Stimulating Durable Purchases: Theory and Evidence *

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Abstract

This paper uses a benchmark life-cycle model with incomplete markets and durable consumption as a laboratory to investigate the design of fiscal stimulus. We calibrate the model to match microdata moments from standard sources, administrative data on homeownership transitions, and quasi-experimental estimates from the First-Time Homebuyer Credit in the U.S. We present three results. First, frictions that limit agents' ability to smooth durable purchases over time are crucial to reconciling competing empirical findings. With liquidity constraints and fixed adjustment costs, the standard real-business-cycle intuition that responses should quickly reverse no longer holds. A first-time homebuying subsidy that can be applied to the down payment induces a response that persists over many years. This persistence arises because the subsidy enables young, constrained agents to transition to homeownership several years earlier than they otherwise would have and because homes are a better store of value than other durables. Second, whereas in standard models the marginal propensity to consume (MPC) out of cash transfers declines rapidly with the size of a cash transfer, we find a much slower decline in our baseline model, with durable goods adjustments driving the result. Finally, we combine the model with techniques from the public finance literature to assess welfare implications of alternative durable stimulus and cash transfers. Large fiscal or welfare spillovers are necessary for targeted durable subsidies to match the benefits of unconditional cash transfers.

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1 Introduction

Policies designed to stabilize the economy often target the purchase of durable goods, such as cars or houses. The logic is intuitive: durable goods spending is procyclical and highly volatile compared to non-durable consumption, and durable spending is thought to be relatively policy-elastic in response to temporary subsidies.[1] The existing quantitative literature has found intertemporal substitution is the dominant feature explaining how durable goods respond to fiscal stimulus. An implication of this result is that any boost in durable goods spending caused by temporary stimulus tends to be offset quickly by a drop in spending once the policy ends.

Growing evidence suggests the impact of durable goods stimulus across domains may be more complex. While quasi-experimental studies on car scrappage programs find rapid reversals in spending patterns (Mian and Sufi (2012), Green et al. (2020)), research on housing stimulus programs, which often take the form of temporary credits, find that these policies can have enduring impacts (Best and Kleven (2017), Berger, Turner and Zwick (2020)). The theoretical literature typically abstracts from details in program design, targeting, and differences between various durable goods, which makes reconciling these disparate findings a challenge for existing models. Morever, the role of other frictions, such as financial constraints, in mediating responses to durable goods stimulus remains largely unexplored.

This paper uses a benchmark life-cycle model with incomplete markets and durable consumption as a laboratory to investigate how durables respond to targeted fiscal stimulus. Our model includes numerous frictions common to the literature, including fixed costs, down payment constraints, and a wedge between the value of renting versus owning. We calibrate the model to match microdata moments from standard sources, administrative data on homeownership transitions, and quasi-experimental estimates from Berger, Turner and Zwick (2020) on the First-Time Homebuyers Credit. We then deploy the model to study a rich suite of policies parameterized to recent episodes in the U.S., including the FTHC, the Cars Allowance Rebate System (CARS, a.k.a., “Cash for Clunkers”), and unconditional cash transfers.

We find that frictions that limit households’ ability to smooth durable purchases over time are crucial to reconciling the competing empirical findings in the literature. Without these frictions, one can prove that intertemporal substitution drives the response of durable purchases to temporary policies. This logic lies at the foundation of standard real business cycle models

[1] Since 1960, declines in broad durable spending (consumer durables and residential investment) accounted for 26.6% (58.3%) of real GDP changes during recessions as well as more than half of the fall in output from 2007 to 2009 (Berger and Vavra, 2015*a*).

and New Keynesian models that study durable goods adjustment without financial frictions.

Using simulated data from the model, we conduct and contrast FTHC and CARS policy experiments, for which the standard theory predicts similar aggregate responses but the empirical evidence suggests otherwise. The CARS policy induces responses from wealthier households for whom down payment constraints are less likely to bind, leading the aggregate response to quickly reverse after the policy expires. These policy takers are older than the general population and have large durable gaps—they resemble the representative agent in the standard frictionless model with lumpy adjustment. Further, households who buy due to the CARS policy are outnumbered by households who would have bought absent the subsidy. It is thus the latter group who captures most of the subsidy value.

Only first-time homebuyers below an income threshold qualified for the FTHC, so the program effectively targeted young households with low net worth and income. It is precisely this group that drives the persistent response in the aggregate. For these households, the credit relaxes the down payment constraint and enables them to transition to homeownership sooner than they otherwise would have. Using counterfactual model simulations, we show that, absent the policy, many of these households would have waited years to switch from renting to owning. In the FTHC experiment, the share of total policy takers who are marginal with respect to the policy is also considerably higher than in the CARS experiment.

A second feature that distinguishes the results for cars versus houses owes to the underlying nature of these durable goods. Cars steadily lose value over time due to depreciation and information asymmetries. Houses depreciate much more slowly and a substantial share of a house's value derives from land that tends to increase in value over time. These differences imply that houses are a better store of value over a longer period of time than cars. Whereas a car nets relatively low trade-in value at the time of adjustment, a house can be used more effectively to overcome a future down payment constraint (Stein, 1995; Ortalo-Magne and Rady, 2006). Consequently, in response to a temporary subsidy, households are more likely to accelerate a homebuying decision from the distant future relative to a decision to trade in a used car. We use counterfactual policy simulations and durable goods environments to show this force can bring the aggregate responses for the FTHC and CARS experiments closer to each other.

Taken together, the magnitude and relative efficiency of the response to durable goods stimulus depend on which population is targeted and the underlying nature of the particular durable good. A final critical factor is the extent to which the policy helps household relax binding financial frictions. We find that a counterfactual policy that prevents first-time homebuyers from using the credit for the down payment produces a much weaker response with nearly complete reversal in the short run. Underlying this result is the fact that low net worth households took up the temporary FTHC because it relieved down payment constraints. Compared to our baseline FTHC experiment, this counterfactual policy only induces eligible households with substantial wealth and income distributions to buy earlier, limiting the stimulus's scope.

Including durables also shapes the response of consumption to unconditional cash transfers, which is the focus of a voluminous literature. We study the impact of such transfers on durable and non-durable consumption within our baseline model and in an alternative model without durables. A well-known result from the quantitative theoretical literature is that the marginal propensity to consume (MPC) declines rapidly as the size of the cash transfer increases. We find a much slower decline in our baseline model, with durable goods adjustments driving the result.

We rank the efficiency of each stimulus policy using techniques from the public finance literature, namely, the marginal value of public funds (MVPF) framework of Hendren and Sprung-Keyser (2020). Having explicit utility functions and counterfactual consumption paths for model agents allows us to measure the inputs to the MVPF for each agent, which include the willingness to pay for the policy and the agent's behavioral response to it. Deploying this framework reinforces the qualitative lessons from our comparison of various programs. Unconditional cash transfers are valued more highly than the FTHC on average, and the CARS program has the lowest MVPF of the three policies. Allowing the FTHC to apply to the down payment materially increases the MVPF of the policy. The framework also illustrates how large fiscal or welfare spillovers need to be to reverse these results. For example, if the FTHC raises house prices for everyone, this spillover can cause the program to look more attractive than a cash transfer.

Our paper contributes to a growing literature that studies how introducing durable goods into macroeconomic models alters conclusions about fiscal and monetary policy (Erceg and Levin, 2006; Berger and Vavra, 2015*a*; Gavazza and Lanteri, 2021; McKay and Wieland, 2021, 2022; Attanasio et al., 2022). Rather than focus on the effects of monetary and fiscal policy more broadly, we study policies that directly target durable goods spending, in the spirit of detailed analysis of scrappage programs in Adda and Cooper (2000) and homebuyer subsidies in Floetotto, Kirker and Stroebel (2016). Relative to these papers, we study multiple types of durables, different stimulus policies, and calibrate our model to match both steady-state and quasi-experimental moments from a recent policy episode. The richness of our environment allows us to examine which durable features and policy details are crucial for reconciling existing evidence, as well as which policy levers generate the largest welfare gains.

We find an important role for financial frictions in amplifying the response of durable goods consumption to stimulus policy. This finding adds to a large empirical literature on stimulus checks that tends to find liquidity-constrained households consume a larger fraction of transfers sooner than others.[2] In other domains, Vissing-Jørgensen (2002) argues that financial constraints influence the participation margin for investing in stocks, and this fact materially affects estimates of the elasticity of intertemporal substitution. Zwick and Mahon (2017) find that financial frictions amplify the response of business investment to capital subsidies. Kaplan and Violante (2014) develop a model in which liquidity constraints can increase the non-durable consumption response to cash stimulus, but they do not consider durable goods purchases.

We use our model to ask how introducing durable goods affects conclusions about the MPC out of unconditional cash transfers, a central moment in heterogeneous agent macro models (Kaplan and Violante, 2022). In our model, average MPCs are both higher and decline more slowly with the size of the cash transfer than in a model without durable goods. This finding is consistent with contemporaneous work by Beraja and Zorzi (2023), who reach a similar conclusion using a different durable goods model. When accounting for durable goods consumption out of a transfer, we follow Laibson, Maxted and Moll (2022) and express impacts on consumption in terms of the marginal propensity to spend (MPX).

Our paper contributes to the empirical literature studying the response of durable and non-durable consumption to various stimulus policies, including targeted credits and sales tax holidays.[3] We provide a quantitative theoretical foundation for understanding the heterogeneous responses observed across various policy episodes, which can inform policy design. In a methodological contribution, we show how the MVPF framework of Hendren and Sprung-Keyser (2020) can be used in quantitative macro models to discipline comparisons across policy counterfactuals.

[2] See Johnson, Parker and Souleles (2006), Johnson et al. (2011), and Misra and Surico (2014) for evidence from consumption and consumer credit data; Souleles (1999) and Agarwal, Liu and Souleles (2007) for complementary evidence from tax rebates; and Aaronson, Agarwal and French (2012) for evidence from minimum wage hikes. Gross, Notowidigdo and Wang (2020) find that MPCs out of newly available credit are higher during bad economic times. Shapiro and Slemrod (2003*a*,*b*, 2009) and Sahm, Shapiro and Slemrod (2010) offer survey evidence that suggests substantial average responses but less support for the liquidity constraints story. Orchard, Ramey and Wieland (2023) revisit the evidence from the 2008 stimulus and argue the aggregate MPCs are biased upward, but do not focus on heterogeneous responses.

[3] This literature includes, among others, Mian and Sufi (2012), Green et al. (2020), Best and Kleven (2017), Berger, Turner and Zwick (2020), who focus on subsidies targeting durable goods; Cashin and Unayama (2016), D'Acunto, Hoang and Weber (2016), Baker et al. (2019), and Ding et al. (2023) study the impact of sales tax holidays and coupons on durable and non-durable consumption.

2 Motivation

Policies aimed at stimulating durable goods purchases are a common tool in the policy toolkit. One key reason is that durable purchases are very responsive to economic incentives (Adda and Cooper, 2000): if a government policy makes it temporarily more attractive to purchase durables today, this incentive will shift spending from the future—where the economy is close to potential—to the present—where government spending multipliers are higher.

A consensus view, based on neoclassical models of investment, is that these shifts in spending purely reflect intertemporal substitution. After the policy expires, cumulative spending on the good quickly reverses back to earlier trends. The top panel of Figure 1 shows empirical evidence from auto scrappage programs implemented during the Great Recession that is consistent with this view. Each study in the panel shows results from different empirical evaluations (Mian and Sufi (2012); Green et al. (2020)) of the 2009 Cars Allowance Rebate System (CARS) program, commonly referred to as "Cash for Clunkers." This program consisted of payments of $3,500–4,500 to consumers in exchange for trading in their older vehicle and purchasing a new one. While each paper uses a different research design, they find the same key results. The CARS policy was successful at shifting spending from the future to the present. However, this fiscal stimulus was short-lived—within one year, all of the induced spending had fully reversed.

Recent studies that examine temporary policies directed at home purchases tell a different story. The bottom panel of Figure 1 shows evidence from Best and Kleven (2017), who study the elimination of a housing transaction tax in the UK, and Berger, Turner and Zwick (2020), who study the effect of a temporary $8,000 tax credit awarded to first-time homebuyers in the US. At a conceptual level, these two policies share many similarities to the auto scrappage policies discussed, as all of these policies temporarily lower the price of purchasing a durable good. The main difference appears to be the type of durable good. Yet despite this commonality, both Best and Kleven (2017) and Berger, Turner and Zwick (2020) find different results from the CARS studies. All policies are effective at increasing demand, while policy effects with homebuying subsidies do not reverse quickly. The bottom panel of Figure 1 shows that in both cases sales only modestly decline, if at all, once the policy was over. Thus policies aimed at stimulating housing demand appear to generate large and long-lasting stimulus.

The difference in outcomes is surprising because these policies are conceptually similar. Consider the simple example illustrated in Table 1. We assume that the economy is made up of cohorts of households, who do not differ in preferences and can only adjust to a common durable size.

In the first two rows, the durable good is a car that should be scrapped after ten years. Assume cohorts only differ in owning different vintages of the fixed size durable good. In steady state, car scrappage is staggered such that every year sees one unit of new cars purchased. In the second row, a temporary scrappage program induces a cohort that would have adjusted in ten years to adjust in nine. As a result, two units of cars are purchased in year 0, but zero units are purchased the next; cohorts merely shifted a purchase ahead by a year. This pattern is similar to what has been documented empirically with the CARS stimulus.

The bottom two rows show the effects of a stimulus for first-time homebuyers. Analogous to the environment with cars, assume homebuyers purchase their first home at age 30. In steady state, each year sees only one unit of housing purchased due to the cohort aging into homeownership. Consider a FTHC that offers a one-year stimulus only for first-time homebuyers. Homeowners who are 29 years old, instead of purchasing next year, buys their homes while the policy is in effect. Thus, we have two units of homes purchased today, then zero the next period because those households have already purchased. Under these assumptions, the patterns for auto and homebuying stimulus are the same.

This logic is more general. Consider the case of a simple infinitely lived real business cycle (RBC) model, where households derive utility from both non-durable and durable consumption. One can prove the following proposition:[4]

Proposition 1. *Consider an RBC model with CRRA utility over durable stock, d_t, and non-durable expenditures, c_t, and with separable endogenous labor supply, l_t. If there are no adjustment costs on durable spending and the expected real rate is constant, then the impulse responses of (linearized) non-durable and durable consumption expenditures, ($e_t = d_t - (1-\delta)d_{t-1}$)), to a time-0 i.i.d. aggregate preference shock, z_0, are given by:*

1. *(Non-durable expenditure)* $\hat{c}_0 = \frac{z_0}{\gamma}$, $\hat{c}_t = 0 \quad \forall \quad t > 0$

2. *(Durable expenditure)* $\hat{e}_0 = \frac{z_0}{\gamma\delta(1-\beta(1-\delta))}$, $\hat{e}_1 = -(1-\delta)\hat{e}_0$, $\hat{e}_t = 0 \quad \forall \quad t > 1$

In response to a positive aggregate demand shock, both non-durable and durable expenditure increase. Durable expenditure, however, quickly reverses; in the case of zero depreciation ($\delta = 0$), reversal is complete. If we hope to match the heterogeneity in the empirical evidence, we need to enrich this model.

Adjustment costs and lumpy investment may not, on their own, dampen how responsive durable expenditures are to price shocks like in the RBC model (House, 2014). However, there

[4] This is simplified version of the proposition in Beraja and Wolf (2021).

are additional ways that realistic housing and auto purchases differ from RBC investment behaviour and from each other. They also differ in the extent and nature of financing constraints, life-cycle interactions, and whether households hold them as an asset or not.

In the next section, we introduce a dynamic life-cycle model, where all of these restrictions are relaxed. We use the model to study what features are crucial for generating the patterns we observe in the data and to quantify their aggregate importance.

3 A Life-Cycle Model with Durable Purchases

We consider a dynamic, incomplete markets model of household consumption in discrete time. Households have finite lives and face uninsurable idiosyncratic income risk. Households can partially insure against risk by investing in a riskless bond or owning a durable good, against which they can borrow subject to a credit constraint. The durables market is subject to frictions in financing as well as the level of housing services each household can purchase. We begin our analysis in partial equilibrium. In Section 6, we explore the robustness of our main quantitative results when durable prices are endogenously determined.

3.1 Model Setup

Demographics. The stationary economy consists of households i, each living for J periods. Each household works for the first J_y periods and retires afterward for J_o periods. We normalize the distribution of households to have measure one.

Preferences. Households born at time t maximize the expected utility function

$$E_t\left[\sum_{j=1}^{J}\beta^j U(C_{i,t+j}, D_{i,t+j}) + \beta^{J+1}B(\tilde{W}_{i,t+J+1})\right],$$

where C_{it} denotes consumption of non-durable goods, D_{it} is the current level of durable services and $\tilde{W}_{i,t+J+1}$ is a measure of real wealth bequeathed by the household to future generations, given by

$$\tilde{W}_{i,t+J+1} = \frac{P(1-\delta)H_{i,t+J} + (1+r)A_{i,t+J}}{P_X},$$

where the numerator is the wealth bequeathed to the next generation, net of any financial debt. The denominator is a price index that adjusts for changes in the future cost of durables.[5] The per-period utility function and the bequest function are, respectively,

$$U\left(C_{i,t}, D_{i,t}\right) = \frac{1}{1-\gamma}(C_{it}^{\alpha} D_{it}^{1-\alpha})^{1-\gamma}, \qquad B(\tilde{W}_{i,t+J+1}) = \Psi \frac{1}{1-\gamma} \tilde{W}_{i,t+J+1}^{1-\gamma}, \tag{1}$$

where Ψ is a parameter controlling the strength of the bequest motive.

Financing and Adjustment Frictions for Durables. A household i at time t can hold one of two assets: a risk-free asset, A_{it} and a durable good, D_{it}. The risk-free asset is perfectly liquid and yields a constant interest rate r. The durable stock yields service flows one-for-one, depreciates at rate δ, and trades at a price P_t. We assume that in each period a household must must choose whether to be an owner or a renter of the durable good. Either option subjects the household to some market frictions.

If a household rents, she repurchases durable services D_{it} every period at a price $\varphi = (\phi + \frac{r+\delta}{1+r})P$, which is the user cost of durables plus ϕP. The term ϕP reflects a rental operation premium that is perfectly correlated with the price level of owned durables. A household renting a durable can adjust the level held at no cost, but cannot use it as collateral to borrow other assets. We therefore abstract from any liabilities held by renter households: their net assets A_{it} consists only of the risk-free asset. Additionally, following Kaplan, Mitman and Violante (2020), we assume that there is an upper limit $\overline{R}$ on the amount of rental services a household can purchase.

If the household chooses to purchase a durable, this purchase can be financed, the timing of which is before any durable maintenance is made. Durable financing requires paying a fraction θ of the durable's value as a down payment. The household may borrow against the value of durables held according to the following the borrowing constraint:

$$(1-\theta)(1-\delta)PD_{it} + (1+r)A_{it} \geq 0. \tag{2}$$

This highlights the dual benefits of owning durables for the household: in addition to providing a utility service flow, an owned durable can be used as collateral for borrowing subject to the borrowing constraint. In our model, there is only short term debt. These loans can be interpreted as a sequence of one-period HELOCs approved at the start of each period (Luengo-Prado (2006), Diaz and Luengo-Prado (2008)), with an interest rate spread of m above the

[5] Specifically, $P_X = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}\left(1 - \frac{(1-\theta)(1-\delta)}{1+r}\right)P^{1-\alpha}$.

risk-free rate.

When holding an owned durable, households pay maintenance costs δPD every period to maintain durable value. They also pay a tax on the durable τ_D. Following Kaplan, Mitman and Violante (2020), we assume owned durables must be of at least size $\underline{D}$. To consume durable services less than $\underline{D}$, the household must rent. This highlights the characteristic of many durable markets being segmented, making it challenging to rent the highest quality durables.

To match the fact that households only infrequently adjust their stock of durables, we model adjustment costs for buying and selling durables. Our approach assumes that costs for the buyer are convex, while costs for the seller are explicitly linear n their current durable value. We interpret the combination of these costs as a reduced form way to capture *all* required costs involved in adjusting, including both financial and psychological costs.

First, all buyers pay a purchasing cost F_B that is a function of durable services before and after the adjustment:

$$F_B(D_{it}, D_{it-1}) = F\left[D_{it}^{\chi}(D_{it} + D_{it-1})^{1-\chi}\right], \tag{3}$$

where D_{it-1} is either existing durables for owners, or the level of durables a renting household wants to rent. To unpack this cost function, note that it is linear in durable services if $\chi = 1$. If $\chi = 2$, the function can be expressed as $F(\frac{D_{it}}{D_{it}+D_{it-1}})^2(D_{it} + D_{it-1})$. Similar functional forms were used in Winberry (2021), Koby and Wolf (2020) and McKay and Wieland (2021).[6]

The seller cost for existing durable owners is a standard linear function of durable value: $F_S(D_{it-1}) = \kappa P_{it} D_{it-1}$. We allow a smaller buyer cost scale parameter F for buyers, so they do not face disproportionate adjustment costs compared to new owners. Putting this together, total adjustment costs are thus:

$$ADJ(D_{it}, D_{it-1}) = \begin{cases} F_B(D_{it}, D_{it-1}) & \text{for renters,} \\ \frac{F^{rpt}}{F} F_B(D_{it}, D_{it-1}) + F_S(D_{it-1}) & \text{for owners,} \\ 0 & \text{for non-adjusters.} \end{cases}$$

[6]The main conceptual difference is that, instead of costs being quadratic in the ratio of investment over capital, what is nonlinear is instead the *degree of durable upsizing*, $U = \frac{D_{it}}{D_{it}+D_{it-1}}$. For example, the more a renting household wants to downsize into a smaller owned D_{it} the closer U is to 0. As long as $\chi > 1$, a lower χ means fewer savings on adjustment costs for a household if it changes its intensive margin of purchased durable services. Optimization over the life cycle therefore is more reliant on waiting longer between new durable purchases. As long as $\chi \in [1, 2]$, we can show that downsizing durable services by one percent leads to a less than one percent fall in buying costs as share of durables, F/D. This elasticity approaches $\chi - 1$ as U approaches 0.

Renting versus Owning. Households thus face a trade-off when choosing between renting and owning. The advantage of renting is that it allows households to keep their savings in the form of liquid assets, thus providing a better buffer against income shocks. The disadvantages are that renting is costlier due to the rental operation premium and renting durables precludes their use as collateral.[7]

The model naturally captures the fact that homeownership rates increase in age. Because households are more financially constrained when they are young, they typically choose to rent when young in order to benefit from the financial flexibility of renting. As they age, they decide when to own durables as well as when to upsize or downsize their durable stock as their income processes evolve. The frictions we add to the model, such as the minimum house size and adjustment costs, affect how likely households spend down savings to buy new durables at a given income level.

Labor Earnings. Households inelastically supply one unit of labor while of working age, but face an exogenous productivity process that drives their income. When the household works, income is given by

$$Y_{it} = \exp\{\chi(j_{it}) + z_{it}\}, \tag{4}$$

composed of a deterministic age-dependent parameter $\chi(j_{it})$, where j_{it} is the age of household i at time t, and an AR(1) income process z_{it},

$$z_{it} = \rho z_{it-1} + \nu_{it}, \tag{5}$$

with autocorrelation parameter ρ and a Gaussian noise term $\nu \sim \mathcal{N}(0, \sigma_\nu^2)$.

In our overlapping generations model, young households' income levels differ from older households in two ways. First, young households have lower mean levels of the age fixed effect $\chi(j_{it})$. Second, the distribution of productivity shocks starts from lower values than a stationary Markov distribution, but converges to the stationary distribution as households age. In Section 4.1, we describe how we calibrate the income process. Finally, we assume that, as in Guvenen and Smith (2014), income is given by a Social Security transfer when the households retire. This transfer is untaxed and is a function of income in the households' last working-age

[7]The latter advantage is not enough, on its own, to induce households to own, because renting reduces the need for borrowing more than it reduces the availability of collateral (i.e., $\theta < 1$). Thus we assume that $\varphi > (r+\delta)/(1+r)$, where $(r+\delta)/(1+r)P$ is the user cost of housing services for a homeowner facing a constant house price P.

period.

Government. The government in our model is simple and has only one major mandated outlay: Social Security payments to retired households. It collects revenue from three sources. First, there is a progressive income tax with the schedule $\mathbf{T}(Y_{it}) = \tau^0 Y_{it}^{1-\tau^y}$, where τ^y is a tax progressivity parameter. Second, it collects a flat property tax on all durable wealth in the economy at rate τ^d. Third, it collects as a resource monopolist all profits from the durables suppliers before expenditures on production factors: $PD^{new} - wL^d$[8]. If there is a surplus or deficit after these items, the government reimburses a flat transfer or charges a flat levy $\tilde{\mathrm{T}}$ from all households.

Household Budget Constraint Each period, the household maximizes its utility subject to the following budget constraint:

$$\underbrace{C_{i,t}}_{\text{Consumption}} + \underbrace{P_t D_{i,t} + A_{i,t}}_{\text{Next-period wealth}} = \underbrace{Y_{i,t} - \mathbf{T}_{i,t}}_{\text{After-tax income}} - ADJ(D_{i,t}, D_{i,t-1}) + \underbrace{(1-\delta-\tau_D) P_t D_{i,t-1} + (1+r) A_{i,t-1}}_{\substack{\text{Net worth after depreciation,} \\ \text{maintenance and taxes}}}$$

where $\mathbf{T}_{it}$ is a progressive income tax. The household earns labor and asset income, pays taxes and chooses how much to save in the liquid asset and to consume in both non-durables and durables. If the household chooses to adjust its durable stock, it must pay in an adjustment cost as described above.

In our baseline calibration, we assume the durable is housing that must be maintained every period, at a cost of $\delta P_t D_{it}$. We explore the importance of this assumption extensively in Section 5.

4 Calibration

We now calibrate the model to assess its quantitative implications for both non-durable and durable consumption responses to durable goods stimulus. We use the First-Time Homebuyer Credit (FTHC) as our calibration policy, targeting both steady-state moments and quasi-experimental moments from that stimulus episode. We then evaluate the out-of-sample fit of

[8]When the durable good is housing, the assumption implies the government captures all land rents for new homes built every year.

the model to untargeted moments, including the household wealth distribution and the age distribution of homebuyers during the policy period. In the following sections, we use the model to compare the FTHC to other fiscal policies, including durable good stimulus policies such as the CARS program and stimulus checks.

4.1 Predefined Parameters

Our predefined model parameters largely follow the literature, specifically, Floetotto, Kirker and Stroebel (2016) (henceforth FKS), Berger et al. (2017) (henceforth BGLV), Kaplan, Mitman and Violante (2020) (henceforth KMV), and Berger, Turner and Zwick (2020) (henceforth BTZ). Table 2 summarizes the parameters and their sources.

Demographics and Preferences. The model is annual and the first year is interpreted as age 22. Households then work for $J_y = 38$ years, enter retirement at age 60, and are retired for up to $J_o = 15$ years. In retirement, households face risk of death, based off of age-specific probabilities from BGLV. The income share on housing services $\alpha = 0.241$ follows estimates from cross-sectional data in Davis and Ortalo-Magne (2011).

Endowments. For the deterministic life-cycle component, we fit a cubic polynomial in age over Panel Survey of Income Dynamics (PSID) data used in Blundell, Pistaferri and Preston (2008), as in Kaplan and Violante (2010). To estimate the parameters of the AR(1) income process, we reuse the GMM estimator in Flodén and Lindé (2001) but over the 1997–2013 PSID waves. The permanent component has persistence $\rho = 0.920$ and innovation standard deviation $\sigma_z = 0.160$. Appendix A offers computational details on how we discretize the income process.

Housing and Finance. Following Berger and Vavra (2015*a*), the depreciation rate for housing is set at $\delta = 2.2\%$ annually. FKS estimates real returns for U.S. treasuries and the spread for fixed-rate mortgages, and we adopt their real return $r = 2.4\%$ and their lending premium $m = 0.8\%$. Based on the literature and the terms for U.S. conventional mortgages, we set the down payment percentage $\theta = 20\%$. In a GE extension with endogenous housing supply, the housing supply elasticity ε is set at 1.5, following KMV and the specification in Saiz (2010) assuming common supply elasticities across U.S. housing markets.

The adjustment cost function described in Section 3.1 has four parameters. One of them, the scale of seller costs κ, follows BGLV so owners must pay 6% of existing house value when they sell their homes. The rest are calibrated internally, as described in Section 4.2. To match observed rates of household mobility, we also follow FKS and allow for an exogenous moving shock to hit owner-occupier households, at an annual rate of $P = 2.2\%$.

Government. Retirees receive Social Security payments according to the payoff function in Guvenen and Smith (2014). We follow KMV and set the property tax rate at $\tau_D = \tau_h = 1\%$ of house values. For income taxes, the tax progressivity parameter $\tau_y = 0.15$ and the tax scaling factor $\tau_0 = 0.167$ follow KMV, implying a total tax rate of 20% over workers.

Initial Wealth and Income. In our model, households start out by drawing their starting income state and wealth endowments over a multivariate distribution. The distribution is based on the empirical distributions for young households over the 1998–2004 Survey of Consumer Finances (SCF) waves.

We filter on surveyed heads of households over the ages of 22 to 25. We first net out the deterministic income component at age 22 from self-reported incomes, which backs out a distribution of latent income states $F(z)$ poorer than the stationary distribution we would expect from the income process. Then, we estimate distributions of financial assets, homeownership and house value conditional on what income bin young SCF households belong to.

Using the empirical conditional distributions $\hat{G}(A, D \mid z)$, we parametrize smooth distributions $\tilde{G}(A, D|z)$ to be used in our model. Assuming an independence condition, the multivariate density that model households draw initial states from is $H(A, D, z \mid t = 22) = \tilde{G}(A, D|z) \times F(z)$. Appendix A provides the computational details and the parametrizations we use to derive $\tilde{G}$.

4.2 Internally Calibrated Moments

Nine parameters remain that we overidentify with ten data moments. Our approach is to compute iteratively the stationary equilibrium and minimize the sum of squares of these moments. Table 3 shows each calibrated parameter and its corresponding empirical moment.

Three calibrated parameters relate to preferences: (1) the inverse of the elasticity of intertemporal substitution (EIS) γ; (2) the bequest parameter Ψ; (3) the discount factor β. Along with the rental premium ϕ, these parameters shape the dynamics of homeownership and the amount of saved housing wealth over the life cycle. The discount factor is chosen to match the median net worth in the SCF, excluding the right tail of high net worth households. Because ϕ and Ψ affects the rental option's value for homeowners during working and retirement age, respectively, they are disciplined by the working households' homeownership rate and retirees' homeownership rates.

The EIS parameter γ affects the willingness to wait to become homeowners up to their deterministic income component peaking in their forties, so the share of homeowners buying their first home in their 30s versus later on in life disciplines γ.

The five remaining parameters all deal with constraints and frictions in the housing market, limiting flexibility of housing adjustments. The minimum durable size $\underline{D}$ changes based on how quickly young, but persistently rich, households enter homeownership, proxied by the share of FTHBs in their 20s. The larger the minimum housing size, the longer it takes for even highly productive households to accumulate enough savings to purchase their first home. The maximum rental housing size $\overline{R}$, following a strategy in KMV, is identified from the ratio of incomes between homeowners and renters. The three parameters of the adjustment cost function for repeat and first-time homebuyers are disciplined by two steady-state and one non-steady-state parameters.

The two scale parameters are chosen to match the average transition rate from being a renter to being a first-time homebuyer. The scale parameters are identified from the relative propensity of renter-owner, renter-renter and owner-owner transition spells. The scale parameter for first-time homebuyers is the level of FTHBs over all renters, the "renter-owner transition rate." For repeat buyers, the scale parameter is identified from the level of FTHB transactions over all transactions, the latter of which includes new purchases by owners.

All of our moments concerning the age distribution of first-time homebuyers are taken from IRS data, also used in BTZ. Our sample pools household filings over 2004–2012, excluding the years in which the FTHC was active (2009 and 2010) to estimate the stationary distribution. With these same data, BTZ also esimate a renter-to-owner transition rate of 5.4% annually. The rest of our moments are calculated from the 1998–2004 pooled SCF sample, except for the share of transactions that are FTHB purchases. Bai, Zhu and Goodman (2015) estimates this share to be 40% before the financial crisis, and we adopt that rate.

The shape parameter is chosen to match how responsive households are to a temporary credit for a housing durable good. We discipline this parameter using quasi-experimental evidence from BTZ. The model-implied responsiveness of households to a temporary credit is twice the size of the moment from BTZ. We show below that this moment is sensitive to how the policy is implemented. In reality, some homebuyers were able to use the credit at the time of purchase, while others were not. The empirical moment 0.6 lies between the value for a temporary credit that cannot be applied to the down payment and our calibration experiment that permits this for all buyers. For clarity, we do not target the moment under imperfect takeup and use counterfactual policies to show how policy efficacy depends on this aspect of program design. The other moments targeted in the model are very near to their data counterparts.

The calibrated parameters are also realistic and in line with empirical estimates. The EIS is 0.3, close to the bias-corrected mean in the meta-analysis by Havránek (2015). The minimum house size parameter, when converted from model normalization, amounts to a minimum house value of around $140,000 in 2013 dollars. The mean adjustment costs for a FTHB is $16,300 in 2013 dollars, with a standard deviation of $1,200. For repeat home buyers, adjustment costs are $20,100 on average in 2013 dollars with a standard deviation of $5,250.

4.3 Out-of-Sample Tests of Fit

Figure 2, Panel A plots the age distribution of first-time homebuyers in our model during the policy period against the counterfactual steady-state age distribution. Panel B plots the empirical counterpart to this figure using the IRS data assembled in BTZ. We match the key features of the steady-state age distribution, as both distributions peak around the late 20s and fall gradually for older ages.

As in the data, the model displays a shift toward younger buyers when the FTHC is in effect. Unlike the steady-state age distribution, we match this moment even though we do not target it in our calibration. The model-simulated steady-state age distribution is 35.7; it falls to 35 during the policy period. The empirical shift in the age distribution is quite similar, with an average 36.8 in non-policy years; the average age falls to 35.7 during the FTHC.

As a second out-of-sample validation, Table 4 plots moments of the wealth distribution for renters in the model and for owners, compared to these moments in our pooled SCF data. The model accurately matches moments of the liquid asset distribution for renters, which form the target population for the housing policies we study. The model is reasonably close to the data over the net worth distribution for homeowners, especially for homeowners below the distribution median.

5 Durable Goods Stimulus Policies

We now explore the ability of the model to match the variety of empirical outcomes observed in the literature in response to identified policies. We begin our analysis by focusing on the calibration policy, the First-Time Homebuyer Credit (FTHC), and an auto scrappage policy modeled after the Cash-for-Clunkers program (CARS). We focus on these programs both because they are illustrative of a broader set of policies targeting durable goods and because we have access to micro data that allows us to further validate the model's ability to match the empirical evidence.

Our setup allows us to answer questions that are infeasible without a model. For example, we use the model as a laboratory to simulate the post-policy period many periods out in the future and observe the long-run behavior of simulated policy claimants in a way difficult to accomplish with empirical analysis.[9] First, we identify and characterize policy takeup among inframarginal versus marginal households. Second, we implement counterfactual policies to understand which factors are crucial for the observed empirical regularities. Finally, we conduct welfare analyses for the model's agents in under various regimes, allowing us to rank policies using welfare-based criteria.

5.1 Policy Setup

We model the FTHC as an unanticipated, one-period policy that is available only to renters who have never purchased a house. To qualify, a renter must not have purchased a home in the prior three periods, must earn an income below a relevant threshold ($75,000), and must purchase a house above the minimum house size. The renter receives $8,000 in the period after the purchase.[10] While this policy simulation resembles the actual FTHC, we do not model a financial sector that might offer a temporary loan for a buyer at the time of the purchase with the credit as collateral. Instead, we allow the household to elect to apply the credit to the down payment.[11]

We model CARS as an unanticipated policy available to every vehicle owner who owned the same durable good for 5 years or longer. Because the credit was transferred from the government to dealers, rather than purchasers, the credit is modeled as an approximately $5,000 decrease in the vehicle's purchase price. We make two changes in the model to reflect the fact that CARS applied to automobiles and not houses. First, we add a constant scrap value that a seller receives upon disposal of the asset. Second, we do not allow the household to pay a maintenance cost that allows the durable to last forever. In reality, cars depreciate much

[9] The empirical studies we cite all lose statistical power when they estimate effects further out in time.

[10] The sum is "approximately" $8,000 because, in the model, all values are normalized to the mean household income from the SCF cross-section, which is about $67,000. The transfer in the model is rounded to two decimal places.

[11] According to Berger, Turner and Zwick (2020), the Department of Housing and Urban Development issued guidance during the program that explained lenders could allow buyers to apply for the credit in advance and apply it to the down payment.

faster than houses regardless of owner inputs, both because of the nature of the physical asset and because a house includes a claim on non-depreciating land. This change in environment converts the household's economic problem into an optimal stopping problem, consistent with reality and how scrappage policies are modeled in the literature (Adda and Cooper, 2000).[12] We explore the importance of these changes in Section 5.4.

We simulate both policies for 38 years, such that every household exposed to the policy will have lived to retirement age. We begin by conducting both simulations in partial equilibrium with asset prices fixed at their market-clearing level. In ongoing work, we allow for a policy transition path with changing prices, while following Floetotto, Kirker and Stroebel (2016) in assuming households have perfect foresight about the price transition path.

5.2 Baseline Results

This section highlights one of our main results: within the same life-cycle incomplete markets model, we are able to match the disparate empirical responses of both the CARS program—which *does* induce quick intertemporal substitution—and the FTHC program—which *does not*. This result generalizes the conventional wisdom that durable stimulus policies only reflect the retiming of behavior.

The first row of Figure 3 shows the aggregate responses to both credits in the model. Both panels plot total durable transactions in the economy, relative to their pre-policy steady state levels, as well as a cumulative series that sums transaction levels across the years since policy enactment. Panels A and B show the aggregate response and policy reversal path for the FTHC and CARS programs, respectively. Importantly, while we used the magnitude of the period-0 response to the FTHC in calibration, we did not target the post-period.

In contrast to the textbook representative agent model in Section 2, our model can match the diversity of empirical responses observed in the data. The auto scrappage program induces dynamics that are consistent with neoclassical intuition and the empirical literature. While the subsidy increases durable purchases during the policy period by nearly 15% relative to the steady state, the effect on transactions quickly reverses by over 80% within one year and fully reverses after two years.

The FTHC likewise causes a large response in transactions, nearly 50% more relative to the steady state. A key difference, however, is that the transactions response endures into the long run. Even after 6 years, more than 25% of the initial effect remains. This response is qual-

[12] In the budget constraint, this means the durable value $(1-\delta-\tau_D)P_tD_{t-1}$ term in the durable adjuster's problem is replaced by a constant scrap value s^D.

itatively and quantitatively consistent with the empirical literature on temporary homebuyer subsidies.[13]

5.3 Characterizing Marginal Responses

To understand why these conceptually similar policies generate different results, we introduce some terminology. First, define *marginal* buyers as those households who were induced by a given policy to make a durable purchase during the policy window. *Inframarginal* buyers are policy-period buyers who would have bought during this time absent the policy. Second, define the *timing margin* as describing households who retime their purchases in response to stimulus policy, but still make the same number of purchases over their life cycle. *Extensive margin* buyers are households who change the total number of transactions over their life cycle. A concrete example of the extensive margin is a person who, absent the policy, would have purchased two homes over her life, once at age 35 and once at 60. Because of the policy, she instead buys a smaller, starter home at 32, then upgrades at 38, and buys again at 60.

The second row of Figure 3 hints at the different nature of marginal buyers in the FTHC and CARS experiments. Instead of plotting the number of purchases, Panels C and D plot the total value of purchases relative to steady state for the FTHC and CARS policies, respectively. For the FTHC, we see the ratio of the cumulative transacted value to the steady-state value is lower than for the ratio of total transactions. We see the opposite pattern for the CARS experiment. These figures imply that induced purchases in the FTHC policy are cheaper houses than those bought in steady-state, while CARS purchase are more expensive. The evidence is consistent with the FTHC inducing more financially constrained entrants into the market, leaving more scope for a later tradeup of value and future transactions.

Figure 6 presents a more systematic analysis of the characteristics of marginal versus inframarginal buyers in each policy experiment. For each experiment, we run multivariate regressions using the policy-eligible population of the probability of being a marginal or inframarginal policy claimant on different characteristics. We then plot the regression coefficients and confidence intervals from these regressions.

We start with the auto scrappage policy. The quick and full reversal indicates that the response reflects almost entirely short-term retiming of purchases by households to capture

[13] We see two perspectives for why a partial reversal of transactions in the model remains quantitatively consistent with the quasi-experimental evidence. First, a lack of statistical power into the long run means quasi-experiments also cannot reject a partial reversal. Second, the model results do not feature "vacancy chains," where sellers of resale homes turn around and buy a new home, increasing total transactions further than implied by the demand response in the model (see, e.g., Anenberg and Ringo (2022)).

the temporary subsidy. Because households are unable to maintain their durable forever, the economic problem faced by households is an optimal replacement problem. In the presence of adjustment costs, the optimal policy choice is to purchase more of the durable good whenever the gap between how much of the durable they currently own and how much they currently desire is large enough. We refer to this as the *durable gap*.

Figure 6 highlights that the durable gap is far more important than the household's income and wealth position. The scrappage feature of the program deters adjustment for buyers with still-valuable cars. As a result, policy takers are comprise those who would have adjusted anyways and those with old cars who likely would have adjusted relatively soon absent the policy. The low correlation with income and wealth further suggests that marginal households are mostly financially unconstrained. We explore this point further in a moment.

Finally, we see that age is strongly positively related to inframarginal and marginal purchase propensity. This result is intuitive: if we think it is older people who hold on to older cars, when they scrap their durable car has depreciated a great deal. We confirm this finding in Figure 2, Panels C and D, which plot the policy-period and counterfactual age distributions for the CARS experiment and in the FRBNY Consumer Credit Panel/Equifax Data.[14] In contrast to the FTHC figures, CARS buyers tend to be *older* than counterfactual buyers. The mean age in both the model and data increase by 0.4 and 1.0 years, respectively, when the policy is in place. These older buyers are likely less financially constrained by virtue of their life-cycle profile and likely have larger durable gaps by virtue of their own longevity.

Turning to the profiles of marginal respondents in the FTHC experiment, Figure 6, Panel B shows that net worth is strongly positively correlated with policy takeup. Policy takers appear to have both higher net worth and lower income relative to non-takers. We interpret this pattern as suggesting these are individuals on the trajectory toward homebuying in the future, but who have been unable to save an adequate down payment to date. The credit complements the savings they have already accumulated and induces them to adjust across the threshold.

Figure 7 delves further into the relative wealth of marginal and inframarginal buyers for each policy. In each case, we plot the steady-state densities of net worth for the targeted population and partial densities for the marginal and inframarginal buyers during the policy period. The partial densities, which divide the number of households in a bin by the total number of marginal and inframarginal households, allow us to show simultaneously the importance of these groups to the aggregate response.

The figure delivers three takeaways. First, the share of buyers who are marginal is much

[14] These data come from an anonymized random sample of 5% of U.S. households with a credit file, constructed from Equifax credit data.

higher in the FTHC experiment than in the CARS experiment. Second, marginal buyers in the FTHC tend to have lower net worth than inframarginal buyers, with averages of around $30K and $50K respectively. Finally, the target population in the case of the FTHC, which excludes current homeowners and is subject to an income threshold, is dramatically poorer than in the CARS experiment. As a result, the average FTHC taker has much lower net worth than the average CARS taker.[15] In Section 7, we show the marginal FTHC takers have the largest consumption spillovers and welfare gains from the credits.

In Figure 8, we connect our results on financially constrained marginal households to the reversal of the policy-period response in total transactions. For each simulated household, we compute the difference between the purchase year under the policy regime and counterfactual year in which they would purchase absent the policy. We present scatterplots of the mean difference in purchase timing versus policy period income and net worth for both experiments.

In the case of the FTHC, we find a strong relation between the extent of retiming and both income and wealth. In particular, marginal buyers with lower incomes and higher net worth tend to shift purchases from farther in the future. In contrast, the retiming motive for CARS takers appears to have little relation with proxies for financial resources. The results suggest the incomplete reversal in the FTHC episode is driven by longer-term intertemporal substitution by households that are more likely to face financial constraints. Marginal households are also more likely to buy smaller homes in their initial adjustment and subsequently upgrade, leading to a nontrivial extensive margin response on top of the intertemporal margin from the distant future. These responses contrast with results in House (2014), where wealth is "irrelevant" to retiming. Our environment differs from the neoclassical behavior in that paper, because homebuyers anticipate upsizing over their life cycle but is constrained in their decisionmaking by financial frictions.

We note the higher scope for shifting by higher net worth buyers is consistent with these buyers having enough savings to be close to homebuying in the absence of the policy. The FTHC provides these households with the crucial push over the adjustment threshold.

What accounts for the lack of reversal between the FTHC and CARS policies? When durable goods are temporarily cheap, there is an incentive to purchase more today rather than tomorrow, a dynamic that strongly affects both policies through the intertemporal margin. Additionally, there is an insurance margin, where households purchase today to secure future wealth or to upgrade to a larger durable good later. Here, houses and cars differ significantly as assets

[15]Due to computational tractability, we do not model households jointly choosing their housing services and automobile services. In the CARS experiment, high net worth reflects households investing more in riskless liquid assets.

because their value retention is crucial to long-term financial planning. While homes maintain their value, cars depreciate rapidly—losing roughly 15% per year, leaving them worth less than 40% of their original value after five years. If a durable good is being used to store a down payment to upgrade to a larger asset later in life, houses are a far better store of value than cars. This life-cycle tradeoff helps explain why car purchase policies tend to experience more reversal.

5.4 Counterfactuals

In this section, we use the richness of our theoretical environment to implement counterfactual policies that modify aspects of the baseline FTHC and CARS experiments. These counterfactuals allow us to isolate the policy design factors that matter most for our results. Figure 9 plots impulse responses of cumulative transactions relative to steady state for counterfactual FTHC environments in Panel A and CARS environments in Panel B.

Consider first counterfactuals of the FTHC environment. If we do not permit households to apply the credit to the down payment, we find a notable change in results. The policy-period response falls to approximately one-third of the baseline response and the incomplete reversal result goes away. Thus, to the extent the FTHC is not targeting the financial constraint binding on some households, the model returns to resemble the neoclassical model with rapid and complete reversal.

Appendix Figure C.1 shows that, in our model, the mean net worth of marginal households is similar to those of inframarginal households. The lack of a net worth shift resembles what was seen for the CARS simulation in Figure 7. Appendix Figures C.2 and C.3 further show marginal households for a credit not on the down payment are closer to CARS policy takers: they shift purchases forward by fewer years on average, and exhibit less heterogeneity by income and net worth.

A second change we consider is to the storability of homes. If we implement forced depreciation as in the case of CARS, we see a smaller policy period response and a considerably less persistent response. We conclude that durability is essential to sustain longer-term shifts in behavior.

Turning to counterfactuals of the CARS environment, we consider the impact of various financing arrangements and changes in the scrappage value for the exchanged car at purchase. Reducing the scrappage value to zero amplifies the policy-period response and steepens the medium-term reversal, as households use the policy to "upscale" their cars, leaving them less likely than in the baseline to make purchases in subsequent period. In the case of financing arrangements, we find that both reducing the down payment required to buy a car and turning off the borrowing margin completely have small effects on the overall response. This result is consistent with the second order importance of financing constraints in mediating the policy response in the CARS experiment.

Taken together, the results point toward two key factors in reconciling the disparate evidence from the FTHC and CARS settings. The first is targeting. A FTHC that applies to the down payment constraint interact with financial constraints that were particularly binding for eligible households; the CARS policy is not. This fact comports well with our results on the identify of marginal households and their role in the longer-term intertemporal substitution response. It explains why the marginal share of buyers is higher in the FTHC experiment.

The second key factor is the underlying nature of durable goods. Some durable goods can be maintained and have their value preserved over time. Such goods are less likely to feature temporary stimulus responses that fully reverse immediately after the policy expires.

6 General Equilibrium

A long and rich literature explores models with investment subject to fixed costs. Several studies in this literature find that partial equilibrium results need not hold once one accounts for general equilibrium (GE) forces (Khan and Thomas, 2008; Berger and Vavra, 2015*b*; Winberry, 2021; McKay and Wieland, 2021). We extend our analysis by modeling housing supply within a GE framework, which allows us to assess the robustness of our primary findings. Accounting for GE feedback in the housing market, our core results remain both quantitatively and qualitatively robust to this extension.

6.1 Model Description

We focus on the new model features that are necessary to extend the model in Section 3 to a GE environment.

Housing Supply Function. Following Favilukis, Ludvigson and Van Nieuwerburgh (2017) and Kaplan, Mitman and Violante (2020), we assume that the production of new housing services exhibits constant returns to scale in two factors, newly available and buildable land L and labor input N_h:

$$H = (ZN_h)^{1-\psi} L^{\psi}, \quad \text{with} \quad \psi \in (0,1), \tag{6}$$

where ψ is the share of land used in the production function. The government sells buildable land at a competitive market price to developers. Thus, the construction sector earns zero profits. A profit-maximizing developer solves:

$$\max_{N_{h,t}} P_t \left[(Z N_{h,t})^{1-\psi} L^{\psi} \right] - w N_{h,t}. \tag{7}$$

When labor markets are competitive ($w = Z$), this yields the closed-form function for new housing supply H_t^{new}:

$$\log H_t^{new} = \log((1-\psi)^{\frac{1-\psi}{\psi}} L) + \frac{1-\psi}{\psi} \log(P_t).$$

where $\epsilon \equiv \frac{1-\psi}{\psi}$ is the elasticity of housing supply.

Market Clearing. In every period, housing demand arises from two sources, depreciation and all households' housing service choices. Rental prices are determined by the user cost of housing, which includes depreciation, property taxes, the opportunity cost of safe bonds, and an operational premium φ. At each price φ, landlords lease out housing such that rental supply meets demand:

$$H^r(\Omega) = \int_{\mathbf{s}|D=0} \tilde{D}\, d\mu(\mathbf{s};\varphi) + \int_{\mathbf{s}|D>0} \tilde{D}\, d\mu(\mathbf{s};\varphi). \tag{8}$$

House prices P_t clear the market for new home construction H_t^{new}:

$$H_t^{new} = \delta \left(H_{t-1} + H_t^r \right) + \int_{\mathbf{s}} D_t d\mu(\mathbf{s}; P_t) - \left(H_{t-1}^r - H_t^r \right) - \left(\int_{\mathbf{s}|D>0} D_{t-1} d\mu(\mathbf{s}; P_t) + \int_{\mathbf{s}|j=J} D_t\, d\mu(\mathbf{s}; P_t) \right) \tag{9}$$

The terms on the right-hand side account for (1) the adjustment in rental housing stock between the current and previous periods, which is returned to the owned housing market if $H_{t-1}^r - H_t^r > 0$; (2) the resale of homes by owners purchasing new properties; and (3) housing bequests upon the death of retirees. Following Kaplan, Mitman and Violante (2020), we assume that that rental and owned housing markets are not segmented, such that rental and owner-occupied housing can be easily converted between each other.[16]

[16]Recent work by Greenwald and Guren (2021) has raised questions about the empirical validity of this assumption in general. We are sympathetic with this critique. However, since we are calibrating our model to housing data from the Great Recession, when a substantial portion of the housing stock was vacant, we believe our segmentation assumption is defensible for this time period.

6.2 Calibration with Endogenous Prices

We focus on the new moments needed to discpline the GE extension. Appendix B presents details of this alternative calibration. The additional parameter we need to be calibrate is ϵ, the elasticity of housing supply. We pick this parameter to match the observed price response to the FTHC using the quasi-experimental estimates in Berger, Turner and Zwick (2020).

This calibration strategy requires solving for transitional price dynamics after an unexpected temporary shock. Specifically, we solve for a *transitory rational expectations equilibrium*, which is a collection of a transition duration T, idiosyncratic policy functions, and aggregates $\{P_t, H_t^{new}\}_1^T$ such that the following conditions hold:

1. Households have perfect foresight of $\{P_t\}$ for T periods and the policy functions maximize utility at each period $t = 1, \dots, T$.

2. At each t, H_t^{new} and P_t satisfy the production function and market-clearing conditions.

3. P_T is equal to the steady-state market clearing price P_0 without the tax credit.

Our calibration implies a housing price elasticity of $\epsilon = 3.3$, within the empirical range of estimates in Baum-Snow and Han (2024). Figure 4 shows the price dynamics when the \$8,000 FTHC we simulate is applied in period 1, and then prices are allowed to transition up to period 10. In period 1, the simulated price level—2.5% above the steady state—is close to the empirical target of 2.4% price growth from Berger, Turner and Zwick (2020). [17] The price then falls below the steady-state level for two periods, to a drop 2% below, before converging back to steady state. The logic behind prices declining below the steady-state level is straightforward: Marginal policy takers no longer buy in the years from which they shifted forward their home purchases. Demand in the medium run falls as a result, and prices drop. A similar dynamic is observed empirically in Berger, Turner and Zwick (2020).

6.3 Results

We present two main findings from the calibrated GE model (Figure 5) and contrast these with the takeaways from our baseline FTHC in Figure 3 and the alternative policy in Figure 9 where the tax credit cannot be applied to the down payment.

[17] BTZ uses cross-sectional variation to identify the price growth effect from a 1 standard deviation rise in policy exposure. A move from the 10th percentile ZIP code by exposure to the 90th is a change of 2.2 SDs, which implies a rescaled estimate of 2.4% price growth between those geographies.

First, endogenous price effects dampen the initial transaction response. In the baseline scenario with a credit that can apply to the down payment, the increase in transactions relative to steady state declines by 25% from 0.52 to 0.40. A similar decline is observed in the alternative scenario where the tax credit is not applied to the down payment.

Second, while the overall dynamics of the policies remain broadly similar, there is notably less reversal in the GE mode. This difference is due to price dynamics that cause spillovers on both first-time buyers and existing homebuyers. These forces tend to attenuate the sharp reversal seen in the baseline model when the credit does not apply to the down payment.

The bottom panel of Figure 5 illustrates this response, showing both first-time homebuyers (FTHB) and existing homeowners who buy under both policy regimes. Since prices are expected to decline and then rebound along the perfect foresight path, many existing homeowners opt to take advantage of temporarily lower prices and make an additional purchase in periods 1 and 2. As a result, overall transactions and investment increase.

This GE spillover effect amplifies the lack of reversal through a distinct mechanism from a "real estate chains" force, in which home sellers become future buyers. The reason the feedback response appears particularly strong for the alternative policy is due to the relatively smaller size of the first-time buyer response compared to the baseline case.

7 Implications for Other Fiscal Stimulus Policies

7.1 Durable Expenditures and Measured MPCs

Matching empirical estimates of the marginal propensity to consume (MPC) is important in macroeconomic models because it helps to predict how changes in disposable income affect consumption. By matching the MPC, economists can better understand how changes in government spending or taxation will affect overall economic activity through changes in consumption. Thus, accurate estimates of the MPC are needed to understand efficient design of government policies to support the economy, whether via tax rebates or direct expenditures.

For most policy applications, economists need to understand the dynamics of consumption expenditures. For non-durable goods, there is no difference between consumption and expenditure: all goods that are purchased are immediately consumed. In the presence of lumpy durable goods, there is a distinction between consumption and expenditure. While expenditures may be lumpy, where a household may only purchase an automobile every few years, what matters for welfare is their service flow from the automobile. In order to make consumption responses comparable across distinct models of durable goods, we consider the marginal propensity to spend (MPX) as defined in Laibson, Maxted and Moll (2022). Instead of calculating marginal changes in nondurable and durable expenditures, we add to nondurable consumption the undistorted user cost of consumer durables to put durable spending in service flow terms.

Standard models that exclude lumpy durable purchases (e.g., Kaplan and Violante (2014)) have the implication that measured MPCs are strongly decreasing in transfer sizes. Kaplan and Violante (2014) find that two-quarter MPCs may fall by 50% if the transfer increases from $500 to $2500. This result occurs in their model because, if the transfer is large enough, households will reoptimize their portfolio choices (which requires paying a fixed cost) and deposit the government check into a high-return asset. If the check is too small, then it is not worth it to pay this fixed cost, so the household consumes more of the transfer. For policymakers, this result suggests that maximizing the bang-per-buck of a transfer policy necessitates having as small a transfer as possible.

This calculus changes if households are allowed to purchase a durable good, especially if such a purchase can be financed. In this case, a household receiving a large transfer may choose to use some or all of the transfer to finance a new durable purchase. This extensive margin response is absent in the case of non-durables and creates a reason why MPCs might instead increase with the transfer size.

The results shown in Panel A of Figure 10 confirm this intuition, which shows how measured MPCs vary with cash transfer size. The dashed red line from Kaplan and Violante (2014) shows the standard result: increasing the transfer size from $500 (roughly the average household transfer in the 2008 stimulus) to $2500 dollars (roughly the average household transfer for the first two rounds of the 2020-21 stimulus) causes the MPCs to fall by over 50%. The solid blue line shows the results for our baseline model. In this case, average MPCs are much higher, and more interestingly, the relationship between MPCs and transfer size is much flatter. Thus, there are few trade-offs in our richer model between bang-per-buck and transfer size, suggesting that optimal transfer sizes are likely higher than previously thought.

The data depicted in Panel B of Figure 10 underscores which households in a model with lumpy durables maintain higher MPX for large transfers. Among all households, above-average propensities to spend come from both hand-to-mouth households with minimal savings and households with net worth from $20-30K. Breaking down the population further, the non-hand-to-mouth households with higher MPX are almost exclusively those who buy a new durable good. Large transfers therefore continue to stimulate buyers on the brink of an adjustment decision, while not stimulating the wealthiest households already at their optimal allocation.

7.2 Ranking Stimulus Policies

Our results underscore the importance of financial constraints for understanding the effects of durable goods stimulus. Because the model can simulate many policy levers, we can also use it to rank such policies. Simulations reveal how alternative policy designs target the constraints of specific subpopulations, achieving commensurate aggregate responses to less targeted policies with higher costs.

We focus on two concepts stimulus policies might be designed to maximize. The first is the cumulative medium-run aggregate impact relative to a counterfactual equilibrium three years after policy expiration.This outcome might be desirable as it better matches the duration of business cycle slumps relative to a short-run response. Our second concept deploys the framework of Hendren and Sprung-Keyser (2020) for evaluating the welfare effects of government policy via computing the "marginal value of public funds" (MVPF).

The MVPF is a ratio where the numerator is the total willingness to pay (WTP) across individuals for a government policy. Measurement using the WTP exploits the envelope condition, as any marginal effects of the policy on choice behavior will not affect the individual's total welfare. We express WTP in dollar terms by dividing utility changes with each person's marginal utility of income λ_i. An unconditional transfer of one dollar, after this conversion, also has a WTP of one dollar.[18] A durable subsidy that depends on a new purchase will generally have a smaller WTP than an unconditional cash transfer because it constrains the choice set available to agents.

The denominator of the MVPF is the net effect of the policy in dollars on the government's budget. We focus on measures that exclude the policy's indirect fiscal spillovers due to behavioral responses (e.g., through transaction taxes). This approach highlights how our structural model can be used to infer WTP for complex policies, which is a challenge in empirical settings. We define the "no spillover" MVPF for policy p_j over households i as

$$MVPF_j = \frac{\sum_i WTP_i^j}{dR/dp_j}, \tag{10}$$

[18] Formally, the WTP is the equivalent variation for the price change implied by the subsidy. Our formula for the numerator of the MVPF comes from solving for the WTP using the first-order approximation of the value function:

$$V_i^{policy}(a, \mathbf{s}_{-a}) = V_i(a + WTP, \mathbf{s}_{-a}) \approx V_i(a, \mathbf{s}_{-a}) + \lambda_i \times WTP.$$

where

$$WTP_i^j = \frac{dU_i}{dp_j}\frac{1}{\lambda_i}. \tag{11}$$

In cases with externalities or tightly binding financial constraints, the WTP term can exceed the monetary equivalent transfer associated with p_j. In cases where policy conditions require purchasing too much or little of a good or service relative to the agent's optimal bundle, the WTP can be lower than the monetary equivalent. As emphasized in Hendren and Sprung-Keyser (2020), the MVPF is closely related to traditional cost-benefit analyses of policy. However, MVPF analyses can lead to different conclusions on the relative attractiveness of various policies due to the MVPF's emphasis on welfare criteria and net revenues inclusive of behavioral responses.

Using multiple model simulations, we calculate the WTP in the MVPF numerator and then scale levels by the credit size awarded under the policies. First, we record the change in the value function—the time-discounted utility over the life cycle—of households when they take up a policy versus their stationary equilibrium value functions. This change gives us $\frac{dU_i}{dp_j}$. Next, to numerically approximate marginal utilities of income, we simulate value function changes when households receive a $500 cash transfer.

Table 5 produces the stimulus and MVPF measures for the durable goods subsidies targeting cars and houses and for two levels of unconditional cash transfers. First, note the diverging welfare consequences of the CARS program and the FTHC. The CARS program does not stimulate long-term growth in transactions, though it does lead to medium-term growth. However, the CARS program has an average MVPF of only 0.22 compared to 0.69 for the FTHC. The gap suggests that households who buy under the CARS program have smaller welfare gains than in the FTHC experiment. This result largely reflects the lower welfare gains from marginal households having different degrees of financial constraint.

Next, we note substantial differences in the value of the FTHC when it cannot be applied to the down payment. We contrast the $8,000 tax credit received with a delay to a $3,000 tax credit that can apply to the down payment. The latter credit produces a similar aggregate response, in both total stimulus and welfare terms, to the former, but at less than half the fiscal cost. For households, the value of this policy critically depends on whether the policy relaxes financial constraints.

Interestingly, the FTHC on the down payment does not have that much more of a stimulative effect three years out relative to a much smaller unconditional cash transfer, despite targeting distinct populations. The baseline FTHC generates 8.4% more investment relative to stationary equilibrium levels by then, compared to 10.3% for the $500 unconditional cash transfer. However, the FTHC's larger face value generates a larger response in transactions in the policy period itself, 54% compared to 30% for the $500 transfer. Overall, both durable goods stimulus programs underperform the cash transfer, at least in the absence of unmodeled spillovers to individual utility or net revenue.[19]

The results imply that the cost-effectiveness of policies like the FTHC depends on their targeting. Additional welfare gains and lower net costs, while holding medium-run stimulative effects constant, could arise from redesigning eligibility. An alternative FTHC in 2009 could have awarded more than $8,000, but with a lower threshold on household income and assets.

The histograms in Figure 11 show mean MVPFs mask substantial dispersion in how much different households value these policies. For the CARS policy, marginal buyers make up more of the households who value the policy at relatively low levels. The distribution has minimal mass above an individual MVPF of 0.6, suggesting better targeting cannot improve bang for the buck much above 60 cents on the dollar.

The gains from targeting are greater with the FTHC, where we see inframarginal buyers have less dispersion in MVPF than marginal buyers. Among households who value the credit close to 1, marginal buyers have disproportionate representation. A subsidy schedule which pays little to likely inframarginal household types, but more to types that are marginal, can achieve stimulative targets with a greater mass of policy takers who value the credit close to the level of the cash transfer. Because such a policy would only compensate purchases, its overall cost would also be lower than the unconditional transfer that generated the same amount of aggregate activity.

8 Conclusion

Why do some durable stimulus policies lead to stronger spending effects? We study the economic mechanisms driving divergent empirical findings using a benchmark life-cycle model with incomplete markets and heterogeneous agents. With liquidity constraints and fixed adjustment costs, the standard real-business-cycle intuition that responses should quickly reverse no longer holds. We use the model to reconcile disparate evidence across recent episodes of targeted fiscal stimulus, to investigate how incorporating durable goods affects conclusions

[19]For example, fire sale externalities through house prices of the kind documented in Berger, Turner and Zwick (2020) could push the MVPF for the FTHC above that of a cash transfer. In the case of CARS, if the program delivered a liquidity injection to automakers in a way that kept them from failing, this effect could create both fiscal spillovers and additional welfare terms through saved jobs.

about MPCs, and to rank the relative attractiveness of different policy levers. How income and net worth vary in the cross-section matters for a subsidy's effects on aggregate consumption and welfare. How these subsidies are targeted, in terms of eligibility requirements and implementation, matters for policy efficiency.

One lesson for macroeconomic policy is that policy targeting can have a substantial effect on the efficiency and welfare benefits of a particular program. For a policy like the First-Time Homebuyers Credit, this idea is reflected in the difference between households induced to adjust by the credit versus the higher-net-worth households that would have bought anyway. For the Cash for Clunkers program, it is reflected in the fact that eligibility criteria led to a buyer profile that was older and richer than the general population. In the case of unconditional cash transfers, because large transfers are more likely to help constrained households overcome down payment constraints, the overall MPC declines more slowly with transfer size than in models without durables.

Our model is capable of simulating a variety of temporary subsidies in different settings and show subsidies' dynamic effects on aggregate transactions, durable investment and prices. In one direction, we can evaluate the welfare benefits of proposed government interventions in housing markets, such as a $25,000 grant on down payments (Clow, 2024) or policies to promote housing supply. In another, we can simulate how policy effectiveness changes when coupled with aggregate shocks to interest rates or credit conditions. We hope to study these questions in future work.

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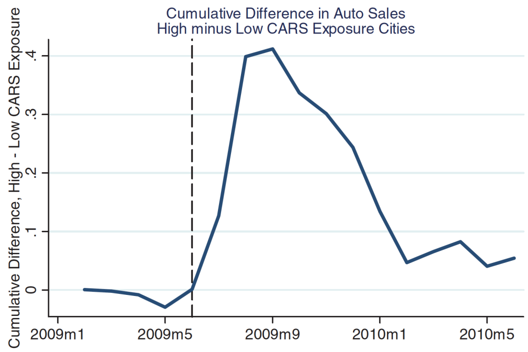
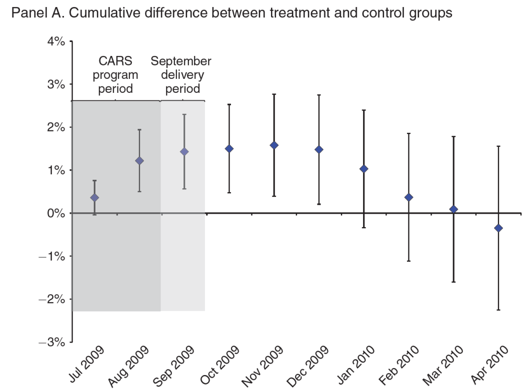
Figure 1: Durable Goods Stimulus Policy Responses from Previous Studies

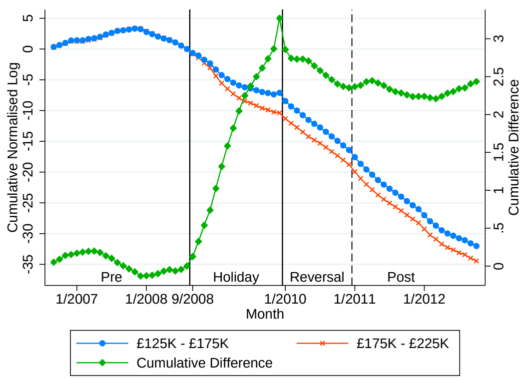
A. Auto Purchase Subsidies



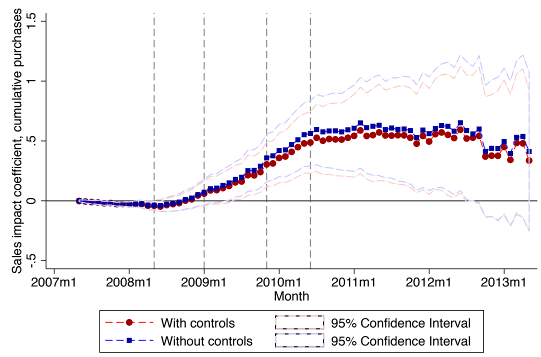


B. Homebuying Subsidies

C: Cumulative Effect

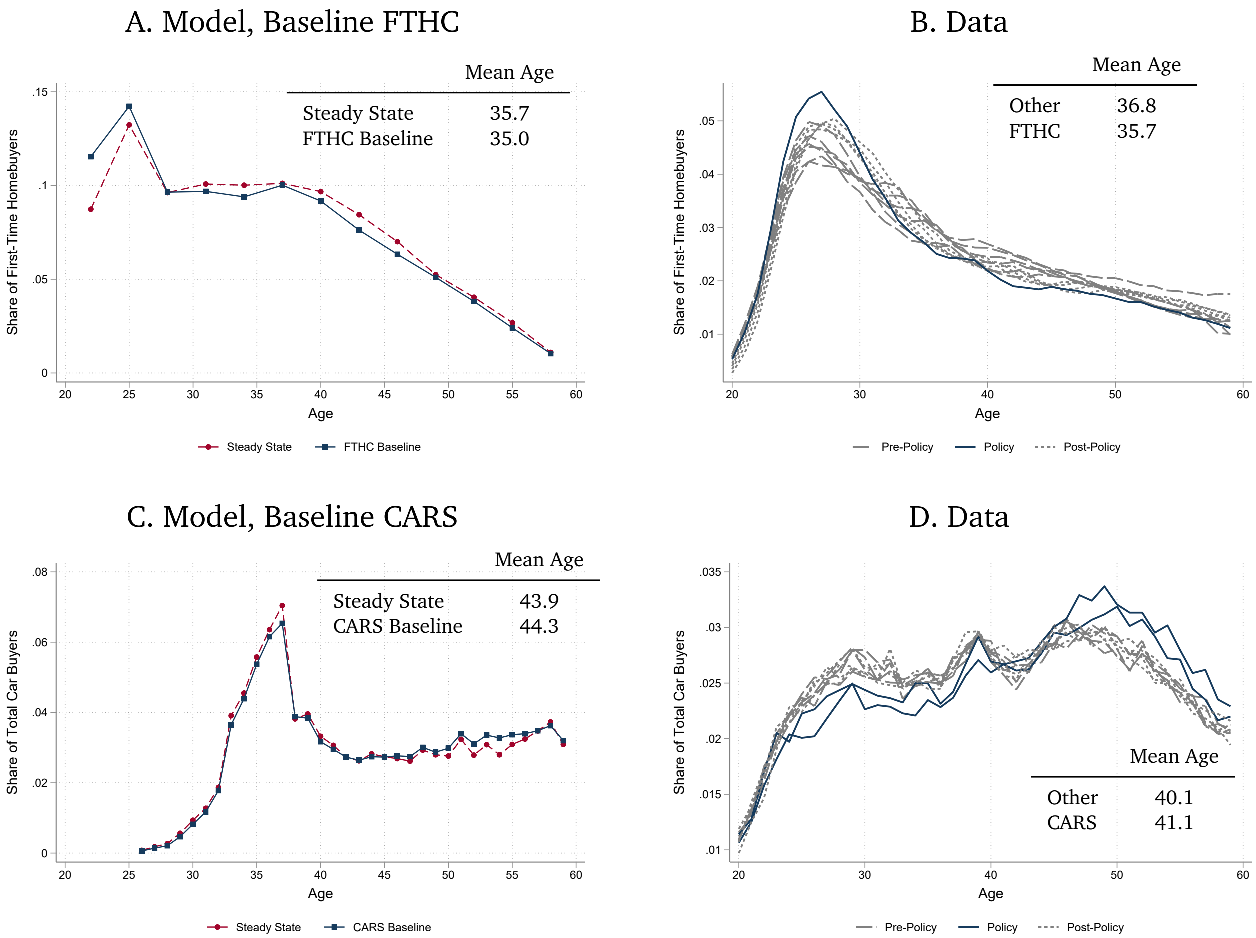


(c) Cumulative ZIP with CBSA Fixed Effects



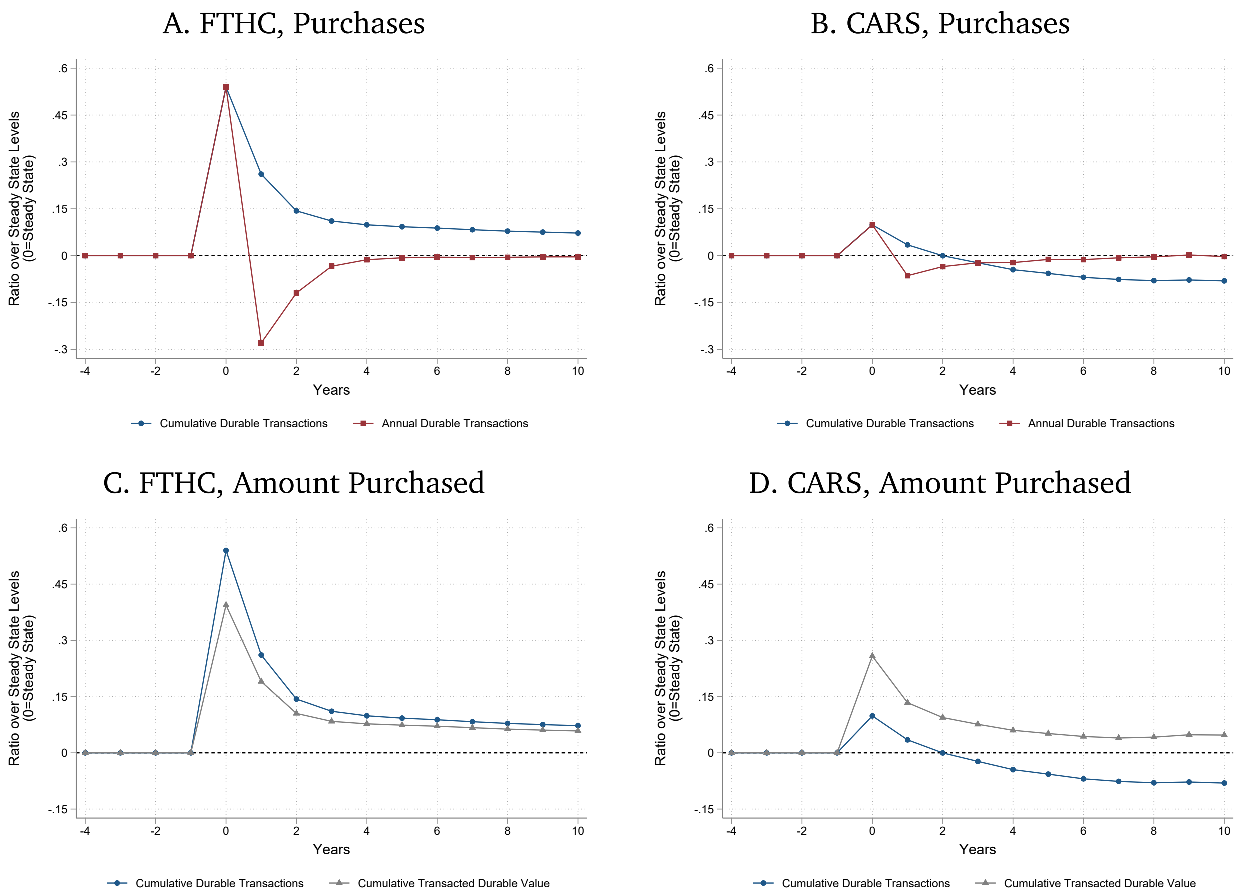
Notes: These figures present cumulative response estimates for different durable goods stimulus policies estimated in prior work. Panel A shows estimates from the Cash for Clunkers program from Mian and Sufi (2012) and Green et al. (2020). Panel B shows estimates from the UK housing transaction tax holiday in Best and Kleven (2017) and from the US First-Time Homebuyers Credit in Berger, Turner and Zwick (2020).

Figure 2: Age Distributions: Model vs. Data



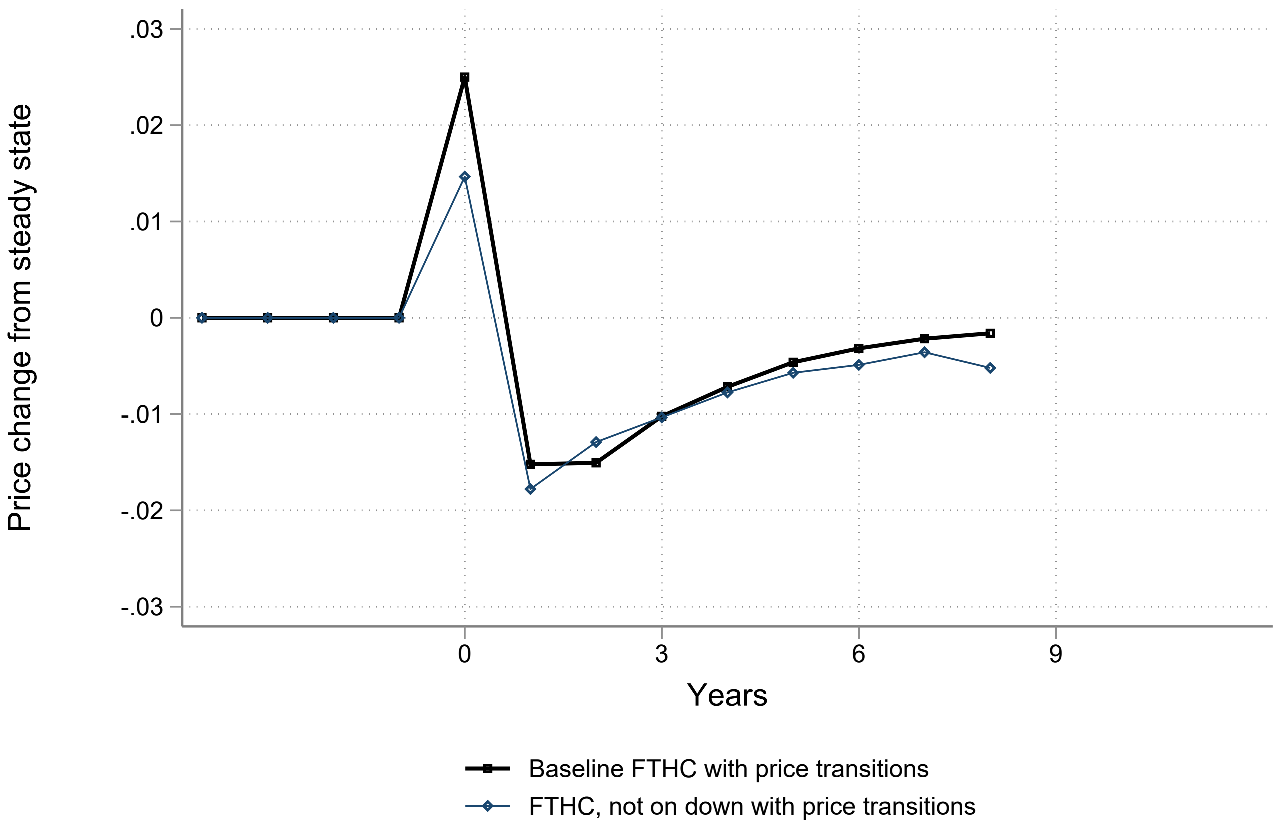
Notes: Panels A and C plot model simulated age distributions of first-time home buyers and repeat car buyers, respectively, when the policy is active. In addition, they plot the distributions in the stationary equilibrium. Panels B and D plot the empirical age distributions when the policy is active, relative to pooled distributions outside the policy period. We use 2010 as a policy year for the FTHC program and July and August 2008 as the policy months for the CARS program. Details on constructing the pooled distributions are in Section 5.1. The FTHB distributions are from Berger, Turner and Zwick (2020) and the CARS distributions are from FRBNY Consumer Credit Panel/Equifax Data.

Figure 3: The Effects of the FTHC and CARS Programs



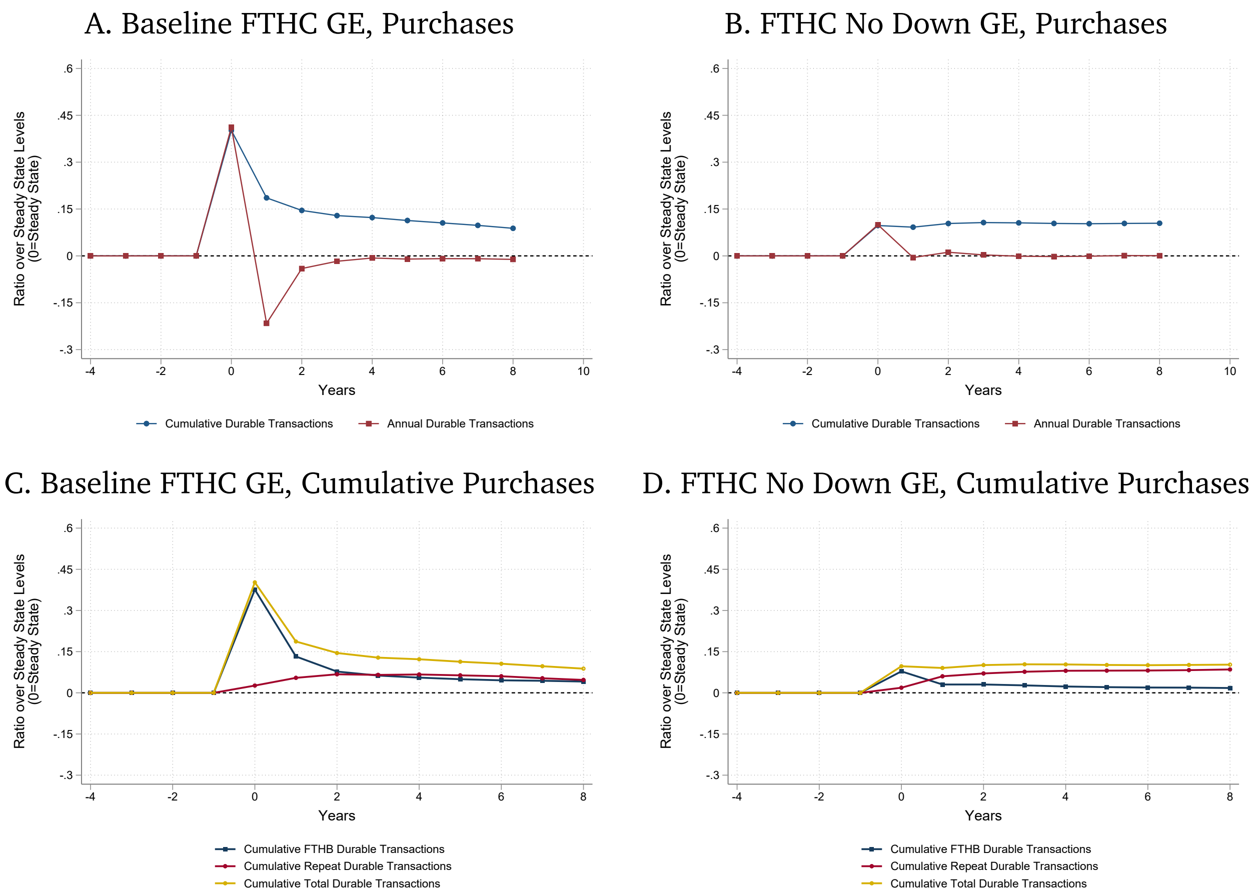
Notes: Panels A and B show the transition path on aggregate transactions of two temporary durable credits. With the CARS Policy and FTHB Credit defined in Section 5.1 offered only in Year 0, the figures compare percentage change of transactions to levels in the stationary equilibrium. Panels C and D plot alongside transactions the market value of durables bought by transacting households. Cumulative series plot the running sum of the annual series.

Figure 4: Price Transition Dynamics



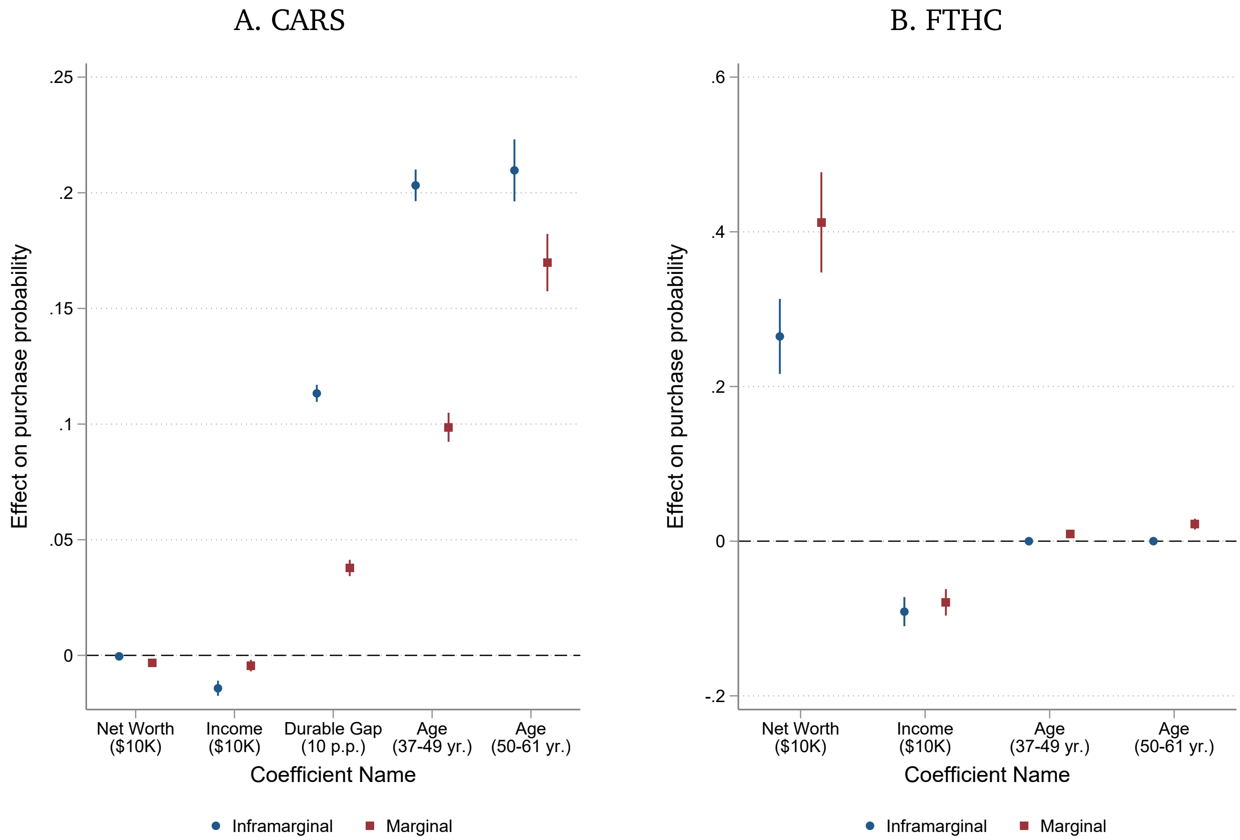
Notes: This figure presents the aggregate price level of housing durables after two kinds of temporary one period durable credits take effect. With both policies, a first-time homebuyer receives $8,000 after buying a house. The difference is in whether the amount can be used on the down payment, or only available as a tax credit after purchase. The policy period is normalized as Year 0 on the graph, and the price level is normalized to the stationary equilibrium price level. Section 6 describes the supply model used to generate these dynamics.

Figure 5: FTHC Program Effects Allowing For Price Dynamics



Notes: Panels A and C show the transition path on aggregate transactions of two temporary durable credits. With both policies, a first-time homebuyer receives $8,000 after buying a house. The difference is in whether the amount can be used on the down payment, or only available as a tax credit after purchase. Panels B and D decompose the transactions dynamics into first-time homebuyers, who are eligible for the policy, and existing homeowners who have perfect foresight on future price dynamics. Cumulative series plot the running sum of the annual series. Section 6 describes the supply model used to generate these dynamics.

Figure 6: Determinants of Durable Purchases and Policy Takeup



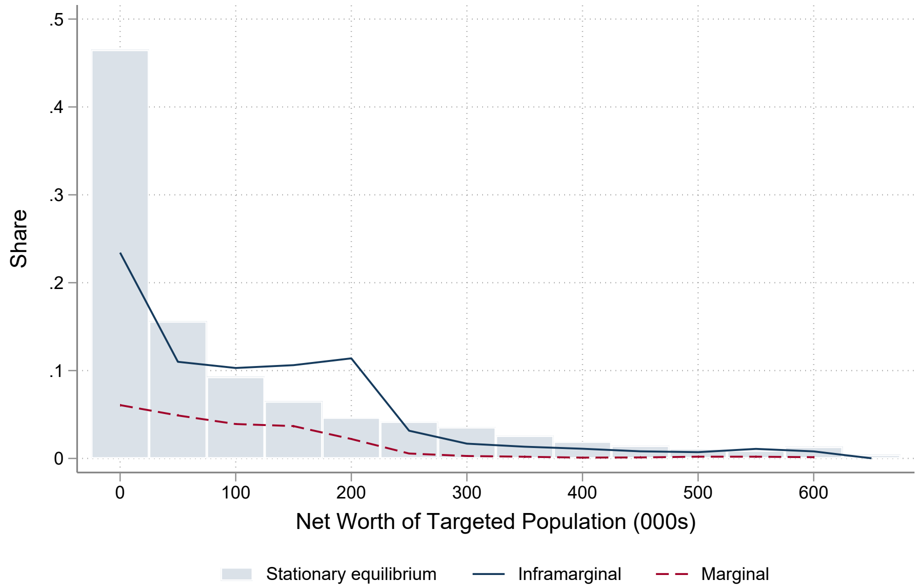
Notes: This figure shows how household heterogeneity determines the probability of purchasing a durable when the two baseline durable credits are in effect. The plotted effects are coefficients from a stacked regression of working-age households simulated in the model, following the equation

$$\text{Status}_{i,model} = \alpha_{model} + Age'_{i,model}\delta^{model} + \mathbf{X}'_{i,model}\beta^{model} + \varepsilon_{i,model},$$

where the outcome is whether a household purchases a durable good in the stationary equilibrium ("Inframarginal") or only when the credit is available ("Marginal"). $Age_{i,model}$ are the two age category dummies, while $\mathbf{X}_{i,model}$ is an interacted secord-order function of assets, income, and the difference between durable value net of depreciation versus its purchase price ("durable gap"). Only the linear, non-interaction terms are plotted. 95% confidence intervals are shown with standard errors clustered at the household level.

Figure 7: Wealth Gaps Among CARS vs. FTHC Marginal Buyers

A. Baseline CARS Policy ($5,000)

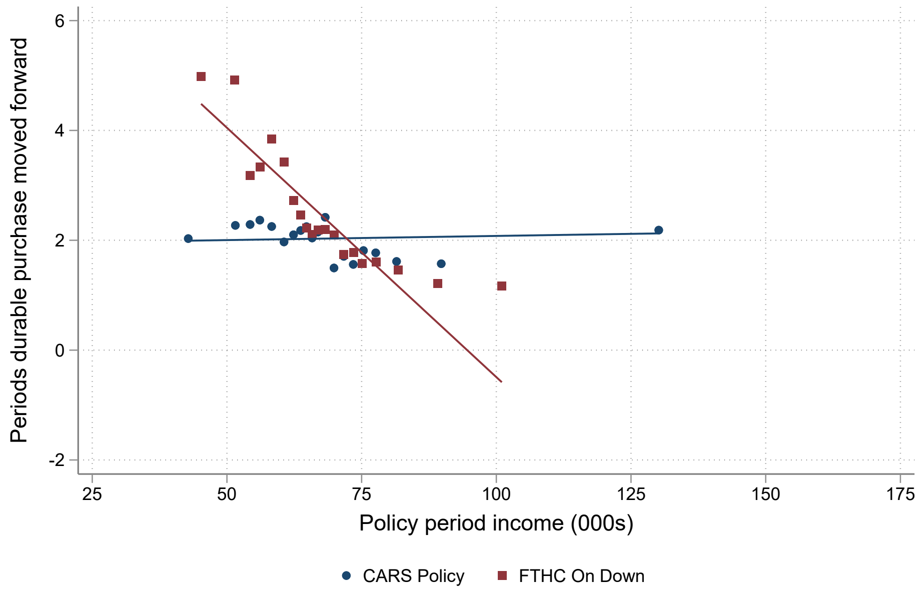


B. Baseline FTHC (On Down, $8,000)

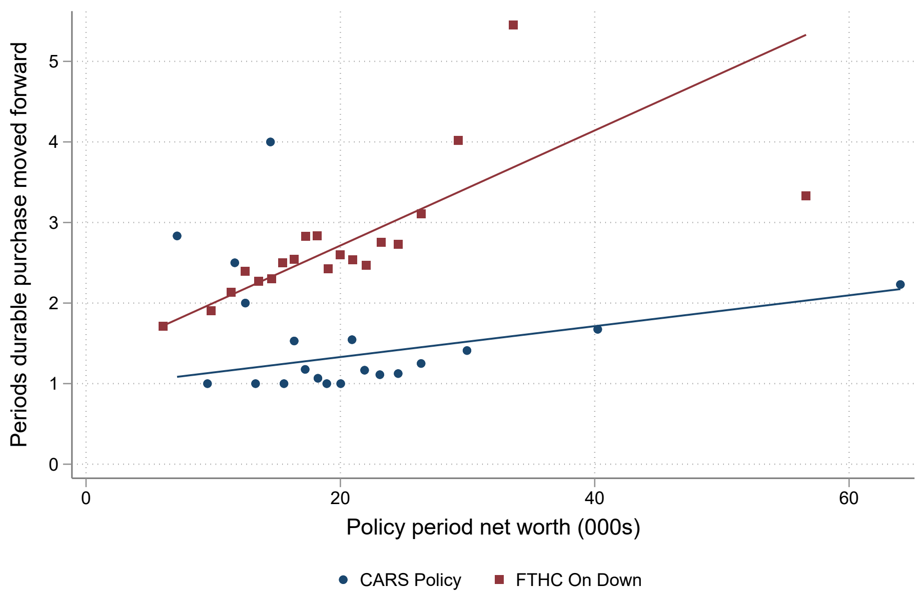
Notes: Each panel shows three separate distributions of net worth for a durable credit and model environment (cars versus houses). The histograms plot the assets distribution in stationary equilibrium across the durable credit's target population: car owners and renters. The linear distributions plot the same variable on the subpopulations of inframarginal and marginal buyers in the policy periods. The buyer distributions in each panel are rescaled: the sum of the areas beneath the functions is what sums to 1. In Panel B, we omit the 71% of renters who have financial assets less than $4,000.

Figure 8: Intertemporal Substitution by Income and Net Worth

A. Substitution by Income



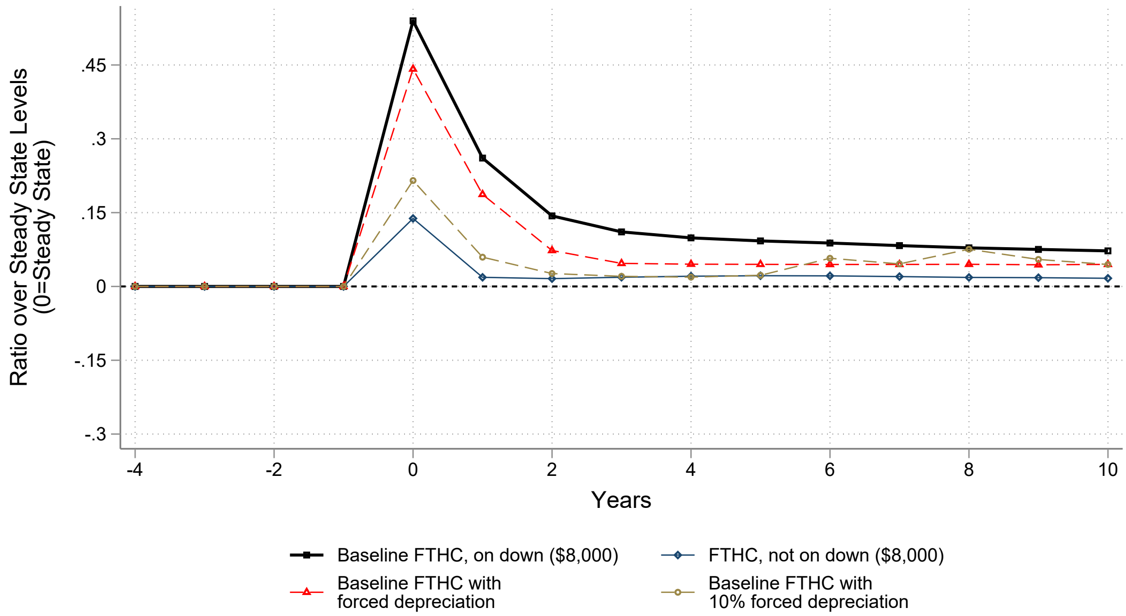
B. Substitution by Net Worth



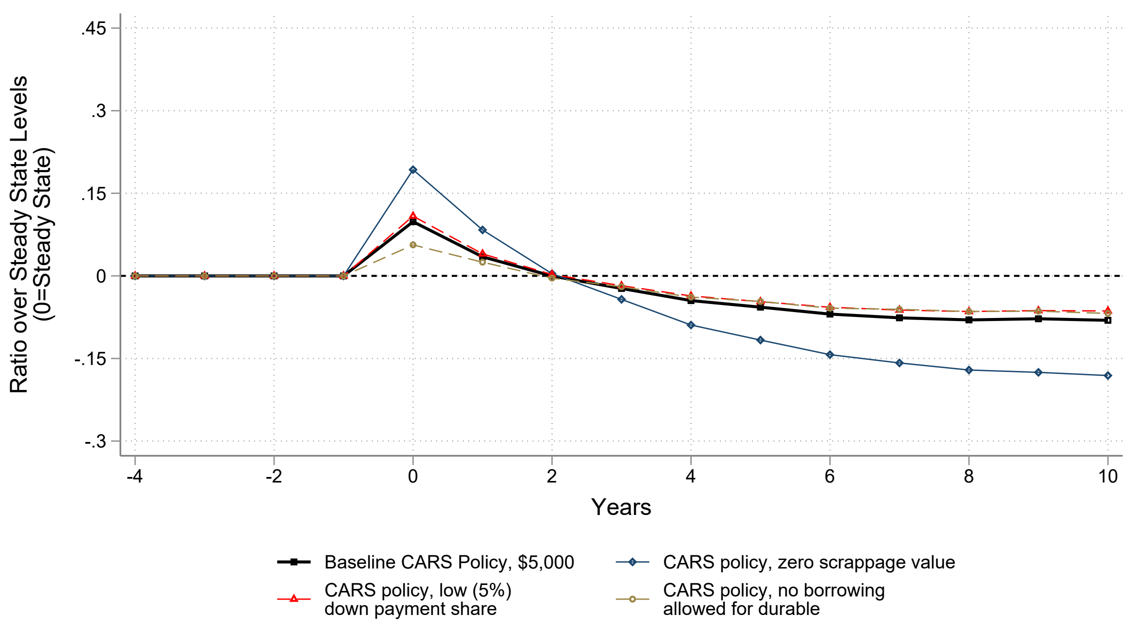
Notes: In these figures, we restrict to marginal buyers in the model during policy periods. We recover how many years older they would be when they make their next durable transaction in the stationary equilibrium counterfactual, under the same income shocks. This difference are the years the purchase were "moved forward." We plot binned scatterplots and linear trends in years moved forward between the two baseline durable credits, based on the marginal buyer's net worth and household income at time of purchase.

Figure 9: Counterfactual Environments and the Effect on Cumulative Durable Transactions

A. Alternative FTHC Models



B. Alternative CARS Models

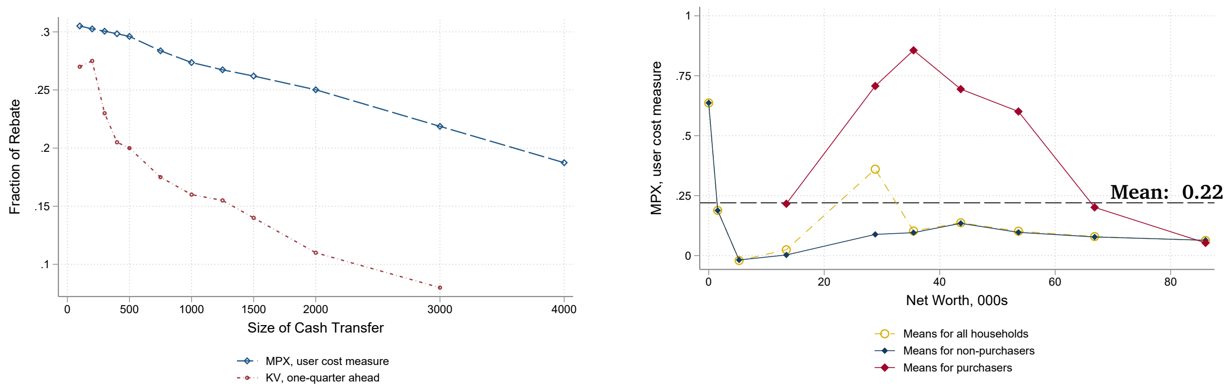


Notes: Each panel compares aggregate transaction dynamics of the baseline durable credits with results when model features are modified. In Panel A, the bolded dynamics are compared with the "not on down" credit, given only in the year after purchase. It is also compared with counterfactuals where the house is forced to depreciate at 2.2% or 10%, respectively. In Panel B, the bolded baseline dynamics are compared with results when the scrappage value and required down payment shares are changed. Ratios are taken with respect to stationary equilibrium levels in the modified model environments. However, market clearing prices are not recomputed for the modified cases.

Figure 10: Variation in Marginal Propensities of Expenditure (MPX)

A. MPX across stimulus sizes

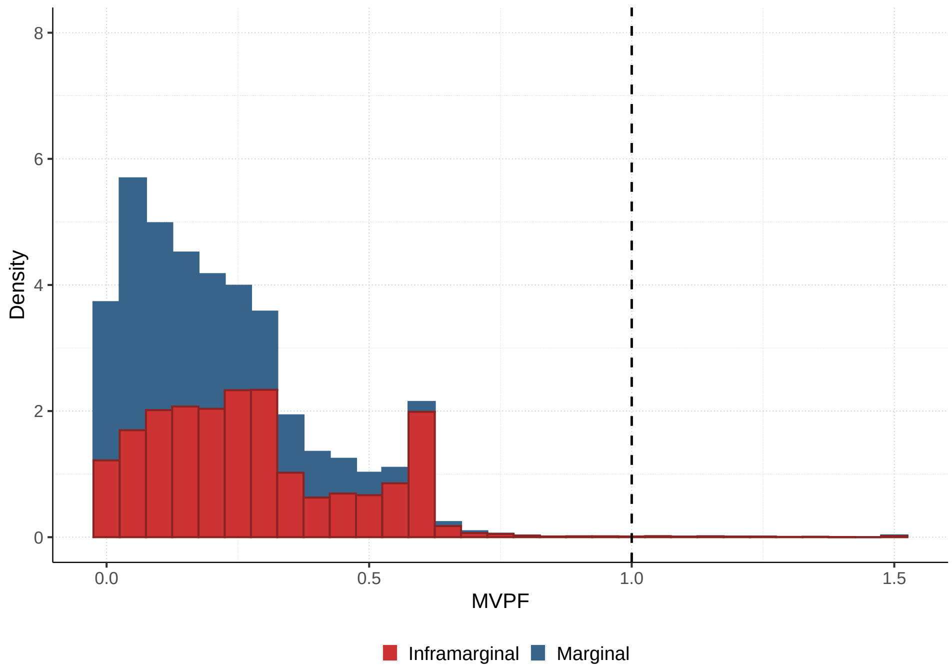
B. Heterogeneity in response to $3,000 credit



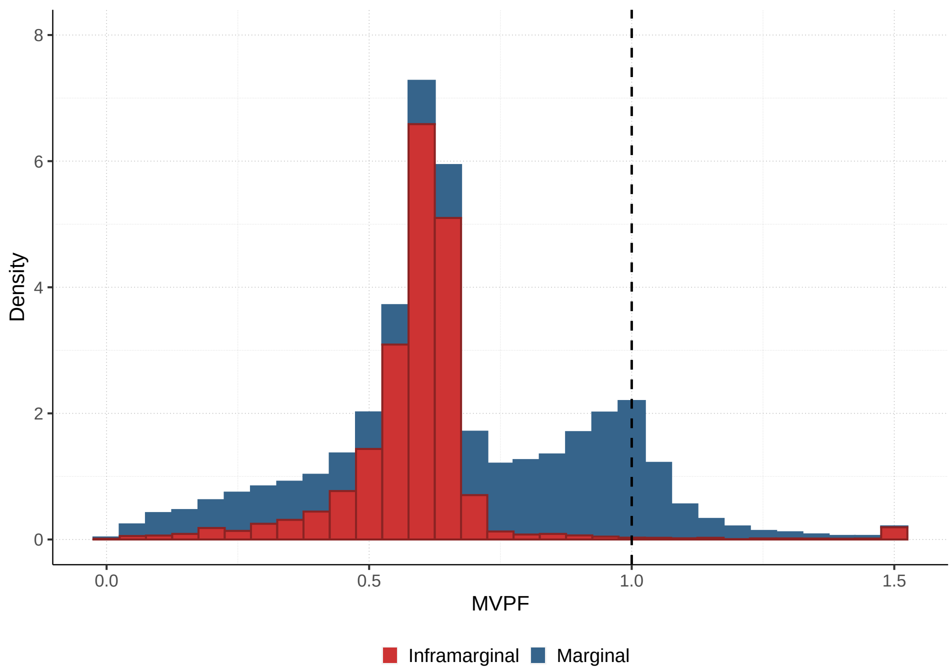
Notes: Both panels plot levels of the MPX within the model, where expenditure follows the definition in (Laibson et. al. 2023) that accounts for nondurables plus the user cost of durables. Panel A plots the mean MPX across all households change in our model as the value of an unconditonal cash transfer grows. Levels are compared with the MPC values produced in Kaplan and Violante, 2014. Panel B plots the cross-section of MPX responses from the $3,000 credit. Over all households, as well as subgroups of housing purchasers and non-purchasers, we bin net worth levels separately and plot binned means of the MPX.

Figure 11: Distributions of Marginal Value of Public Funds For Policies

A. Baseline CARS Policy ($5,000)



B. Baseline FTHC (On Down, $8,000)



Notes: Each figure is a stacked histogram over fixed width bins, visualizing heterogeneity in policy MVPFs across households. We highlight, for each durable credit, the MVPF distribution for only inframarginal buyers versus marginal buyers. Section 7.2 describes MVPF construction and our approximation of households' money metric valuations for the durable credits. Small unconditional cash transfers under our calculation yield MVPFs of 1, a level we highlight in both panels.

Table 1: A Simple Example of Durable Goods Stimulus

Period	t	t+1	t+2	t+3	t+4
Cars, Baseline	1	1	1	1	1
Cars, Stimulus	2	0	1	1	1
Houses, Baseline	1	1	1	1	1
Houses, Stimulus	2	0	1	1	1

Table 2: External Parameters

Variable	Symbol	Value	Source
Preferences			
Expenditure share of housing	$1-\alpha$	0.241	DO-M (2011)
Endowments			
Deterministic income	$\chi(j)$	SCF means	SCF
Income persistence	ρ_z	0.920	PSID sample
Income innovations	σ_z	0.160	PSID sample
Annualized moving probability	P	2.2%	CPS sample, FKS (2015)
Age 22 income distribution		Fit on SCF data	
Housing/Finance			
Depreciation of housing	δ	2.2%	BGLV (2018)
Down payment	θ	20%	Conventional
Selling transaction cost	κ	6%	BGLV (2018)
Annual real interest rate	r	2.4%	FKS (2015)
Mortgage premium	m	0.8%	FKS (2015)
Government			
Tax progressivity parameter	τ_y	0.15	KMV (2020)
Tax scaling parameter	τ_0	0.167	20% tax on income
Property tax on housing	τ_h	1%	KMV (2020)

Table 3: Calibrated Parameters

Parameter	Moment	Calibrating	Value	Model	Data
Preferences					
Discount factor	Net worth ratio, workers	β	0.947	0.899	0.900
Bequest preferences	Homeownership rate, retirees	Ψ	0.400	0.871	0.813
Risk aversion (1/EIS)	Share of ages 31-40 FTHBs	γ	3.330	0.115	0.092
Housing/Secondary Market					
Rental premium	Homeownership rate, workers	ϕ	3.75%	0.626	0.622
Maximum rental size	Ratio of homeowner to renter incomes	$\overline{R}$	$ 170K	1.824	2.036
Minimum durable size	Share of ages 22-24 FTHBs	$\underline{D}$	$ 140K	0.089	0.078
Minimum durable size	Share of ages 25-30 FTHBs	$\underline{D}$	$ 140K	0.119	0.131
Transaction cost scale for renter buyers	Renter-to-Owner transition rate	F	0.161	0.062	0.054
Transaction cost scale for owner buyers	Share of FTHBs over all transactions	F^{rpt}	0.055	0.444	0.400
Buyer transaction cost shape	FTHC policy semielasticity	χ	1.210	1.215	0.600

Table 4: Wealth Distribution in the Model and Data

	Model	Data		Model	Data
Net Fin Assets, Owners			**Net Fin Assets, Renters**		
10th Percentile	-1.48	-2.99	10th Percentile	0.00	0.00
25th Percentile	-1.26	-1.92	25th Percentile	0.00	0.00
50th Percentile	-0.67	-0.97	50th Percentile	0.00	0.01
75th Percentile	0.48	-0.09	75th Percentile	0.087	0.06
90th Percentile	2.28	0.23	90th Percentile	0.26	0.27
Net Worth, Owners			**Net Worth, Renters**		
10th Percentile	0.56	0.31	10th Percentile	0.00	0.00
25th Percentile	0.86	0.75	25th Percentile	0.00	0.00
50th Percentile	1.85	1.79	50th Percentile	0.00	0.03
75th Percentile	3.70	3.71	75th Percentile	0.087	0.24
90th Percentile	6.02	6.41	90th Percentile	0.26	0.88

Notes: All values are normalized by mean incomes in model simulations and SCF data, respectively.

Table 5: Stimulus and Welfare Effects Across Durable Subsidies

	Policy period	3 years post		
	Transaction growth	Cumulative transactions	Cumulative investment	Mean MVPF
Baseline CARS policy, $5,000	9.9%	-1.8%	7.8%	0.22
Baseline FTHC, $8,000	54.0%	11.1%	8.4%	0.69
FTHC not on down payment, $8,000	13.8%	1.9%	1.7%	0.54
FTHC on down payment, $3,000	17.5%	1.9%	1.5%	0.57
Unconditional cash transfer, $500	29.9%	9.4%	10.3%	1.02
Unconditional cash transfer, $1,000	69.6%	32.0%	35.4%	1.07

Notes: This table plots aggregate statistics across multiple durable subsidies, simulated in the model. All policies are temporary and active for one period only. Growth rates are percentage changes to levels in the stationary equilibrium, and cumulative levels are running sums of past annual growth rates. MVPFs are aggregated over all policy takers and constructed as in Section 7.2. The MVPF means are trimmed, keeping households with values between the 1st and 99th percentiles.

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A Computational Appendix

Household problems. Every period, households decide whether to rent a durable, adjust their durable holdings or not adjust the durables they own. Denote P, P' as current and future housing price levels, as equilibrium prices is the one aggregate state that can vary in the model. Given state vector $\mathbf{s} \equiv (A, D, z, j)$, the value function is

$$\mathbf{V}(\mathbf{s}; P) = \max\left\{V^{adjust}(\mathbf{s}; P),\ V^{noadj}(\mathbf{s}; P),\ V^{rent}(\mathbf{s}; P)\right\}$$

The respective subproblems are:

$$\begin{aligned}
V^{adjust}(\mathbf{s}; P) = &\max_{C, A', D'} U(C, D') + \beta E\left[V(\mathbf{s}'; P') \mid z\right] \\
s.t. \quad & C + A' + PD' = Y(z, j) - \mathbf{T}(z, j) - ADJ(D', D) + (1 + \tilde{r})A + (1 - \delta)PD, \\
& A' \geq -(1 - \theta)\frac{1 - \delta}{1 + r}PD', \\
& D' \geq \underline{D}, \\
& \tilde{r} = r + m\mathbf{1}[A' < 0], \\
& \mathbf{s}' = (A', D', z', j + 1).
\end{aligned}$$

$$\begin{aligned}
V^{noadj}(\mathbf{s}; P) = &\max_{C, A'} U(C, D) + \beta E\left[V(\mathbf{s}'; P') \mid z\right] \\
s.t. \quad & C + A' + \delta PD = Y(z, j) - \mathbf{T}(z, j) + (1 + \tilde{r})A, \\
& A' \geq -(1 - \theta)\frac{1 - \delta}{1 + r}PD, \\
& D \geq \underline{D}, \\
& \tilde{r} = r + m\mathbf{1}[A' < 0], \\
& \mathbf{s}' = (A', D, z', j + 1).
\end{aligned}$$

$$\begin{aligned}
V^{rent}(\mathbf{s}; P) = &\max_{C, \tilde{D}, A'} U(C, \tilde{D}) + \beta E\left[V(\mathbf{s}'; P') \mid z\right] \\
s.t. \quad & C + A' + \varphi P\tilde{D} = Y(z, j) - \mathbf{T}(z, j) + ADJ(0, D) + (1 + \tilde{r})A + (1 - \delta)PD, \\
& A' \geq 0, \tilde{D} \leq \overline{R}, \\
& \tilde{r} = r + m\mathbf{1}[A' < 0], \\
& \mathbf{s}' = (A', 0, z', j + 1).
\end{aligned}$$

Some special cases are worth noting:

- In the last period of life, the continuation term $\beta E[V(\mathbf{s}'; P')|z]$ is replaced with the bequest term $\beta B(\tilde{W})$ as defined in Section 3.1.
- For experiments where durable depreciation is mandatory, the V^{noadj} problem is altered to remove the δPD term, and the D term in $\mathbf{s}'$ is replaced with $(1-\delta)D$.
- For experiments where durables are scrapped instead of sold, all PH terms in the budget constraint for the adjustment and rent problems are replaced with a fixed constant.

To simplify the liquidity constraint on owned durables, we follow the procedure in Diaz and Luengo-Prado (2008) and instead use the voluntary equity state variable, $Q \equiv A+(1-\theta)\frac{1-\delta}{1+r}PD$. The liquidity constraint is therefore $Q' \geq 0$ in all subproblems. We note that due to changes in house prices, the existing Q of a household could be negative. We therefore also solve the model for certain negative values of Q, as low as $Q = -\frac{0.4}{1+r}$.

Discretized state space. We solve the dynamic programming problem through backward recursion using a 75 point grid for Q and a 35 point grid for D. We concentrate the grid points towards values close to 0 for the Q grid, and values close to the minimum house size $\underline{D}$ for the D grid. For income, we discretize 25 points that span the logged values of the AR(1) process. Because our process is persistent, we discretize the process into a Markov chain using the method in Rouwenhorst (1995) and Kopecky and Suen (2010).

Simulating the model forward then involves linear interpolation between the choice variables, either just Q or also including D', of the value and policy functions.

Parametrizing initial state space distributions. We describe the details behind the initial income and wealth distributions mentioned in Section 4.1. With the initial income state distribution $F(z)$, we first filter the data for households headed by young people to only those earning less than $87,500, in US dollars.[20] The equation $\exp(\overline{z} + \chi(1)) = 87.5K$ implicitly defines an upper bound $\overline{z}$ over initial income states.

Then, we scale all incomes by the $87,500 cap to create income ratios in $[0,1]$. With the distribution's support bounded this way, we fit a beta distribution to the sample. To each point on the logged income grid z, we can then calculate the CDFs $F(\exp(z)/\exp(\overline{z}))$ to get a parametrized distribution of initial income states, onto which we rescale with the fixed effect $\chi(1)$. The result is that the initial income distribution in the model for age 22 households has a mean of $44K and a standard deviation of $19K.[21]

Over the young head of household sample, we then divide the sample into bins separated at terciles of the income distribution. Over each income bin, we construct voluntary equity measures in the data and then fit separate gamma distributions over the measure. We also generate homeownership rates for each bin by taking a sample-wide homeownership rate of 13.5%, then shrinking the rate based on how many households have reported house values

[20] Doing so still keeps 92.7% of our sample.

[21] By construction, without age fixed effects, the mean income of households at the stationary distribution would be $67K. The simulated mean, which includes age fixed effects, is $71K.

lower than the calibrated minimum house size. As a result, 6% of households in our calibrated model choose to own at age 22, a rate that quickly grows to 19% by age 25.

Solving for stationary equilibrium. Our baseline calibration satisfies conditions for a stationary equilibrium, where $P = P'$ and new construction markets clear. The market-clearing price P is solved in a root finding procedure that iterates between the dynamic programming and model simulation steps. The dynamic programming step uses derivative-free numeric methods to find the policy functions in each subproblem.[22] After each simulation, we calculate excess housing demand at the price level we guessed.

All of our simulations were produced from Fortran code compiled by `gfortran`, executed on an 8-core node on the Duke Computing Cluster.

[22]For the non-adjustment problem, there is one policy function and we use the golden search method. For all others, there are two policy functions and we use the Nelder-Mead algorithm.

B Calibration with Price Transitions

We extend our baseline calibration, which matches key moments of the US housing market ahead of the 2005-9 housing bubble and crash, to also match the reduced-form price effect of the 2009 FTHB Tax Credit. The price effect disciplines the additional parameter ϵ, the supply elasticity of newly constructed units.

Appendix Tables B.1 and B.2 are analogous versions of Tables 3 and 4, but based on the alternative calibration and also includes ϵ. Both tables show how both targeted and untargeted model moments in the new calibration fit with the data.

Allowing for some change in the discount rate β and the size of transaction costs relative to the baseline calibration, the targeted moments in the calibration remain close to what is found in the data. Compared to the targeted price moment of 2.4%, our calibration produces a price moment of 2.5%. Wealth distributions in Table B.2 also remain similar to the quantiles we found in the baseline calibration.

Our estimate of the new construction elasticity ϵ matches microeconometric estimates from that time frame, even if new housing development rates have declined in the following years. Baum-Snow and Han (2024) leverage cross-sectional variation in neighborhood demand in the 2000s to estimate housing supply elasticities at granular geographies. They find that the median elasticity of new residential floorspace on undeveloped land is 3.2. This is close to our calibrated value of $\epsilon = 3.3$, as floorspace is a closer parallel to housing services in our model than housing units.

Table B.1: Calibrated Parameters, GE version

Parameter	Moment	Calibrating	Value	Model	Data
Preferences					
Discount factor	Net worth ratio, workers	β	0.938	0.914	0.900
Bequest preferences	Homeownership rate, retirees	Ψ	0.400	0.915	0.813
Risk aversion (1/EIS)	Share of ages 31-40 FTHBs	γ	3.330	0.116	0.092
Housing/Secondary Market					
Rental premium	Homeownership rate, workers	ϕ	5.25%	0.621	0.622
Maximum rental size	Ratio of homeowner to renter incomes	$\overline{R}$	$ 190K	1.808	2.036
Minimum durable size	Share of ages 22-24 FTHBs	$\underline{D}$	$ 140K	0.079	0.078
Minimum durable size	Share of ages 25-30 FTHBs	$\underline{D}$	$ 140K	0.115	0.131
Transaction cost scale for renter buyers	Renter-to-Owner transition rate	F	0.217	0.060	0.054
Transaction cost scale for owner buyers	Share of FTHBs over all transactions	F^{rpt}	0.053	0.393	0.400
Buyer transaction cost shape	FTHC policy semielasticity	χ	1.180	0.899	0.600
Housing supply elasticity	FTHC price response	ϵ	3.340	0.026	0.024

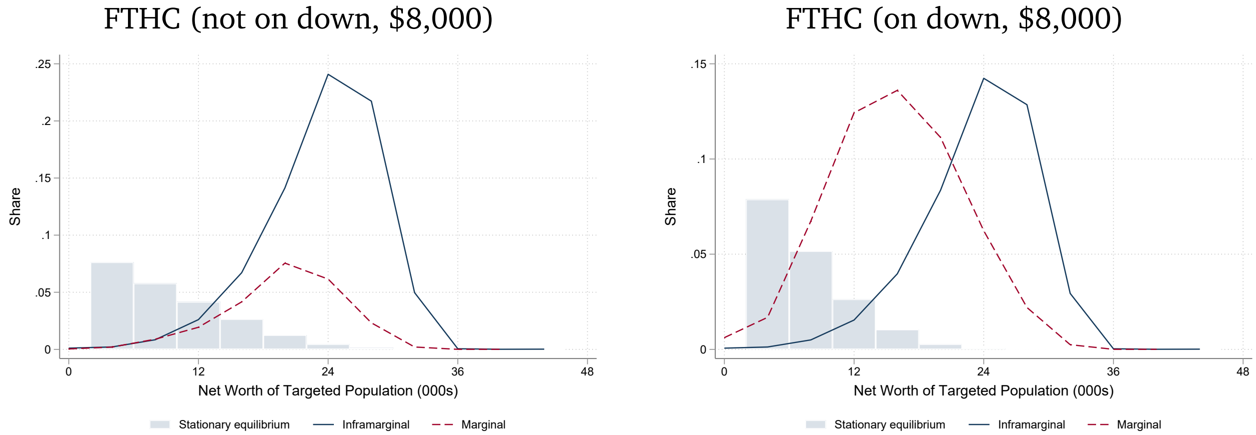
Table B.2: Wealth Distribution in the Model and Data, GE version

	Model	Data		Model	Data
Net Fin Assets, Owners			**Net Fin Assets, Renters**		
10th Percentile	-2.02	-2.99	10th Percentile	0.00	0.00
25th Percentile	-1.54	-1.92	25th Percentile	0.00	0.00
50th Percentile	-1.05	-0.97	50th Percentile	0.00	0.01
75th Percentile	0.46	-0.09	75th Percentile	0.075	0.06
90th Percentile	2.37	0.23	90th Percentile	0.27	0.27
Net Worth, Owners			**Net Worth, Renters**		
10th Percentile	0.57	0.31	10th Percentile	0.00	0.00
25th Percentile	0.85	0.75	25th Percentile	0.00	0.00
50th Percentile	1.82	1.79	50th Percentile	0.00	0.03
75th Percentile	3.81	3.71	75th Percentile	0.075	0.24
90th Percentile	6.32	6.41	90th Percentile	0.27	0.88

Notes: All values are normalized by mean incomes in model simulations and SCF data, respectively.

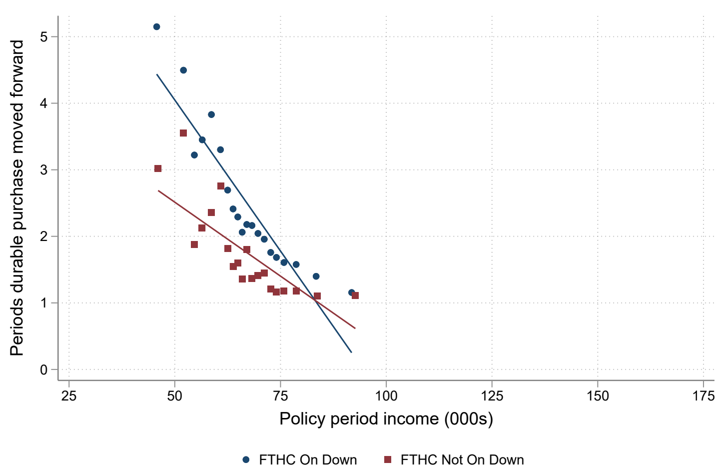
C Appendix Figures

Figure C.1: Marginal Buyer Traits FTHC On Down vs. FTHC Not On Down



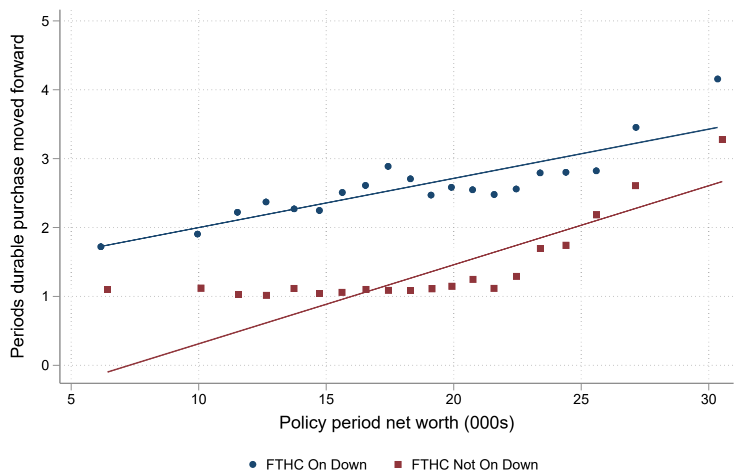
Notes: This figure shows the share of inframarginal vs. marginal buyers in each asset category for the Baseline FTHC On Down Policy vs. the Not On Down Policy. It also includes the stationary equilibrium for buyers who are neither marginal nor inframarginal. In both panels, the financial assets are binned into groups of four. Panel B shows that the FTHC On Down Policy has a strong effect on the marginal buyer. In Panels A and B, we omit the stationary equilibrium share for the financial asset bin from zero to four. This share is 0.57 for FTHC Not On Down and 0.62 for FTHC On Down.

Figure C.2: Income Pull-Forward Binscatter FTHC On Down vs. FTHC Not On Down



Notes: This figure shows the correlation between income and pulling durable purchases further from the future due to the FTHC On Down vs. FTHC Not on Down Policies. This figure shows that individuals with higher income are less likely to push forward housing purchases to future periods for each respective FTHC policy.

Figure C.3: Net Worth Pull-Forward Binscatter for FTHC On Down vs. FTHC Not on Down



Notes: This figure shows the correlation between existing assets and loans and pulling durable purchases further from the future due to the FTHC On Down vs. FTHC Not on Down Policies. This figure shows that individuals with higher assets are more likely to push forward housing purchases to future periods for each respective FTHC policy. The correlation appears stronger/more pronounced in the case of the FTHC not on down policy.