_{t-1}, \epsilon_t, h_t) = h_t$, the 'keep' region) is displayed. The x-axis denotes liquid wealth $z_t = a_{t-1} + \bar{y}$, and the y-axis the resale price p^u.

FIGURE 9: **Optimal durable policies – low risk economy, unemployed agents**



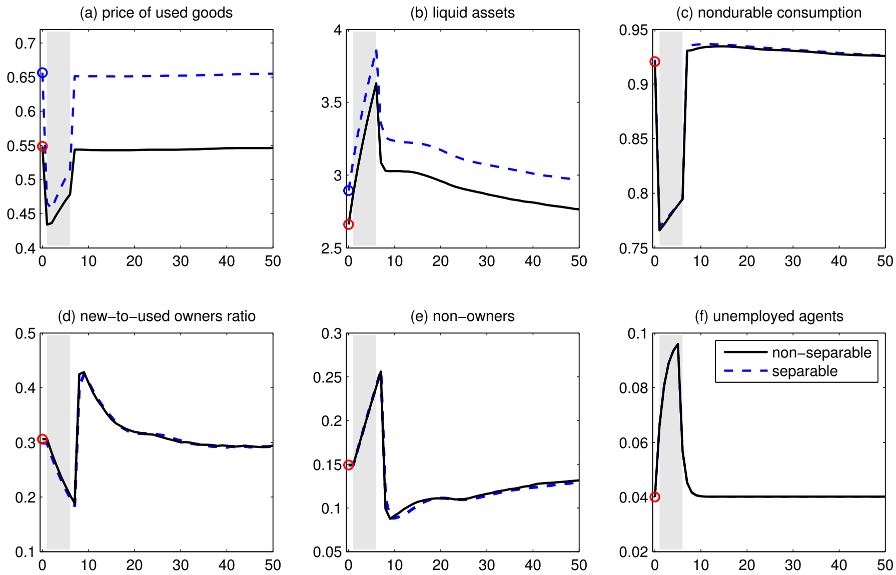
Notes: Asset policies $a(a_{t-1}, \epsilon_t, h_t)$. Solid blue lines are associated to quantities in the low-risk economy (aggregate state G). Dotted red lines concern aggregate state B. Panel a: $h_t = o$, $\tilde{h}_t = n, u, o$, $\epsilon_t = 1$; panel b: $h_t = o$, $\tilde{h}_t = n, u, o$, $\epsilon_t = 0$; panel c: $h_t = \tilde{h}_t = u$, $\epsilon_t = 1$; panel d: $h_t = \tilde{h}_t = u$, $\epsilon_t = 0$; panel e: $h_t = \tilde{h}_t = n$, $\epsilon_t = 1$; panel f: $h_t = \tilde{h}_t = n$, $\epsilon_t = 0$

FIGURE 10: **Asset policies**

	Low unemployment risk	High unemployment risk
Price of used durables	0.656	0.655
Owners of new goods	0.20	0.18
Owners of used goods	0.65	0.59
Non-owners	0.15	0.23
Nondurable consumption	0.92	0.89
Liquid asset holdings	2.89	6.71

Notes: Steady-state results in the case of separable preferences between nondurable and durable consumption. The first column shows results for the economy that is permanently in state G (the low-risk economy). The second column is the equivalent for aggregate state B (the high-risk, recessionary economy).

TABLE 3: **Steady state results under separable preferences**



Notes: Path of model variables following a transitory shock to unemployment probabilities. In $t = 0$, the economy is assumed to be in the long-run equilibrium under aggregate state G. Then, from $t = 1$ to 6 (the shaded areas) the aggregate state switches to B, before returning indefinitely to G. Solid black lines represent the behaviour of variables in the baseline specification with non-separable preferences between nondurable and durable consumption. The dashed blue lines are the counterpart for the case of separable preferences.

FIGURE 11: **Transition path of model variables: non-separable vs. separable preferences**

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