Durables and Size-dependence in the Marginal Propensity to Spend*

Martin Beraja — MIT and NBER

Nathan Zorzi — Dartmouth

September 12, 2023

Abstract

Stimulus checks have become an increasingly important policy tool in recent U.S. recessions. How does the marginal propensity to spend (MPC) vary with the size of stimulus checks? To quantify the size-dependence in the MPC, we augment a canonical model of durable spending by introducing a smooth adjustment hazard. We discipline the shape of this hazard by matching the micro-evidence on (i) the relative MPCs of durables and non-durables; (ii) the short-run price elasticity of durables; (iii) the size distribution of adjustments; and (iv) the conditional probability of adjustment since the last purchase. We find that the MPC declines slowly with the size of stimulus checks. The MPCs in our model lie in between those of canonical models of non-durables and durables spending, both in terms of levels and size-dependence. Finally, we embed our spending model into a heterogenous-agent New-Keynesian model to evaluate the effect of stimulus checks in general equilibrium. In a typical recession, the stimulus check that fully closes the output gap is half as large compared to a canonical model of non-durables with the same MPC out of a small transfer.

*Martin Beraja: maberaja@mit.edu. Nathan Zorzi: Nathan.G.Zorzi@dartmouth.edu. We thank Adrien Auclert, Isaac Baley, Andres Blanco, David Berger, Corina Boar, Ricardo Caballero, Greg Kaplan, Andrea Lanteri, Benjamin Moll, Gianluca Violante, Johannes Wieland, Tom Winberry and Christian Wolf for helpful discussions.

1 Introduction

Stimulus checks have become an increasingly important policy tool in recent U.S. recessions. The average household received a tax rebate of \$300 in 2001 and \$600 in 2008 when eligible, and an economic impact payment of $\$2,000$ in 2020–2021. The government relied on these stimulus checks to boost spending and narrow the output gap in each of these recessions. Yet, we know surprisingly little about the effectiveness of checks as they become larger. A \$2,000 check could be barely more effective than a \$600 check if households spend less and less of each additional dollar they receive.

How does the marginal propensity to spend (MPC) vary with the size of stimulus checks?[1] Measuring the *size-dependence* in the MPC empirically is challenging.[2] The few available studies find a wide range of estimates: the MPC can be decreasing (Coibion et al., 2020), essentially flat (Sahm et al., 2012), or even increasing (Fuster et al., 2021). State-of-the-art models predict that the marginal propensity to spend in non-durables falls rapidly with the size of stimulus checks (Kaplan and Violante, 2014). The relevant quantity for the question of interest is total household spending, however, including durables. Indeed, durable spending represents a large share of the MPC of total spending (Souleles, 1999; Parker et al., 2013). It has been conjectured that durable purchases could become more responsive as checks become larger (Fuster et al., 2021), both because durables are lumpy (Bertola and Caballero, 1990; Eberly, 1994) and can be financed by making a down payment (Attanasio et al., 2008).

To quantify the size-dependence in the MPC, we augment a canonical incomplete-markets model of lumpy durable spending (e.g., Berger and Vavra, 2015) by allowing for time-dependent adjustments in a flexible way. Households are subject to linearly additive taste shocks for adjustments (McFadden, 1973; Artuç et al., 2010) whose variance controls the degree of time-dependence in adjustment. This specification delivers a smoother adjustment hazard than the typical (s, S) bands produced by the canonical model (where adjustment is purely state-dependent). In turn, the model can generate a decreasing, flat,

[1] We use the term "marginal propensity to spend" (MPC) to refer to the average spending response divided by the size of the check. The empirical counterpart of this object is what Kaplan and Violante (2014) refers to as the "rebate coefficient." The MPC includes spending in non-durables and durables. The response of durable spending is sometimes called the "marginal propensity to invest" (MPX) as in Laibson et al. (2022).

[2] The MPC is notoriously difficult to estimate even in *levels*. Part of the reason is that the MPC varies with the state of the business cycle (Gross et al., 2020), the depth of the recession, what agents expect about the recovery, etc. Estimating the size-dependence in the MPC is even more challenging, since we do not directly observe multiple checks of different sizes for the *same* household at the *same* point in the business cycle. Lottery gains are typically much larger than the size of stimulus checks observed so far (Fagereng et al., 2021; Golosov et al., 2021).

or increasing MPC, depending on how steep the adjustment hazard is. We also assume that households must make a down payment in cash to purchase a durable, and can use credit to borrow the rest subject to an LTV constraint.[3]

We discipline the shape of the hazard by matching four pieces of micro evidence that a purely state-dependent or time-dependent model cannot replicate jointly. In particular, our model (i) matches the evidence on the relative marginal propensity to spend on durables and non-durables; (ii) generates a realistic short-run price elasticity; (iii) replicates the size distribution of adjustments in the data; and (iv) matches the empirical probability of adjustment as a function of the time passed since the last adjustment, which is central to the response to shocks in fixed cost models (Alvarez et al., 2016b). The calibrated model also matches several additional moments well; for example, the MPC out of small income shocks in Fagereng et al. (2021), the fraction of hand-to-mouth agents in Aguiar et al. (2020), and the skewed distribution of MPCs (with many above 1) in Misra and Surico (2014) and Lewis et al. (2019).

We find that the MPC declines slowly with the size of stimulus checks. The MPC is around 0.45 out of a \$100 check, 0.4 out of a \$1000 check, and 0.35 out of a \$2000 check; in line with the evidence of Sahm et al. (2012) and Coibion et al. (2020). The MPCs in our model lie in between those of canonical models of non-durables and durables spending, both in terms of levels and size-dependence. A canonical non-durables model (Kaplan and Violante, 2014) produces smaller MPCs which decline much more rapidly, whereas a version of our model with only state-dependent adjustments of durables (as in Berger and Vavra (2014), for example) produces much larger MPCs which increase at first and then decline.

The *extensive* margin of durable adjustment plays an important role in this result. As stimulus checks become larger, a proportionately larger and larger share of households adjust its stock of durables, which is consistent with survey evidence (Fuster et al., 2021). This effect offsets the usual precautionary savings motive (Carroll and Kimball, 1996) at the *intensive* margin which contributes to a rapidly decreasing marginal propensity to spend in non-durables models. Yet, the extensive margin is more muted in our model than in purely state-dependent durables models: our calibration implies some degree of time-dependence. In turn, the marginal propensity to spend on durables is both lower compared such models and never increases with the size of stimulus checks.

[3] Down payments are an important feature of durable goods purchases in practice (Argyle et al., 2020), and are key to understand the response of durable purchases to shocks (Jose Luengo-Prado, 2006). Our specification implies that households cannot continously refinance. This is realistic for consumer durables (cars, furniture, etc.) that account for essentially all of the marginal spending on durables in response to stimulus checks.

We conclude the paper with an application. We embed our spending model into a heterogenous-agent New-Keynesian model to evaluate the effect of stimulus checks in general equilibrium. In particular, we assess the size of checks that fully closes the output gap in a recession. This analysis provides an upper bound for policymakers: checks exceeding that amount overheat the economy.[4] Quantifying this bound requires specifying the supply side of the economy (trade openness, price setting, capacity constraints, etc.) and solving for the general equilibrium of the model globally to capture the non-linearity that we are interested in.[5] We consider different scenarios where we vary the extent of price stickiness, how constrained monetary policy is, the durables supply elasticity, or the spending leakage due to imports. We focus on recessions driven by aggregate demand shocks in our main analysis. We later explore the sensitivity of our results when incorporating supply side constraints too. Overall, we find that a \$1,200 to \$1,500 check closes the output gap in a typical recession of 4%.

We find that the general equilibrium transfer multiplier remains elevated even after large stimulus checks, whereas it falls sharply in a model of non-durable spending and increases steeply in the canonical model of durables. As a result, the stimulus check that closes a given output gap is much smaller (larger) in our model compared to the one required in the canonical non-durables (durables) model. For instance, a \$600 stimulus check closes roughly half the output gap during a typical recession of 4% in our model, while a check more than twice as large of \$1,250 is needed in the non-durables model and a check of only \$200 is required in the canonical durables model. Moreover, in our model, checks larger than \$1500 are too much in that they stimulate output beyond potential in a typical recession.

Methodologically, we contribute to a growing literature on durables demand in incomplete markets economies. Most notably, Berger and Vavra (2015) developed the canonical model that spearheaded this literature. McKay and Wieland (2021) find that this canonical model predicts an excessive elasticity of durable demand to interest rate changes. They address this shortcoming by augmenting the canonical model with operating costs, exogenous adjustment shocks, and limited attention. Both models feature standard (s, S) adjustment bands, i.e., discontinuous adjustment hazard at the microeconomic level. In contrast, we introduce a smoother adjustment hazard in the tradition of Caballero (1993) and more recently Beraja et al. (2019) and Alvarez et al. (2020). We find that such smoother

[4] In presence of distortionary taxation or inflation, the government would not fully close the output gap. That is, it would send smaller checks than the upper bound. How close the government gets to this bound depends in part on its preference for redistribution and insurance (McKay and Wolf, 2023).

[5] This sets our paper apart from other work on stimulus checks (Wolf, 2021; Wolf and McKay, 2022) or transfers in fiscal unions (Farhi and Werning, 2017; Beraja, 2023) which uses first order approximations in the aggregates.

hazard is needed to match a rich set of micro level moments.

While the existing literature has used random fixed cost of adjustment as a device to generate smooth hazards, we introduce a discrete choice problem with additive taste shocks for adjustments à la McFadden (1973). This specification allows for purely time-dependent adjustment (constant hazard), purely state-dependent adjustment (binary hazard), and everything in between.[6] An important body of work uses this form of discrete choice to estimate the demand for durables both in static settings (Berry et al., 1995) and dynamic ones (Chen et al., 2013; Gowrisankaran and Rysman, 2012). Some papers in the heterogenous agent literature adopt taste shocks when studying discrete choices (Iskhakov et al., 2017; Auclert et al., 2021). They do so for numerical reasons only; the shocks have an arbitrary small variance and a zero mean. In contrast, we discipline both the mean and the variance of these shocks using micro-data, and these moments are central to the shape of the adjustment hazard and the size-dependence in the MPC.

Finally, our analysis is related to a literature that explores how behavioral frictions affect the size-dependence in the MPC. Laibson et al. (2021) find that MPCs can remain elevated for large shocks when households are present-biased. In an extension, they allow for a durable good whose adjustment is frictionless. In contrast, non-convex adjustment costs are key to our mechanism. Fuster et al. (2021) find that non-convex costs of attention or re-optimization can generate an MPC that increases with income changes. Their model allows for a single non-durable good, whereas durables are central to our analysis. We microfound the logit adjustment hazard in our model by introducing random utility shocks. Matějka and McKay (2015) shows that such hazard has a behavioral foundation when agents make mistakes due to costly information processing.

2 A Model With A Smooth Adjustment Hazard

We now introduce our model of household spending. Households consume non-durables and invest in durables, and they face uninsured earnings risk. Time is discrete, and there is no aggregate uncertainty. Periods are indexed by $t \geq 0$.

[6] This specification is rooted in the psychology literature (McFadden, 2001) and is used extensively in the context of consumption choices (Nevo, 2001), school choices (Agarwal and Somaini, 2020) and occupational choices (Artuç et al., 2010; Caliendo et al., 2019). Random fixed costs of adjustments do not have a clear empirical counterpart.

2.1 Goods and Preferences

Households consume $c_t \geq 0$, and invest in durables $d_t \geq 0$. Their utility is

$$\mathcal{U}_t \equiv u\left(c_t, d_{t-1}\right) + \beta \mathbb{E}_t\left[\mathcal{U}_{t+1}\right], \tag{2.1}$$

for some discount factor $\beta \in (0,1)$. We assume that inter- and intratemporal preferences are isoelastic

$$u\left(c,d\right) = \frac{1}{1-\sigma} U\left(c,d\right)^{1-\sigma} \quad \text{and} \quad \sum_{g \in \{c,d\}} \left(\frac{\vartheta_g^{\frac{1}{\nu-1}} g}{U\left(c,d\right)}\right)^{\frac{\nu-1}{\nu}} = 1, \tag{2.2}$$

where σ is the inverse elasticity of intertemporal substitution, ν is the elasticity of intratemporal substitution, and $\boldsymbol{\vartheta}$ are consumption weights with $\sum_g \vartheta_g = 1$.

2.2 Durable Adjustment Hazard

We specify a flexible adjustment hazard that captures the time- and state-dependence in durable adjustment. Households are subject to linearly additive taste shocks for adjustment. These taste shocks are independent over time and distributed according to a logistic distribution whose mean and variance and controlled by $\kappa > 0$ and $\sigma^2 > 0$, respectively.[7] The durable adjustment hazard is

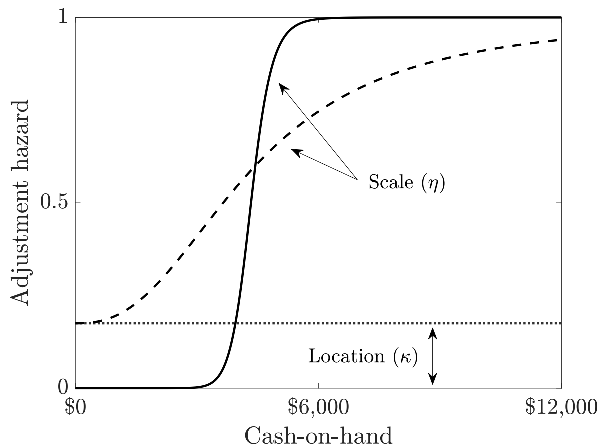
$$\mathcal{S}\left(\mathbf{x}\right) = \frac{\exp\left(\frac{V^{\text{adjust}}-\kappa}{\eta}\right)}{\exp\left(\frac{V^{\text{adjust}}-\kappa}{\eta}\right) + \exp\left(\frac{V^{\text{non}}}{\eta}\right)}, \tag{2.3}$$

where V^{adjust} and V^{not} denote the present discounted values of utility when adjusting and not adjusting, respectively.

The scale parameter η controls the *shape* of the adjustment hazard while the location parameter κ controls its *level*. In particular, the model reduces to a fully state-dependent model when $\eta \to 0$; and κ controls the position of (s, S) bands in this case. In this sense, κ effectively governs the fixed cost of adjustment. Similarly, the model boils down to a fully time-dependent model when $\eta \to +\infty$; and κ controls the probability of adjustment in

[7] The literature typically normalizes the mean of these shocks (Artuç et al., 2010; Caliendo et al., 2019). By letting the mean and variance be unrestricted, we introduce one extra degree of freedom which allows us to match the micro-level evidence (Section 3). Random adjustment costs (Dotsey et al., 1999; Alvarez et al., 2020) would also produce a smooth hazard — although their economic interpretation is somewhat unclear.

Figure 2.1: Adjustment hazard (fixing d)



this case.[8] Figure 2.1 provides an illustration of two such hazards. The first (solid line) is a very steep hazard. It resembles the discontinous adjustment hazard associated with (s, S) bands in canonical models of lumpy durable spending, which are purely state-dependent. The second (dashed line) is a much flatter hazard. For instance, such hazard results from allowing for time-dependent adjustments (Alvarez et al., 2016a). As we discuss at the end of this section after presenting the remaining model elements (Section 2.5), the shape of this adjustment hazard plays a key role for the size-dependence in the MPC. Finally, the stock of durables depreciates at rate δ and requires a mandatory maintenance rate ι so that $d_t = (1-(1-\iota)\,\delta)\,d_{t-1}$ when the household does not adjust.

2.3 Saving, Credit, and Downpayment

Households save in a liquid financial assets $m \geq 0$ (i.e., cash, deposits) with return r^m and borrow using a partially illiquid asset $b \leq 0$ (credit) with return $r^b \geq r^m$. Households are required to make a down payment when they purchase a durable. Specifically, they are required to pay a share $\theta \in (0,1)$ of the value of the stock they buy. That is,

$$b_t \geq -(1-\theta)\,(1-\delta)\,d_t, \tag{2.4}$$

[8] In this limit, $\kappa = \log(1/\phi - 1)\,\eta$ induces a constant hazard $\phi \in (0,1)$.

at origination.[9] We assume that the constraint (2.4) holds with equality at origination, and that is remains binding at any point while the household holds a durable. This assumption allows us not to introduce credit as an additional state variable. It is also fairly realistic: in practice, the vast majority of down payments for cars do not exceed the minimum level required (Green et al., 2020); and most car loans are repaid within $5-6$ years and cars depreciate at roughly 20% (i.e., outstanding credit b tracks durables d).[10] We abstract from endogenous refinancing decisions (Berger et al., 2021; Laibson et al., 2021) between purchases.[11] With this assumption, households make pre-determined credit repayments (Laibson et al., 2021) while they hold their stock, which mimicks the rule out thumb they appear to follow in practice (Argyle et al., 2020).[12]

2.4 Earnings

Households' earnings $e_t \equiv y_t Y_t$ are the product of idiosyncratic productivity y_t and aggregate income Y_t. The productivity y_t follows an AR(1) process as in Berger and Vavra (2015) and McKay and Wieland (2021). We let

$$\mathcal{Y}_t \equiv \psi_0 \left(e_t Y_t\right)^{1-\psi_1} + \left(1 + r^m_{t-1}\right) m_{t-1} + r^b_{t-1} b_{t-1} + T_t \tag{2.5}$$

denote cash-on-hand, where ψ_0 and ψ_1 parametrize progressive taxation (Heathcote et al., 2017), and T_t are lump sum transfers from the government.

2.5 Adjustment Hazard and Size-Dependence in the MPC

Having presented the model, we are now ready to discuss the role that the adjustment hazard plays in the size-dependence in the MPC. Let T be a transfer and $\text{MPC}^d\,(T)$ be the

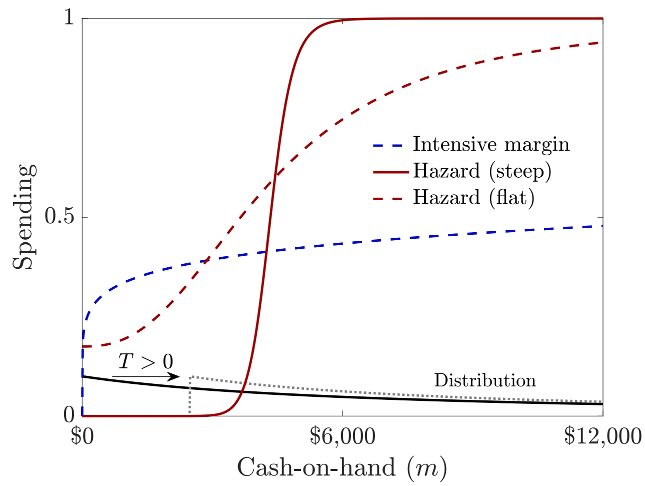
9 Existing models of durables make no distinction between cash and credit (Jose Luengo-Prado, 2006; Berger and Vavra, 2015). They assume a single, liquid asset that is subject to loan-to-value constraint similar to (2.4). This presumes that households can refinance and prepay their debt *continuously*. Refinancing is virtually nonexistent for consumer durables, which we focus on. Auto loan prepayments are relatively rare too (Heitfield and Sabarwal, 2004). Our two-asset specification ensures that the effective supply of liquidity in the economy, i.e., the average distance to the borrowing constraint, matches conventional estimates in the literature (Kaplan et al., 2018). An *even* richer model could allow for refinancing.

10 Our calibration will focus on cars and other consumer durables. We will abstract from housing since it not the relevant margin of adjustment in response to stimulus checks.

11 In the context of consumer durables, the main form of illiquid credit that requires a prepayment fee is auto loan. Prepayment is relatively rare for auto loans.

12 It is worth noting that these assumptions imply that households in our model will use part of their stimulus checks to pay down debt (Shapiro and Slemrod, 2009; Graziani et al., 2016; Coibion et al., 2020) as the extra windfall allows households to make their pre-determined repayments.

Figure 2.2: Spending Functions (fixing d and y)



associated average marginal propensity to spend (on durables)

$$\mathrm{MPC}^{d}(T) \equiv \frac{1}{T} \int \int \underbrace{\mathcal{S}(m,d)}_{\text{extensive}} \underbrace{x(m+d)}_{\text{intensive}} \left\{ d\pi(m-T,d) - d\pi(m,d) \right\}, \tag{2.6}$$

where $\mathcal{S}(m,d)$ is the adjustment hazard and $x(m+d)$ is spending conditional on adjustment for a household with cash-on-hand m and durable stock d, and π is the associated distribution. Stimulus checks shift the distribution of cash-on-hand in the economy (the last term in the expression). Households spend more on durables as result. They adjust their stock of durables both at the extensive margin (as captured by the hazard $\mathcal{S}$) and the intensive margin (as captured by spending conditional on adjustment x).

Figure 2.2 illustrates these two objects as a function of cash-on-hand m (fixing the other states d and y). The figure shows the same two hazards (in red) as in Figure 2.1, with the steeper hazard associated with more state-dependent adjustments. Finally, the spending conditional on adjustment (in blue) is concave due to a standard precautionary savings motive. We also plot the distribution of cash-on-hand (in black). A stimulus check $T > 0$ shifts this distribution to the right (dashed black curve). Households are more likely to adjust their stock of durables (they move along the hazard) and they spend more conditional on adjustment.

The shape of the adjustment hazard is key for the size-dependence in the marginal propensity to spend on durables. To see this, suppose first that the model is purely state-dependent ($\mathcal{S}$ is discontinuous around some threshold $m^{\star}(d)$). It this case, the extensive margin of adjustment is particularly strong (McKay and Wieland, 2022) and it dominates the intensive margin. The marginal propensity to spend on durables becomes

$$\text{MPC}^d(T) \propto \int \int_{m^\star(d)}^{+\infty} \frac{d\pi(m-T,d) - d\pi(m,d)}{T}$$

when the intensive is roughly constant. In this case, the marginal propensity to spend on durables *increases* with the size of stimulus checks T as the distribution of cash-on-hand decreases (as in the data). Next, consider the opposite polar case where the model is purely time-dependent ($\mathcal{S}$ is constant). In this case, there is no extensive margin and the intensive margin dominates. The marginal propensity to spend on durables becomes

$$\text{MPC}^d(T) \propto \int \int \{x(m+d+T) - x(m+d)\} \, d\pi(m,d),$$

and households move along a concave spending function. In this case, the marginal propensity to spend on durables *decreases* with the size of stimulus checks. Similarly, the MPC of total spending (which includes spending on non-durables too) can increase or decrease depending on the shape of the adjustment hazard for durable purchases. We will discipline this hazard carefully in the next section by matching several pieces of micro evidence.

3 Bringing the Model to the Data

We interpret durables as consumer durables (cars, appliances, furniture). We assume that our single, composite durable good behaves as cars (in terms of frequency of adjustment, down payment, etc.) since they make up for most of the spending on consumer durables. We abstract from housing purchases since these are unlikely to be affected by stimulus checks of a realistic magnitude. We start by calibrating some parameters externally (Section 3.1), before calibrating internally the most important ones (Section 3.2). Tables 3.1 and 3.2 summarize the parametrization.

3.1 External Calibration

External parameters are set to standard values in the literature. The inverse elasticity of intertemporal substitution is $\gamma = 2$, which is usual in the literature on durables (Berger and Vavra, 2015; Guerrieri and Lorenzoni, 2017). We choose an elasticity of substitution between durables and non-durables of $\nu \to 1$ to obtain a unitary long-run price elasticity

Table 3.1: External calibration

Parameter	Description	Value	Target / Source
Preferences			
γ	Inverse EIS	2	Berger and Vavra (2015)
η	CES parameter	1	Long-run price elasticity
Durables			
δ	Depreciation rate	5%	NIPA
Earnings process			
ρ	Persistence	0.977	Floden and Lindé (2001)
σ	Volatility	0.198	Auclert et al. (2018)
τ	Distorsionary taxation	0.3	Kaplan and Violante (2014)
Financial asset			
θ	Down payment	0.15	Berger and Vavra (2015)
r^m	Return on cash	-1.5%	0.5% nominal return, 2% inflation
$r^b - r^m$	Borrowing spread	2.78%	Attanasio et al. (2022)

Table 3.2: Internal Calibration

Parameter	Description	Canonical	Our model
Internal calibration			
β	Discount Rate	0.946	0.944
ϑ	Non-durable weight	0.711	0.687
ι	Maintenance rate	0.255	0.257
κ	Location of pref. shifters	0.239	0.803
η	Scale of pref. shifters	0	0.20

for cars (Berry et al., 2004; Orchard et al., 2022).[13] We choose a quarterly depreciation rate $\delta = 5\%$. We set the down payment parameter to $\theta = 0.2$ which lies between the estimates of Adams et al. (2009) and Attanasio et al. (2008). The real return on the liquid asset is $r^m = 1\%$ per year and the borrowing spread is $r^b = 3.5\%$ for auto loans. We assume that idiosyncratic productivity follows an AR(1) process. We set the persistence of the income process $\rho = 0.977$ so as to obtain an annual persistence of 0.91 (Floden and Lindé, 2001). We set the standard deviation of the innovations $\sigma = 0.197$ to match an annual standard deviation of 0.92 in log-earnings (Auclert et al., 2018). We normalize the earnings process so that GDP is 1 at the stationary equilibrium. The elasticity of the tax schedule is $\psi_1 = 0.181$ as in Heathcote et al. (2017), and we choose the intercept $\psi_0 = 0.782$ so the marginal tax rate is 30%.

3.2 Internal Calibration

We calibrate five parameters internally: (i) the discount factor β; (ii) the relative weights on non-durables ϑ; (iii) the maintenance rate ι; (iv) the location parameter for preference shocks κ; and (v) the scale parameter for preference shocks η. We choose the discount factor to match an average stock of liquid asset holdings m of 26% of average annual income (Kaplan et al., 2018). We calibrate the relative weight on non-durables to target a ratio of durables to non-durable expenditures $x/c = 0.26$ based on CEX data.[14] We set the maintenance rate to obtain a ratio of maintenance spending to gross investment of 32.6%, consistent with the one for cars in the CEX. We choose the location parameter κ to match an annual frequency of durable adjustment of 23.8% for vehicles in the PSID, which is in line with conventional estimates (Attanasio et al., 2022; McKay and Wieland, 2021).[15] The rest of this section describes the calibration of the scale parameter η since it plays an important role in our analysis.

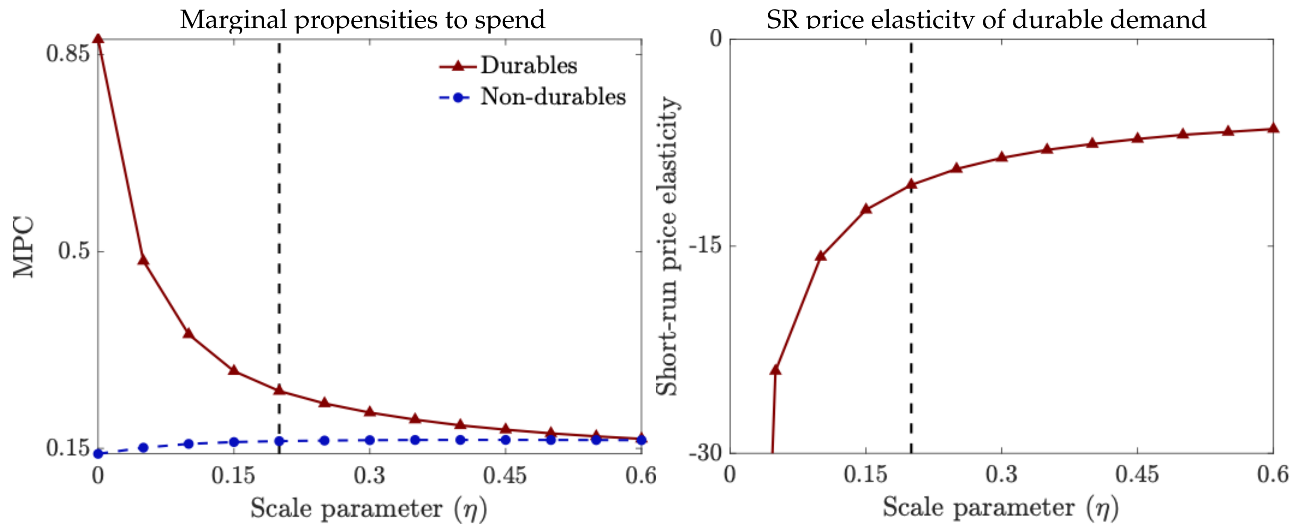
Bounding the scale parameter. The scale parameter η controls the shape of the hazard (2.3). As such, it governs the propensity of households to adjust their stock of durables in response to shocks. Two empirical moments provide upper and lower bounds for this pa-

[13] The long-run price elasticity would be exactly 1 in our model with free adjustments $(\kappa = 0, \eta \to 0)$. We obtain an elasticity of -0.93 in the full model with adjustment frictions.

[14] We exclude housing from both durables and non-durables. We interpret durables as consumer durables (vehicles, appliances, computers, phones, etc.). Durable spending in the CEX consists of: household furnishings and equipment; vehicle purchases (net outlay); maintenance and repairs on vehicles; audio and visual equipment and services; and other entertainment supplies, equipment and services. Non-durable spending consists of total spending minus the categories above and housing.

[15] In Section 3.3, we describe how we estimate the empirical distribution π_k of the duration k between vehicle purchases. The frequency of adjustment is the inverse of the average duration $1/\sum_{k\geq 0} k\pi_k$.

Figure 3.1: Bounding the scale parameter η



Notes: The left panel plots the MPC out of a $500 check on durables and non-durables for various values of the scale parameter η in (2.3). Each MPC is computed as a rebate coefficient, i.e., the average propensity to spend. The right panel plots the short-run price elasticity of durable demand after a one-quarter increase in the price of durables by 1%. The dashed vertical line is our preferred estimate ($\eta = 0.2$).

rameter.

The left panel of Figure 3.1 shows the MPC on durables and non-durables for different values of η. All other parameters are re-calibrated to match the moments described above. The MPC on durables declines monotonically in η: the more time-dependent the model, the lower the MPC on durables. The literature offers a wide range of estimates of the MPCs on durables and non-durables. For instance, Souleles et al. (2006) finds a low MPC on durables, while Parker et al. (2013) finds a rather high one. However, it is generally agreed that the MPC on durables is larger than the one on non-durables (see the meta analysis of Havranek and Sokolova, 2020). For this reason, 0.45 is a plausible upper bound for the scale parameter η. That is, the model cannot be *too* time-dependent to match the evidence on the relative MPC of durables.

The right panel shows the *short-run* elasticity of durable purchases after a one-quarter transitory increase in the price of durables by 1%. It is well-known that conventional models of durable spending produce an excessively high elasticity of durable demand to changes in the user cost (House, 2014; McKay and Wieland, 2021). This effect is almost entirely driven by the extensive margin of adjustment (McKay and Wieland, 2022). Consistently, the fully state-dependent model with (s, S) adjustments bands ($\eta \to 0$) predicts an implausibly high elasticity of -90. Introducing a smooth adjustment hazard is a parsimonious way to dampen this elasticity.[16] There is much uncertainty about the precise elasticity in the empirical literature. Gowrisankaran and Rysman (2012) estimates a short-run elasticity of -2.55 for camcoders. Bachmann et al. (2021) finds an elasticity of -12 among households who were aware of a short-run decrease in the VAT in Germany. For this reason, 0.1 is a plausible lower bound for the scale parameter η. That is, the model cannot be *too* state-dependent to match the evidence on the elasticity of durable purchases.

Overall, our preferred value for the scale parameter is $\eta = 0.2$ — in between the lower and upper bounds. It delivers an MPC on durables of 0.252 out of a $500 windfall, which almost exactly matches the mean estimate in the meta analysis of Havranek and Sokolova (2020). The MPC on total spending is 0.4, which is again similar to the mean estimate in this study. We obtain a short-run price elasticity of durables of -10.6 in our preferred calibration, which lies between the existing estimates. We will show that our results are robust to other choices of η in the region $0.1 \leq \eta \leq 0.45$. Moreover, the next section shows that the model with $\eta = 0.2$ matches well other important (untargeted) moments.

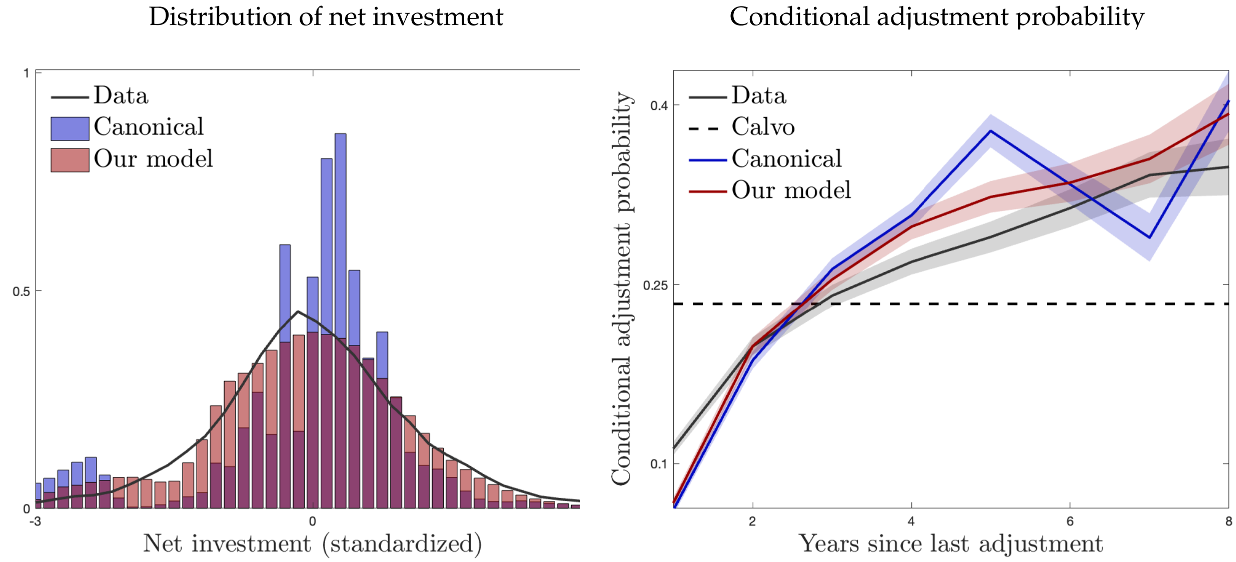
3.3 Untargeted Moments

Our calibrated model performs well along several untargeted dimensions. We start by inspecting two moments — the distribution of net investment in durables and the conditional probability of adjustment — which highlight the importance of allowing for a smooth adjustment hazard. We also examine the distribution of MPCs.

Net investment. The left panel of Figure 3.2 plots the empirical distribution of net investment in vehicles by households who adjust their stock across two consecutive PSID waves w (in grey). To measure net investment, we restrict our sample to household heads (or reference persons) who are male, aged 21 or above, and appear in at least three PSID waves owning at least one vehicle. Households report the purchase year (Year_w) in wave w for their most recently bought vehicle ("#1"). A change in this variable across two consecutive waves indicates a new purchase. Since PSID waves are bi-annual, a purchase occurs ($\text{Purchase}_w = 1$) over the period covered by the current wave if $\text{Year}_w > \text{Year}_{w-2}$. We measure net investment upon a purchase as $\log(d_w) - \log(d_{w-2})$ when $\text{Purchase}_w = 1$, where d_w is the value of the stock of vehicles *net* of liabilities reported by the household. Lastly, we standardize the resulting distribution by de-meaning net investment and normalizing it by its standard deviation (Alvarez et al., 2016b). We trim the top and bottom

[16] McKay and Wieland (2022) dampen this elasticity by introducing a combination of low elasticity of intertemporal substitution, low elasticity of substitution between durables and non-durables, various operating costs, exogenous mandatory adjustments, and limited attention.

Figure 3.2: Untargeted moments



Notes: The left panel plots the distribution of net investment (standardized) across two consecutive PSID waves where the household adjusted. The grey curve is the data, while the red and blue bars are our calibrated model and the canonical version with (s, S) bands (i.e., $\eta \to 0$), respectively. The right panel plots the adjustment probability conditional on a household not having adjusted so far.

1% of the distribution when standardizing.

Figure 3.2 also plots the distribution of net investment in our model with a smooth adjustment hazard ($\eta = 0.2$, in red) and in a version of our model with only state-dependent adjustments ($\eta \to 0$, in blue) as in canonical durables models. To ensure that the data and models are comparable, we discretize our model-simulated series into PSID waves and treat those identically to the actual data. We divide time into years, as our model is set up quarterly. For each individual and wave, we compute Year$_w$ as the year of the most recent purchase. Vehicle wealth is $d_w \equiv P^d_{T(w)} \theta d_{T(w)}$ in the model since households' credit is given by (2.4) at any time, where $T(w)$ is the last quarter in PSID wave w.

Our calibrated model produces a bell-shaped distribution that resembles the one in the data. Crucially, our model matches well the tails of the distribution — an important moment in models with lumpy adjustment (Alvarez et al., 2016b). In contrast, the purely state-dependent model fails to reproduce the empirical distribution. There are too few negative adjustments and most adjustments are concentrated around the same value.

Probability of adjustment. The right panel of Figure 3.2 plots (in black) the empirical probability that a household adjusts its stock of vehicles after a certain number of years *conditional* on not having adjusted so far (Alvarez et al., 2021), which is also known as the Kaplan-Meier hazard. We construct this conditional probability using the purchase dates Year_w as follows. The duration between two consecutive purchases is given by $\text{Duration}_w = \text{Year}_w - \text{Year}_{w-2}$ whenever a purchase occurs ($\text{Purchase}_w = 1$). We restrict attention to the first purchase by a given household.[17] This yields an empirical probability distribution π_k over durations $k = 1, 2, \ldots$ expressed in years. Following Alvarez et al. (2021), we compute the conditional probability of adjustment as

$$\text{Prob}_k = \frac{\pi_k}{1 - \sum_{j<k} \pi_j}. \tag{3.1}$$

The figure compares the empirical probability to the one implied by our model ($\eta = 0.2$, in red) and two alternative calibrations: one with only time-dependent adjustments ($\eta \to +\infty$, dashed) and one with only state-dependent adjustments ($\eta \to 0$, in blue). The conditional probability is flat in the purely time-dependent model. On the contrary, the data suggests that vehicle adjustments are fairly state-dependent. The model with $\eta = 0.2$ matches the empirical profile very well.[18] The overall pattern is roughly similar in the purely state-dependent model ($\eta \to 0$), although the fit becomes poorer as the horizon increases. Overall, this confirms that our calibrated model retains a substantial degree of state-dependence. This also means that the conditional probability of adjustment is only a *partially* informative moment. It allows us to rule out very large values of η (a strong time-dependence), as did the evidence on the relative MPC of durables in the left panel of Figure 3.1. But it does not allow us to discriminate between lower values of η. Very low values of η are instead ruled out by the evidence on the price elasticity in the right panel of Figure 3.1 as well as the evidence on the distribution of net investments in the left panel of Figure 3.2.

Annual MPC. The model delivers an annual MPC of roughly 0.9 out of a \$500 check, which is very similar to the estimates of Fagereng et al. (2021) out of small lottery gains (most gains are much larger) based on evidence from Norway.

Share of hand-to-mouth. We find that 42% of households are hand-to-mouth (Kaplan et al., 2014), i.e., their holdings of liquid assets are less than half of their monthly (gross) income. While untargeted, this figure turns out to be almost exactly identical to the recent estimates of Kaplan and Violante (2022) and Aguiar et al. (2020).

[17] The reason is that subsequent purchases, if observed in the PSID's short time dimension, are more likely to be of shorter duration. Focusing on the first adjustment allows us to circumvent this issue.

[18] Note that the model matches the *average* probability, by construction. The reason is that we target the empirical frequency of adjustment in our calibration, which is computed using the empirical probability of adjustment. The model's success lies in the fact that it matches the *profile* well.

Secondary market. Households who adjust their stock of durables (upward or downward) first *sell* their existing stock. Part of households' gross purchases is thus fulfilled effectively by old cars in the secondary market.[19] In our calibrated model, used cars make 52% of gross purchases. For comparison, used cars represent roughly 55% of total spending on cars in the US (DoT, 2023).[20]

Distribution of MPC. Figure B.1 in Appendix B compares the distribution of the MPC on total spending produced by our model and one of purely non-durable spending.[21] The distribution is bi-modal in the standard incomplete markets model. Most households behave as Ricardian agents, and hence have a low MPC. Some of them are near their borrowing constraint, and hence have a higher MPC (less than 0.5). In contrast, the distribution of MPCs declines much less dramatically in our model of lumpy durable spending. The overall shape of the distribution is consistent with the evidence in Lewis et al. (2019) and Fuster et al. (2021). A non-negligible share of households displays an MPC close to (or above) 1, which is in-line with the findings of Misra and Surico (2014) and Jappelli and Pistaferri (2014). Lumpy adjustment and households' ability to pay only a fraction of the price as a down payment make such high MPCs possible.

3.4 State- *vs.* Time-Dependent Adjustments

The previous section showed that our calibrated model retains both state- and time-dependent features. We now quantify the degree of state-dependence more formally.

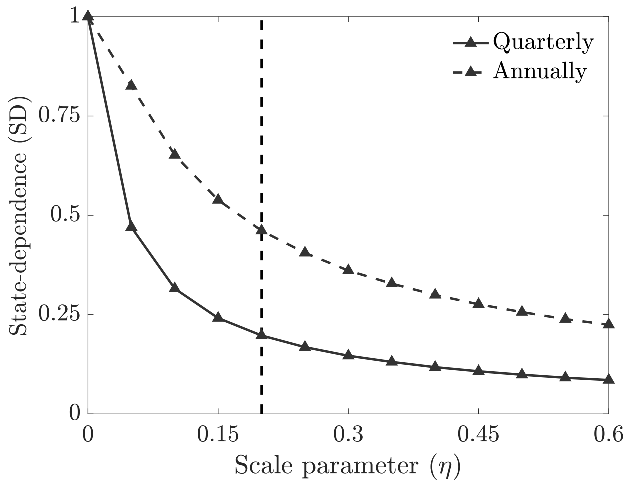
In a purely state-dependent model (i.e., the canonical model), durable adjustment is deterministic conditional on the households' idiosyncratic state $\mathbf{x}$, and it results exclusively from movements in $\mathbf{x}$ along the state space. In a purely time-dependent model (i.e., the Calvo model), durable adjustment is purely random and unrelated to $\mathbf{x}$. The adjustment hazard $\mathcal{S}(\mathbf{x})$ in (2.3) is indexed by the household's state $\mathbf{x}$, yet the adjustment decision is random given the probability $\mathcal{S}(\mathbf{x})$. Put it differently, adjustment occurs $\mathcal{A}(\mathbf{x};\psi) = 1$ if $\psi \leq \mathcal{S}(\mathbf{x})$ with ψ distributed uniformly on the line $[0,1]$, and no adjustment

[19] New and old durables are indistringuishable in our model. In particular, they have the same depreciation rate and households value them equally. Gavazza and Lanteri (2021) model the secondary market explicitly by allowing older cars to be of lower perceived quality.

[20] About 75% of car sales in the US involve a used car. However, used cars are cheaper than new ones in the data and hence account for a smaller share of total spending on cars. Modelling the second market explicitly by allowing for a quality ladder is beyond the scope of the current paper.

[21] For comparability, this model of non-durable spending is our full model (Section 2) specialized with no durables, i.e., with preference parameter $\vartheta_c = 1$. The discount factor is calibrated to match the same average stock of liquid asset holdings as in our full model (Section 3).

Figure 3.3: State-dependence



Notes: The figure plots our state-dependence index SD in (3.3) as a function of the scale parameter η. All other parameters are re-calibrated to match the targets discussed in Section 3.2. The vertical dashed line is our preferred calibration $\eta = 0.2$.

occurs $\mathcal{A}(\mathbf{x};\psi) = 0$ otherwise.

We introduce the following measure of state-dependence[22]

$$\text{State-dependence (SD)} \equiv \frac{\text{share with } \mathcal{A}(\mathbf{x}';\psi\ ) = 1 \text{ and } \mathcal{A}(\mathbf{x};\psi) = 0}{\text{share with } \mathcal{A}(\mathbf{x}';\psi') = 1 \text{ and } \mathcal{A}(\mathbf{x};\psi) = 0} \tag{3.2}$$

where households are tracked over consecutive periods as they move along the state space from $\mathbf{x}$ to $\mathbf{x}'$ and switch from a draw ψ to ψ'. Households decide to adjust for two reasons: either because they moved to $\mathbf{x}'$ or because they got a particular draw ψ'. Our measure of state-dependence captures the share of adjustments that occur *exclusively* through the first effect. By definition, SD $= 1$ in the purely state-dependent model, and SD $= 0$ in the purely time-dependent model.

We plot our measure of state-dependence in Figure 3.3, as a function of the scale parameter η. All other parameters are re-calibrated as we change this parameter. We repeat this experiment at the quarterly and annual frequency. As anticipated in Section 2.2, the model becomes less state-dependent as η increases. In our preferred calibration $(\eta = 0.2)$, roughly 23% (50%) of all adjustments during a quarter (year) occur due to changes in households' idiosyncratic state $\mathbf{x}$. In both cases, our state-dependent index is rather flat around our preferred calibration value $(\eta = 0.2)$. This will help explain why the size-dependence in the MPC is not very sensitive to changes in the scale parameter around

[22] Our measure of state-dependence is computed at the steady state. We could, in principle, compute it after an aggregate shock (e.g., a stimulus check) in the spirit of Caballero and Engel (2007). Our measure is conceptually distinct from their "flexibility index," however.

this value.

4 Size-Dependence in the MPC and Aggregate Stimulus

We now quantify the size-dependence in the MPC in our model (Section 4.1). We compare it to previous estimates in the literature, and highlight the role of our smooth adjustment hazard. We then discuss the role of the extensive margin (Section 4.2), and how aggregate conditions affect the size-dependence (Section 4.3). Lastly, we compute the aggregate spending response to checks of varying size in our model, and compare it to canonical models of non-durables and durables (Section 4.4).

4.1 Size-Dependence in the MPC and the Shape of the Hazard

The left panel of Figure 4.1 plots the marginal propensity to spend on durables and non-durables (at the quarterly level) following stimulus checks of varying size starting from the stationary distribution. While the levels are targeted in our calibration (Section 3.2), this size-dependence is not. We find that the marginal propensity to spend on non-durables declines relatively rapidly. In contrast, the marginal propensity to spend on durables is virtually flat over the range \$100 to \$600, and then declines slowly. The response out of \$2,000 is about 1/3 lower relative to the one out of \$100 for non-durables, compared to 15% for durables.

The right panel plots the total MPC as a function of the size of stimulus checks. We find that the MPC declines slowly with the size of stimulus checks, remaining elevated even for large checks. This finding is consistent with the evidence of Sahm et al. (2012) and Coibion et al. (2018). In contrast, the MPC is lower in levels and declines sharply in the non-durables model of Kaplan and Violante (2014). For example, the MPC out of \$2,000 if about 50% lower compared to the one out of \$100 in their model, compared to 25% in our model.

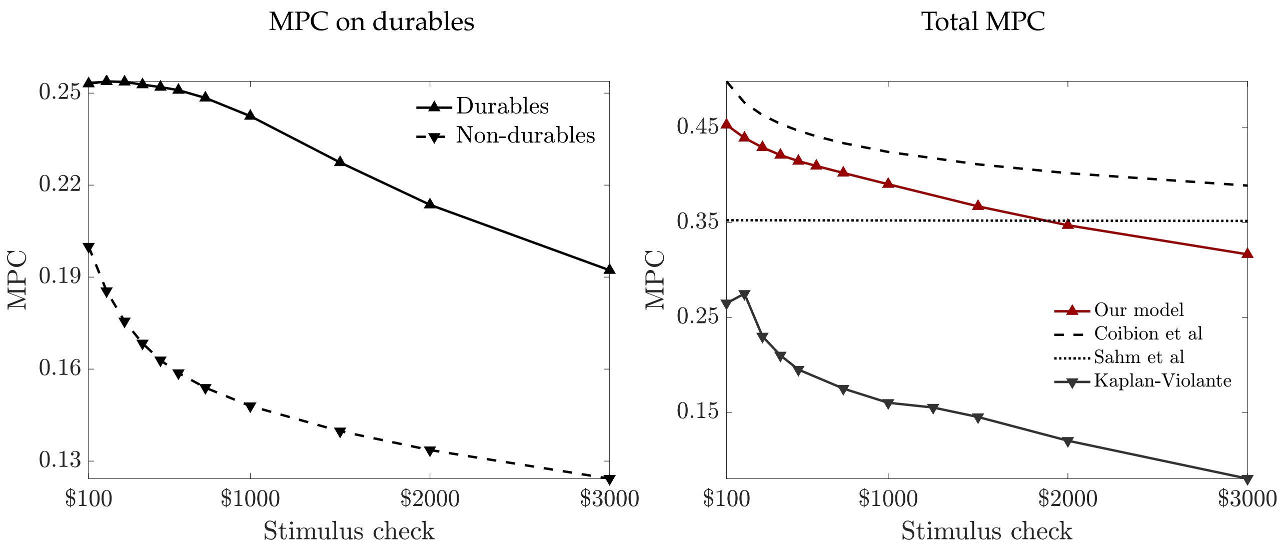
What role does the scale parameter η play in the size-dependence in our model? To answer this question, we measure the size-dependence in the MPC as

$$\text{Size-dependence} \equiv \frac{\text{MPC}\,(\$X)}{\text{MPC}\,(\$100)} - 1 \qquad \text{for } X \in \{\$600, \$2000\}\,, \tag{4.1}$$

for different values of the scale parameter η.[23] This measure captures the concavity in the

[23] The \$600 and \$2000 amounts are chosen because they correspond to the checks sent during the last two recessions.

Figure 4.1: Size-dependence in the MPC



Notes: The left panel plots the marginal propensity to spend on durables and non-durables as a function of the size of the stimulus checks. The right panel plots the total MPC as a function of the size of this checks in our model, and compares it to existing estimates in the literature.

spending function, i.e., how quickly the MPC changes as stimulus checks become larger.[24] Figure 4.2 plots the measure of size-dependence as a function of the scale parameter. Starting with the purely state-dependent model ($\eta \to 0$), the MPC is about 10% *higher* out of \$600 compared to \$100, and roughly equal for \$2,000. In contrast, in our calibrated model ($\eta = 0.2$), the MPC is instead 10% *lower* out of \$600 compared to \$100, and roughly 25% lower for \$2,000. The measure of size-dependence is essentially flat around $\eta = 0.2$, as the degree of state-dependence is roughly constant (Section 3.4).

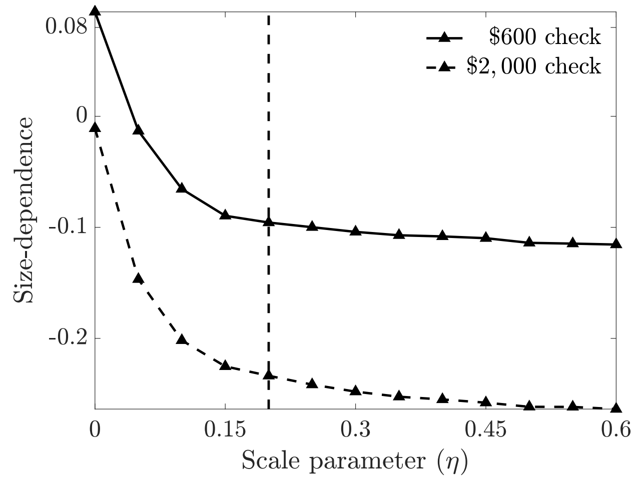
4.2 The Role of the Extensive Margin of Adjustment

Why does the MPC decrease in our calibrated model? The answer lies in the response of durable spending at the *extensive* margin. Figure 4.3 decomposes the response of durables into its extensive and intensive margins. The extensive margin captures changes in the durable adjustment hazard $\mathcal{S}$, holding fixed the policy functions conditional on adjustment. The intensive margin captures the change in these policy functions, holding the hazard fixed.[25] Two facts stand out. First, the two margins contribute to the MPC in roughly the same proportions. Second, the extensive margin actually *declines* as the stim-

[24] The scale parameter also affects the level of the MPC (Section 3). Our measure of size-dependence is invariant to that, as it measures the relative decline in the MPC as stimulus checks become larger.

[25] The extensive and intensive add up to the total response of Figure 4.1 (left panel) up to a residual (since the model is non-linear).

Figure 4.2: Scale parameter and size-dependence in the MPC



Notes: This figure plots our index or size-dependence (4.1) as a function of the scale parameter (η). .All other parameters are re-calibrated to match the targets discussed in Section 3.2. The vertical dashed line is our preferred calibration $\eta = 0.2$.

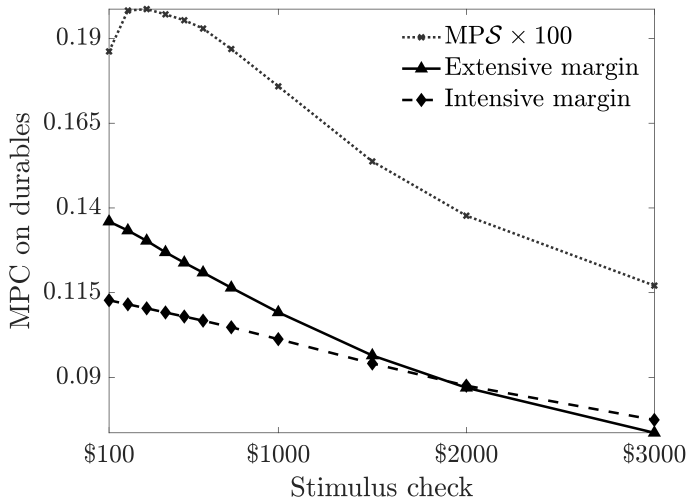
ulus checks become larger. To understand why this is the case, note that the extensive margin is given by

$$\text{Extensive margin} \equiv \frac{\int \overbrace{\left(\mathcal{S}_0\left(\mathbf{x}\right)|_{\tilde{T}=T} - \mathcal{S}_0\left(\mathbf{x}\right)|_{\tilde{T}=0}\right)}^{\#\text{ of marginal adjusters}} \times \overbrace{x\left(\mathbf{x}\right)}^{\text{selection}} \times d\pi\left(\mathbf{x}\right)}{T} \tag{4.2}$$

The extensive margin can decline for two reasons. Either fewer and fewer households adjust at the margin as the stimulus checks become larger. Or the marginal adjusters purchase smaller goods as the stimulus checks grow, compared to those who adjusted for smaller checks — a selection effect that is well known in the price setting literature (Golosov and Lucas, 2007).

To assess the relative contribution of these two effects, the dotted curve in Figure 4.3 plots the marginal propensity to adjust MP$\mathcal{S}$ (i.e., the increase in the probability of adjustment divided by the size of the stimulus check) as a function of the size of checks. As the stimulus check becomes larger, more and more households are pushed into adjustment (MP$\mathcal{S} > 0$) initially at a constant rate (MP$\mathcal{S}$ is flat) and eventually at a lower pace. Overall we find that increasing the size of stimulus checks from \$100 to \$2,000 increases the mass of adjusters by 2% or so, which is broadly consistent with the survey evidence from Fuster et al. (2021). The extensive margin declines immediately, whereas the MP$\mathcal{S}$ is flat initially. This means that the selection effect plays an important role. This effect is intu-

Figure 4.3: Extensive margin



Notes: The solid and dashed curves decompose the response of durable spending into its extensive and intensive margins. The dotted line plots the marginal propensity to adjust, i.e., the increase in the average hazard $\mathcal{S}$ divided by the size of the check.

itive: households who adjust in response to small income shocks were originally closer to their adjustment threshold and hence were more willing to purchase durables in the first place.

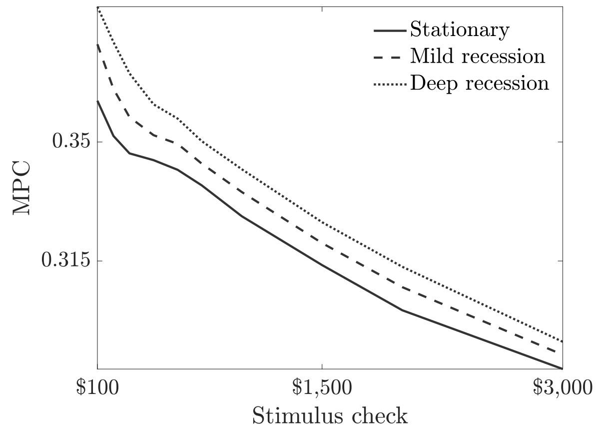
4.3 Aggregate Conditions

We then explore how aggregate conditions affect the MPC and its size-dependence. The right panel of Figure 4.1 plots the size-dependence in the MPC in two different recessions. The first recession is mild: the average household income declines (linearly) by -4% over three quarters and then recovers linearly over two years. The second recession is deeper: average income decline by 8% instead of 4%. The MPCs are mostly unchanged across recessions. If anything, the MPC is somewhat higher in deeper recessions, which is in-line with the evidence of Gross et al. (2020). In contrast, the canonical model of durable spending predicts a sharp decline in the MPC in deeper recessions through the mechanism put forth by Berger and Vavra (2015).

4.4 Aggregate Spending Response to Stimulus Checks

What does the size-dependence that we document imply for the response of aggregate spending to stimulus checks? Figure 4.5 plots the response of aggregate spending as a function of the size of stimulus checks. This exercise serves as an intermediate, partial

Figure 4.4: Aggregate conditions



Notes: 'Stationary' corresponds to the stationary equilibrium. 'Mild recession' corresponds to a recession where average household income declines linearly over four quarters with a through of 4% and then recovers linearly over two years. 'Deep recession' is the same with a decline of 8% instead. The right panel compares MPCs across models starting from a stationary equilibrium.

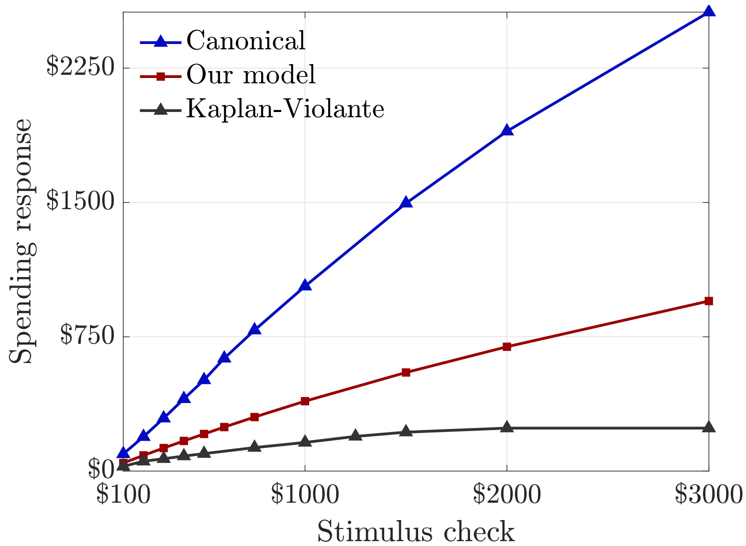
equilibrium step to our dynamic general equilibrium analysis where we quantify the size of the check that closes the output gap (Section 5).

The non-durables model of Kaplan and Violante (2014) (in black) predicts less and less bang-for-buck as stimulus checks become larger. Beyond $2000, larger checks become essentially ineffective at boosting aggregate spending. In contrast, our model (in red) predicts that stimulus checks remain effective even for larger checks. The spending response is still concave as the MPC declines (albeit slowly). A purely state-dependent model of durables (in blue) predicts a much stronger spending response and less size-dependence.

5 Stimulus Checks in General Equilibrium

In the rest of this paper, we use our model of households' spending to quantify the effect of stimulus checks in general equilibrium. We embed our model into a heterogenous agent New Keynesian setup that accounts for various forces that could mitigate the response to these stimulus checks. We start by closing the model (Section 5.1), and then parametrize it (Section 5.2). Next, we quantify the response to stimulus checks of various check sizes using in our model, and we compare these predictions with those of the canonical models of durables and non-durables (Section 5.3). Finally, we introduce supply side constraints and explore how they affect the response to stimulus checks). Numerical details are provided in Appendix A.5.

Figure 4.5: The response of aggregate spending



Notes: This figure plots the response of aggregate spending as a function of the size of stimulus checks. All responses assume that the economy starts at its stationary equilibrium.

5.1 Environment

Households. The household block of the economy is identical to the one introduced in Section 2. Households now receive a stimulus check from the government in the first period if they are eligible. We assume that households who have earned less than $\$75,000$ in the previous year receive a lump sum windfall T from the government. This windfall then decreases linearly with income and reached 0 at $\$80,000$.[26]

Workers import part of their durables and non-durables.[27] These imports dampen the general equilibrium response to stimulus checks. Households' consumption c_t and investment x_t are given by

$$c_t = \left[\sum_{j \in \{H,F\}} \left(\alpha_j^c\right)^{\frac{1}{\rho}} \left(c_t^j\right)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}} \quad \text{and} \quad x_t = \left[\sum_{j \in \{H,F\}} \left(\alpha_j^d\right)^{\frac{1}{\rho}} \left(x_t^j\right)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}, \tag{5.1}$$

where c_t^H and c_t^F are the consumptions of the domestic and foreign goods, respectively, and the weights $\alpha_H^c + \alpha_F^c = 1$ governs the spending share on domestic and foreign goods. The terms x_t^H, x_t^F and α_H^d, α_H^F are defined similarly for investment in durables. We set the elasticity of substitution to $\rho = 2$ in our benchmark calibration. This value lies between

[26] These features mimick the ones of the stimulus checks sent in the U.S. during the COVID recession. We consider alternative thresholds in an extension.

[27] For instance, a fourth of durable expenditure is spent on foreign goods in the US.

the short-run and long-run estimates of Boehm et al. (2023).[28] In the following, we let P_t^c and P_t^d denote the price of the consumption baskets (5.1) expressed in terms of the domestic good. The country can run a current account deficit (i.e., borrow from the rest of the world) to finance its imports. The demands from the rest of the world are similar to (5.1). *Total* consumption of non-durables $c_t^\star$ and investment in durables $x_t^\star$ in the rest of the world are constant and chosen so there are no net imports at the steady state.

Supply and price setting. The economy consist of two sectors: one produces the non-durable good, the other produces the consumer durable good. These goods are produced by competitive firms, subject to sticky wages (or prices). We do not microfound the wage and price setting processes since they are not the focus of the paper. Instead, we assume that inflation in the price of the domestic non-durable good (π_t) follows an ad-hoc Phillips curve[29]

$$\pi_t = \kappa \log\left(\frac{C_t^{\text{dom}}}{C_t^{\text{potent}}}\right) + \beta\pi_{t+1}, \tag{5.2}$$

where C_t^{dom} is the aggregate demand for non-durables produced domestically, C_t^{potent} is potential output in that sector, and $\kappa > 0$ is the slope of the Phillips curve. Following McKay and Wieland (2021) and Orchard et al. (2022), we assume that the supply of investment goods are partially elastic. Prices relative to the non-durable good are

$$p_t^d \equiv \left(\frac{X_t^{\text{dom}}}{X_t^{\text{potent}}}\right)^{1/\zeta} \tag{5.3}$$

where X_t^{dom} is the aggregate demand for durables produced domestically, X_t^{potent} is potential output in that sector, I_t is firm investment, I_t^{potent} is potential output in that sector, and $\zeta > 0$ are the supply elasticities. We will first assume that potential output are equal to the steady state demands (Section 5.3), before allowing for supply side, inflationary shocks (Section **??**).

The price of the foreign good is fixed throughout. The nominal exchange rate is pinned down by purchasing power parity in the long-run, and uncovered interest rate parity during the transition (Appendix A.3). Domestic and foreign prices are normalized to 1 at the initial stationary equilibrium.

[28] This value also falls between the short-run estimate of Auer et al. (2021) using border prices, and the long-run estimates of Caliendo and Parro (2015).

[29] We do not make the distinction between sticky prices and wages, since we effectively assume that workers claim both the wage bills and profits in proportion to their idiosyncratic productivity.

Aggregate demand shifters. The economy experiences investment shocks. They act as aggregate demand shifters and can push the economy into demand-driven recessions.[30] We keep that part of the model purposefully simple. We assume that an investment firm invests using the durable good and produces the same good using the technology AK_{t-1} where K_{t-1} is the stock of capital. This stock evolves as

$$K_t = \left\{1 - \delta^K + \Phi\left(I_t/K_{t-1}\right) + z_t\right\} K_{t-1}, \tag{5.4}$$

with initial condition $K_{-1} = K$ at the steady state, where I_t is investment, δ^K is the depreciation rate of capital, and $\Phi(x)$ is the adjustment cost which is increasing and concave.[31] As in Brunnermeier and Sannikov (2014), the depreciation shocks $\{z_t\}$ are the source of aggregate fluctuations in our economy. The firm smoothes dividends (Leary and Michaely, 2011), so investment shocks affect households' incomes and hence their aggregate demand.[32]

Policy. Monetary policy follows a standard rule

$$r^m_t = \max\left\{r^m + \phi_\Pi \pi^{\text{CPI}}_t + \phi_y \hat{Y}_t, \underline{r}\right\}, \tag{5.5}$$

where r^m is the steady state return, π^{CPI}_t is CPI inflation, ϕ_Π and ϕ_y parametrize the rule, and $\underline{r}$ is the effective lower bound.[33] The government finances stimulus checks and government spending by taxing households' income. It also claims the households' net payments on the illiquid asset.[34] The government's flow budget constraint is

$$B^g_t = \frac{1 + r_t}{1 + \pi_t} B^g_{t-1} + \mathcal{T}_t + \Sigma_t - t_t - G_t, \tag{5.6}$$

where B^g_t is the government's real asset holdings, $\mathcal{T}_t \equiv \int \left(y - \psi_{0,t} y^{1-\psi_1}\right) d\mu_{t-1} \times E_t$ is tax revenues where E_t denotes households' total real income, t_t is real stimulus checks to

[30] Firms investment shocks are the main driver of US business cycle fluctuations (Justiniano and Primiceri, 2008; Auclert et al., 2020). Beyond their realism, investment shocks also allow us to compute efficiently the sequence of shocks that produce a given recession of interest (Appendix A.5) despite the non-linearities inherent to our model.

[31] This specification with a linear technology and concave adjustment costs is common in the asset pricing literature (Jermann, 1998; Brunnermeier and Sannikov, 2014).

[32] Absent dividend smoothing, investment raises output but not incomes in presence of nominal rigidities — as is evident from (5.8)–(5.9) below. We describe the dividend smoothing in more details when we discuss the parametrization in Section 5.2.

[33] The CPI index is $P^{\text{CPI}}_t = \omega_c P^c_t + \omega_d P^d_t$, where ω^c and ω^d are spending shares at the steady state. In turn, CPI inflation is $\pi^{\text{CPI}}_t \equiv P^{\text{CPI}}_t / P^{\text{CPI}}_{t-1} - 1$.

[34] An alternative would be to introduce a separate financial sector.

households, G_t is the government consumption of non-durables, and

$$\Sigma_t \equiv (1-\theta)(1-\delta)\left\{\left(1+r_{t-1}^b\right)P_t^d D_{t-1} - P_{t+1}^d D_t\right\} \tag{5.7}$$

is the net payments on the illiquid asset where $D_t \equiv \int d'(\mathbf{x}) \times \mu_{t-1}(d\mathbf{x})$ denotes aggregate durable holdings. As in our baseline calibration, the government maintains a constant ratio of debt to output at the stationary equilibrium, and taxes income at a constant rate $\tau_t = \tau$. Its spending $G > 0$ on domestic goods balances the budget (5.6). In period $t = 0$, the government sends a one-time nominal stimulus check $T_0 > 0$ to every household. It borrows $(\Delta B_1 < 0)$ to finance these checks. In subsequent periods $t > 0$, the government maintains a constant spending $G_t = G > 0$ and repays its new debt over time.

Resource constraint. The aggregate resource constraint is[35]

$$P_t^c C_t + P_t^d X_t + \mathrm{TB}_t\left(e_t, P_t^c, P_t^d\right) + G + p_t^d Z_t = Y_t \tag{5.8}$$

in each period $t \geq 0$, where C_t and X_t are the households' aggregate demands for the non-durable and investment good, respectively, $Z_t \equiv P_t^k \{I_t - f(K_{t-1})\}$ are the effective investment shocks, and the trade balance TB_t is given by (A.30) in Appendix A.3. Households' real net income before interest rate payments is

$$E_t^{\mathrm{net}}(\mathbf{x}) = \psi_{0,t}\{y(Y_t + \mathrm{Div}_t)\}^{1-\psi_1}, \tag{5.9}$$

where y still captures idiosyncratic income shocks, and real dividends Div_t smooth profits $\pi_t = -Z_t$ over time. Note that (5.8)–(5.9) define a *non-linear* Keynesian cross where spending determines incomes and incomes feed back into spending.

5.2 Parametrization

As in our baseline calibration (Section 3), the interest rate is $r = 1\%$ at the stationary equilibrium, aggregate income is $E_t \equiv 1$, the government maintains a constant ratio of debt to output $-B/Y = 104\%$, and income taxes are $\tau_t = \tau = 30\%$. Households import 23% of their durable spending at the steady state, and 19% of their non-durable spending (Hale et al., 2019). The investment adjustment cost is $\Phi(x) = 1/\phi\left(\sqrt{1+2\phi x} - 1\right)$ with $\phi \equiv 2$, following Brunnermeier and Sannikov (2014). The productivity of the investment

[35] Government spending G and firms' investment Z_t are in local goods only, whereas households' consumption C_t and investment in durables X_t use both local and foreign goods. Hence the different price indices in (5.8).

firm A is chosen so there is no long-run growth. The slope of the Phillips curve is $\kappa = 0.1$ and the Taylor coefficients are $\phi_\Pi = 1.5$ and $\phi_y = 0$ as in Auclert et al. (2021). We set the supply elasticity to $\zeta \equiv 5$, following Orchard et al. (2022). In our benchmark calibration, the government slowly repays the debt it contracted to finance the stimulus checks by raising tax rate $\psi_{0,t}$ uniformly over 15 years, and then let it decay to its long-run value $\tau = 30\%$ over 5 years. Similarly, we assume that the investment firm adjusts its dividend Div_t uniformly to disburse profits, and then lets it decay linearly over the same time frame.

5.3 Demand-Driven Recessions

We are now ready to quantify the effect of stimulus checks in general equilibrium. We first focus on demand-driven recessions where labor markets are effectively slack. We capture this in our model by abstracting from relative price movements ($\zeta = 0$) and by assuming that potential output are equal to the steady state levels. We relax these assumptions in Section **??**.

We suppose that the economy experiences a persistent investment shock such that output contracts over three quarters (by -4%) and then recovers linearly over the next two years.[36] Starting from this point, we are interested in the general equilibrium response of output following stimulus checks of various sizes. We build this response in steps, by introducing one feature of the model at a time.

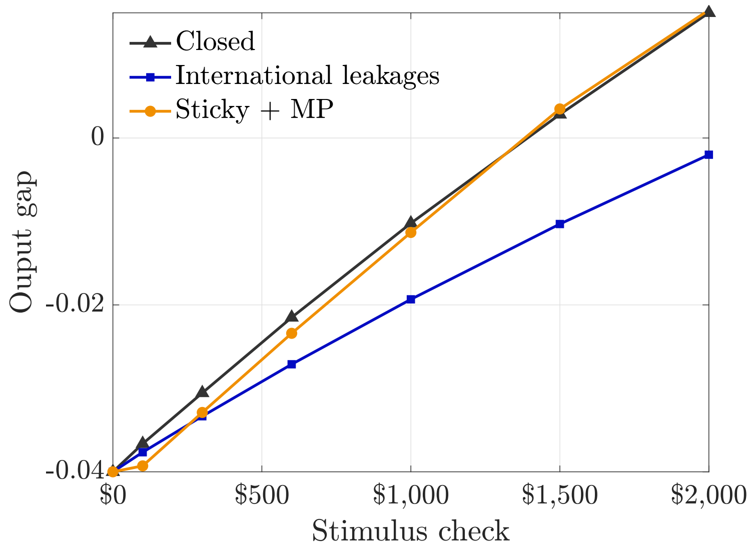
Closed economy. We plot the output gap as a function of the stimulus checks in Figure 5.1. We first consider a closed economy $\left(\alpha_d^F = \alpha_c^F = 0\right)$ with rigid prices ($\kappa = 0$). Compared to Figure 4.5 in Section 4.4, our model captures the full, intertemporal response to stimulus checks in general equilibrium (black line). As the checks grow larger, the government still enjoys a relatively large bang-for-buck. A \$1,400 check (or 8.5% of the average quarterly income) closes the output gap in a typical recession.[37]

International leakages. The blue line plots the response of the output gap when we account for imports. The bang-for-the-buck is smaller, as part of the additional spending is directed towards foreign goods (i.e., it "leaks" abroad) and does not raise domestic incomes. A \$2,000 stimulus check now fully closes the output gap in a typical recession,

[36] We solve the model globally to capture the non-linearities in spending and allow for an occasionally-binding zero lower bound for the interest rate. Therefore, the usual linear perturbation methods (Auclert et al., 2021) that allow to back out a sequence of shocks do not apply. We propose an efficient approach to compute the sequence of investment shocks $\{z_t\}$ that induces a specific sequence of output $\{Y_t\}$ in our non-linear model (Appendix A.5).

[37] We assume an average quarterly income of \$16,500 as in Kaplan et al. (2018).

Figure 5.1: Closing the output gap



Notes: The black line corresponds to a closed economy with rigid prices. The blue line corresponds to an open economy with rigid prices. Finally, the orange line corresponds to an open economy with sticky prices, active monetary policy, and an occasionally binding zero lower bound.

compared to $1,400 in the closed economy.

Inflation and monetary policy. Finally, price and interest rate movements affect the response to stimulus checks. We plot the response of the output gap in an open economy when allowing for a Phillips curve (5.2) and active monetary policy with an occasionally binding zero lower bound (5.5). The response is muted for small checks. The zero lower bound binds during the recession and deflation increases the interest rate. This increase in the user cost decreases the MPC on durables in recessions. For larger checks, the response is substantially stronger compared to the open economy with fully rigid prices. The inflation generated by the checks now lowers the real interest rate, amplifying their stimulus.[38] Overall, the response is similar to the closed economy with rigid prices. A check of roughly $1400 again fully closes the output gap.

Capacity constraints. In extensions, we will allow for capacity constraints and relative price movements. The results will be added to this draft in the coming weeks.

[38] It is well-known that fiscal and transfer multipliers can be much larger when the zero lower bound binds (Farhi and Werning (2016)).

6 Conclusions

We augment a canonical incomplete-markets model of durable spending by introducing a smooth adjustment hazard. The marginal propensity to spend (MPC) can be decreasing, essentially flat, or increasing depending on how steep the adjustment hazard is. We discipline the shape of the hazard by matching evidence on (i) the relative MPCs of durables and non-durables; (ii) the short-run price elasticity of durables; (iii) the size distribution of adjustments; and (iv) the conditional probability of adjustment since the last purchase. We use the model to quantify the size-dependence in the MPC and how large stimulus checks need to be to close the output gap in a recession.

We find that the MPC declines slowly with the size of stimulus checks. A $600 check closes roughly half the output gap in a typical US recession. This check is half as large than in a canonical model of non-durable spending with the same MPC out of a small transfer, and three times larger than in a canonical model of durables. A relevant upper bound for policymakers is the check that fully closes the output gap. Larger checks are too much in that they overheat the economy. Across alternative model specifications, we find that checks beyond the $1,500 to $2,000 range overheat the economy in a typical recession.

References

Adams, William, Liran Einav, and Jonathan Levin, "Liquidity Constraints and Imperfect Information in Subprime Lending," *American Economic Review*, March 2009, *99* (1), 49–84.

Agarwal, Nikhil and Paulo Somaini, "Revealed Preference Analysis of School Choice Models," *Annual Review of Economics*, 2020, *12* (1), 471–501.

Aguiar, Mark A, Mark Bils, and Corina Boar, "Who Are the Hand-to-Mouth?," Working Paper 26643, National Bureau of Economic Research January 2020.

Alvarez, Fernando E., Francesco Lippi, and Aleksei Oskolkov, "The Macroeconomics of Sticky Prices with Generalized Hazard Functions," NBER Working Papers 27434, National Bureau of Economic Research, Inc June 2020.

_ , Katarína Borovičková, and Robert Shimer, "Consistent Evidence on Duration Dependence of Price Changes," NBER Working Papers 29112, National Bureau of Economic Research, Inc July 2021.

Alvarez, Fernando, Francesco Lippi, and Juan Passadore, "Are State- and Time-Dependent Models Really Different?," in "NBER Macroeconomics Annual 2016, Volume 31" NBER Chapters, National Bureau of Economic Research, Inc, January 2016, pp. 379–457.

—, Hervé Le Bihan, and Francesco Lippi, "The Real Effects of Monetary Shocks in Sticky Price Models: A Sufficient Statistic Approach," *American Economic Review*, October 2016, *106* (10), 2817–51.

Argyle, Bronson S, Taylor D Nadauld, and Christopher J Palmer, "Monthly Payment Targeting and the Demand for Maturity," *The Review of Financial Studies*, 01 2020, *33* (11), 5416–5462.

Artuç, Erhan, Shubham Chaudhuri, and John McLaren, "Trade Shocks and Labor Adjustment: A Structural Empirical Approach," *American Economic Review*, June 2010, *100* (3), 1008–1045.

Attanasio, Orazio, Kieran Larkin, Morten O. Ravn, and Mario Padula, "(S)Cars and the Great Recession," *Econometrica*, September 2022, *90* (5), 2319–2356.

Attanasio, Orazio P., Pinelopi Koujianou Goldberg, and Ekaterini Kyriazidou, "Credit Constraints In The Market For Consumer Durables: Evidence From Micro Data On Car Loans," *International Economic Review*, May 2008, *49* (2), 401–436.

Auclert, Adrien, Bence Bardóczy, Matthew Rognlie, and Ludwig Straub, "Using the Sequence-Space Jacobian to Solve and Estimate Heterogeneous-Agent Models," *Econometrica*, September 2021, *89* (5), 2375–2408.

—, Matthew Rognlie, and Ludwig Straub, "The Intertemporal Keynesian Cross," NBER Working Papers 25020, National Bureau of Economic Research, Inc September 2018.

—, —, and —, "Micro Jumps, Macro Humps: Monetary Policy and Business Cycles in an Estimated HANK Model," NBER Working Papers 26647, National Bureau of Economic Research, Inc January 2020.

Auer, Raphael, Ariel Burstein, and Sarah M. Lein, "Exchange Rates and Prices: Evidence from the 2015 Swiss Franc Appreciation," *American Economic Review*, February 2021, *111* (2), 652–686.

Bachmann, Ruediger, Benjamin Born, Olga Goldfayn-Frank, Georgi Kocharkov, Ralph Luetticke, and Michael Weber, "A Temporary VAT Cut as Unconventional Fiscal Policy," NBER Working Papers 29442, National Bureau of Economic Research, Inc October 2021.

Beraja, Martin, "A Semistructural Methodology for Policy Counterfactuals," *Journal of Political Economy*, 2023, *131* (1), 000–000.

_ , Andreas Fuster, Erik Hurst, and Joseph Vavra, "Regional Heterogeneity and the Refinancing Channel of Monetary Policy," *The Quarterly Journal of Economics*, 2019, *134* (1), 109–183.

Berger, David and Joseph Vavra, "Measuring How Fiscal Shocks Affect Durable Spending in Recessions and Expansions," *American Economic Review*, May 2014, *104* (5), 112–115.

_ and _ , "Consumption Dynamics During Recessions," *Econometrica*, January 2015, *83*, 101–154.

_ , Konstantin Milbradt, Fabrice Tourre, and Joseph Vavra, "Mortgage Prepayment and Path-Dependent Effects of Monetary Policy," *American Economic Review*, September 2021, *111* (9), 2829–2878.

Berry, Steven, James Levinsohn, and Ariel Pakes, "Automobile Prices in Market Equilibrium," *Econometrica*, July 1995, *63* (4), 841–890.

_ , _ , and _ , "Differentiated Products Demand Systems from a Combination of Micro and Macro Data: The New Car Market," *Journal of Political Economy*, February 2004, *112* (1), 68–105.

Bertola, Giuseppe and Ricardo J. Caballero, "Kinked Adjustment Costs and Aggregate Dynamics," in "NBER Macroeconomics Annual 1990, Volume 5" NBER Chapters, National Bureau of Economic Research, Inc, March 1990, pp. 237–296.

Boehm, Christoph E., Andrei A. Levchenko, and Nitya Pandalai-Nayar, "The Long and Short (Run) of Trade Elasticities," *American Economic Review*, April 2023, *113* (4), 861–905.

Brunnermeier, Markus K. and Yuliy Sannikov, "A Macroeconomic Model with a Financial Sector," *American Economic Review*, February 2014, *104* (2), 379–421.

Caballero, Ricardo J, "Durable Goods: An Explanation for Their Slow Adjustment," *Journal of Political Economy*, April 1993, *101* (2), 351–384.

Caballero, Ricardo J. and Eduardo M.R.A. Engel, "Price stickiness in Ss models: New interpretations of old results," *Journal of Monetary Economics*, September 2007, *54* (Supplemen), 100–121.

Caliendo, Lorenzo and Fernando Parro, "Estimates of the Trade and Welfare Effects of NAFTA," *Review of Economic Studies*, 2015, *82* (1), 1–44.

_, Maximiliano Dvorkin, and Fernando Parro, "Trade and Labor Market Dynamics: General Equilibrium Analysis of the China Trade Shock," *Econometrica*, May 2019, *87* (3), 741–835.

Carroll, Christopher and Miles Kimball, "On the Concavity of the Consumption Function," *Econometrica*, 1996, *64* (4), 981–92.

Carroll, Christopher D., "The method of endogenous gridpoints for solving dynamic stochastic optimization problems," *Economics Letters*, June 2006, *91* (3), 312–320.

Chen, Jiawei, Susanna Esteban, and Matthew Shum, "When Do Secondary Markets Harm Firms?," *American Economic Review*, December 2013, *103* (7), 2911–2934.

Coibion, Olivier, Yuriy Gorodnichenko, and Mauricio Ulate, "The Cyclical Sensitivity in Estimates of Potential Output," *Brookings Papers on Economic Activity*, 2018, *49* (2 (Fall)), 343–441.

_, _, and Michael Weber, "How Did U.S. Consumers Use Their Stimulus Payments?," NBER Working Papers 27693, National Bureau of Economic Research, Inc August 2020.

Dotsey, Michael, Robert G. King, and Alexander L. Wolman, "State-Dependent Pricing and the General Equilibrium Dynamics of Money and Output," *The Quarterly Journal of Economics*, 1999, *114* (2), 655–690.

Druedahl, Jeppe and Thomas Høgholm Jørgensen, "A general endogenous grid method for multi-dimensional models with non-convexities and constraints," *Journal of Economic Dynamics and Control*, 2017, *74* (C), 87–107.

Eberly, Janice C, "Adjustment of Consumers' Durables Stocks: Evidence from Automobile Purchases," *Journal of Political Economy*, June 1994, *102* (3), 403–436.

Fagereng, Andreas, Martin B. Holm, and Gisle J. Natvik, "MPC Heterogeneity and Household Balance Sheets," *American Economic Journal: Macroeconomics*, October 2021, *13* (4), 1–54.

Farhi, E. and I. Werning, "Chapter 31 - Fiscal Multipliers," in John B. Taylor and Harald Uhlig, eds., *Handbook of Macroeconomics*, Vol. 2, Elsevier, 2016, pp. 2417–2492.

Farhi, Emmanuel and Iván Werning, "Fiscal unions," *American Economic Review*, 2017, *107* (12), 3788–3834.

Floden, Martin and Jesper Lindé, "Idiosyncratic Risk in the United States and Sweden: Is There a Role for Government Insurance?," *Review of Economic Dynamics*, July 2001, *4* (2), 406–437.

Fuster, Andreas, Greg Kaplan, and Basit Zafar, "What Would You Do with $500? Spending Responses to Gains, Losses, News, and Loans [The Spending and Debt Response to Minimum Wage Hikes]," *Review of Economic Studies*, 2021, *88* (4), 1760–1795.

Gavazza, Alessandro and Andrea Lanteri, "Credit Shocks and Equilibrium Dynamics in Consumer Durable Goods Markets," *The Review of Economic Studies*, 03 2021, *88* (6), 2935–2969.

Golosov, Mikhail and Robert E. Lucas, "Menu Costs and Phillips Curves," *Journal of Political Economy*, 2007, *115*, 171–199.

_ , Michael Graber, Magne Mogstad, and David Novgorodsky, "How Americans Respond to Idiosyncratic and Exogenous Changes in Household Wealth and Unearned Income," NBER Working Papers 29000, National Bureau of Economic Research, Inc July 2021.

Gowrisankaran, Gautam and Marc Rysman, "Dynamics of Consumer Demand for New Durable Goods," *Journal of Political Economy*, 2012, *120* (6), 1173–1219.

Graziani, Grant, Wilbert van der Klaauw, and Basit Zafar, "Workers' Spending Response to the 2011 Payroll Tax Cuts," *American Economic Journal: Economic Policy*, November 2016, *8* (4), 124–159.

Green, Daniel, Brian T. Melzer, Jonathan A. Parker, and Arcenis Rojas, "Accelerator or Brake? Cash for Clunkers, Household Liquidity, and Aggregate Demand," *American Economic Journal: Economic Policy*, November 2020, *12* (4), 178–211.

Gross, Tal, Matthew J. Notowidigdo, and Jialan Wang, "The Marginal Propensity to Consume over the Business Cycle," *American Economic Journal: Macroeconomics*, April 2020, *12* (2), 351–384.

Guerrieri, Veronica and Guido Lorenzoni, "Credit Crises, Precautionary Savings, and the Liquidity Trap," *The Quarterly Journal of Economics*, 2017, *132* (3), 1427–1467.

Hale, Galina, Bart Hobijn, Fernanda Nechio, and Doris Wilson, "How Much Do We Spend on Imports?," *FRBSF Economic Letter*, 2019.

Havranek, Tomas and Anna Sokolova, "Do Consumers Really Follow a Rule of Thumb? Three Thousand Estimates from 144 Studies Say 'Probably Not'," *Review of Economic Dynamics*, January 2020, *35*, 97–122.

Heathcote, Jonathan, Kjetil Storesletten, and Giovanni L Violante, "Optimal Tax Progressivity: An Analytical Framework," *The Quarterly Journal of Economics*, 2017, *132* (4), 1693–1754.

Heitfield, Erik and Tarun Sabarwal, "What Drives Default and Prepayment on Subprime Auto Loans?," *The Journal of Real Estate Finance and Economics*, December 2004, *29* (4), 457–477.

House, Christopher L., "Fixed costs and long-lived investments," *Journal of Monetary Economics*, 2014, *68*, 86 – 100.

Iskhakov, Fedor, Thomas H. Jørgensen, John Rust, and Bertel Schjerning, "The endogenous grid method for discrete-continuous dynamic choice models with (or without) taste shocks," *Quantitative Economics*, July 2017, *8* (2), 317–365.

Jappelli, Tullio and Luigi Pistaferri, "Fiscal Policy and MPC Heterogeneity," *American Economic Journal: Macroeconomics*, October 2014, *6* (4), 107–136.

Jermann, Urban J., "Asset pricing in production economies," *Journal of Monetary Economics*, April 1998, *41* (2), 257–275.

Justiniano, Alejandro and Giorgio E. Primiceri, "The Time-Varying Volatility of Macroeconomic Fluctuations," *American Economic Review*, June 2008, *98* (3), 604–641.

Kaplan, Greg and Giovanni L. Violante, "A Model of the Consumption Response to Fiscal Stimulus Payments," *Econometrica*, July 2014, *82* (4), 1199–1239.

— **and** — , "The Marginal Propensity to Consume in Heterogeneous Agent Models," NBER Working Papers 30013, National Bureau of Economic Research, Inc May 2022.

— **, Benjamin Moll, and Giovanni L. Violante**, "Monetary Policy According to HANK," *American Economic Review*, March 2018, *108* (3), 697–743.

— **, Giovanni L. Violante, and Justin Weidner**, "The Wealthy Hand-to-Mouth," *Brookings Papers on Economic Activity*, 2014, *45* (1 (Spring), 77–153.

Laibson, David, Peter Maxted, and Benjamin Moll, "Present Bias Amplifies the Household Balance-Sheet Channels of Macroeconomic Policy," NBER Working Papers 29094, National Bureau of Economic Research, Inc July 2021.

— **,** — **, and** — , "A Simple Mapping from MPCs to MPXs," NBER Working Papers 29664, National Bureau of Economic Research, Inc January 2022.

Leary, Mark T. and Roni Michaely, "Determinants of Dividend Smoothing: Empirical Evidence," *The Review of Financial Studies*, 10 2011, *24* (10), 3197–3249.

Lewis, Daniel J, Davide Melcangi, and Laura Pilossoph, "Latent heterogeneity in the marginal propensity to consume," *FRB of New York Staff Report*, 2019, (902).

Luengo-Prado, Maria Jose, "Durables, nondurables, down payments and consumption excesses," *Journal of Monetary Economics*, October 2006, *53* (7), 1509–1539.

Matějka, Filip and Alisdair McKay, "Rational inattention to discrete choices: A new foundation for the multinomial logit model," *American Economic Review*, 2015, *105* (1), 272–298.

McFadden, Daniel, *Conditional Logit Analysis of Qualitative Choice Behavior*, Institute of Urban and Regional Development, University of California, 1973.

— , "Economic Choices," *American Economic Review*, June 2001, *91* (3), 351–378.

McKay, Alisdair and Christian K. Wolf, "Optimal Policy Rules in HANK," MIIT Mimeo 2023.

— **and Johannes F. Wieland**, "Lumpy Durable Consumption Demand and the Limited Ammunition of Monetary Policy," *Econometrica*, November 2021, *89* (6), 2717–2749.

— **and** — , "Forward Guidance and Durable Goods Demand," *American Economic Review: Insights*, March 2022, *4* (1), 106–22.

Misra, Kanishka and Paolo Surico, “Consumption, Income Changes, and Heterogeneity: Evidence from Two Fiscal Stimulus Programs,” *American Economic Journal: Macroeconomics*, October 2014, *6* (4), 84–106.

Nevo, Aviv, “Measuring Market Power in the Ready-to-Eat Cereal Industry,” *Econometrica*, March 2001, *69* (2), 307–342.

of Transportation", "United States Department, “National Transportation Statistics, Table 1-17,” Technical Report 2023.

Orchard, Jacob, Valerie A. Ramey, and Johannes F. Wieland, “Micro MPCs and Macro Counterfactuals: The Case of the 2008 Rebates,” Technical Report, UCSD Mimeo 2022.

Parker, Jonathan A., Nicholas S. Souleles, David S. Johnson, and Robert McClelland, “Consumer Spending and the Economic Stimulus Payments of 2008,” *American Economic Review*, October 2013, *103* (6), 2530–2553.

Rouwenhorst, Geert, *Asset Pricing Implications of Equilibrium Business Cycle Models'*, Vol. Chapter 10, Frontiers of Business Cycle Research, Princeton University Press, 1995.

Sahm, Claudia R, Matthew D Shapiro, and Joel Slemrod, “Check in the mail or more in the paycheck: does the effectiveness of fiscal stimulus depend on how it is delivered?,” *American Economic Journal: Economic Policy*, 2012, *4* (3), 216–250.

Shapiro, Matthew D. and Joel Slemrod, “Did the 2008 Tax Rebates Stimulate Spending?,” *American Economic Review*, May 2009, *99* (2), 374–379.

Souleles, Nicholas S., “The Response of Household Consumption to Income Tax Refunds,” *American Economic Review*, September 1999, *89* (4), 947–958.

_ , Jonathan A. Parker, and David S. Johnson, “Household Expenditure and the Income Tax Rebates of 2001,” *American Economic Review*, December 2006, *96* (5), 1589–1610.

Wolf, Christian K., “Interest Rate Cuts vs. Stimulus Payments: An Equivalence Result,” Mimeo, MIT August 2021.

_ and Alisdair McKay, “What Can Time-Series Regressions Tell Us About Policy Counterfactuals?,” NBER Working Papers 30358, National Bureau of Economic Research, Inc August 2022.

Young, Eric R., “Solving the incomplete markets model with aggregate uncertainty using the Krusell-Smith algorithm and non-stochastic simulations,” *Journal of Economic Dynamics and Control*, January 2010, *34* (1), 36–41.

A Quantitative Appendix

In this appendix, we discuss the numerical solution of the income fluctuations problem. Section A.1 states the problem recursively for the full model. The intermediate model is a hybrid between the two. Section A.2 discuss the numerical implementation.

A.1 Households' Problem

We now state the household's problem recursively. The household is indexed by three idiosyncratic states: their holdings of durables (d); their holdings of liquid asset (m); and their idiosyncratic income (y). In the following, we let $\mathbf{x} \equiv (d, z, y)$ to save on notation. We state the general problem where the price of the consumption (P^c) and investment (P^d) goods might not be equal to anticipate the open economy case (Section 5).

Continuation values. We follow the steps below to compute recursively a sequence a continuation values $\{V_t(\cdot)\}$.[39]

1. **Consumption-saving.** The household chooses how much to consume and save in liquid asset

$$W_t^C(\mathbf{x}) \equiv \max_{c,m'} u(c,d) + \beta \int V_{t+1}(d, m', y') \, \Gamma(dy'; y) \tag{A.1}$$
$$\text{s.t. } P_t^c c + m' \leq m \quad \text{and} \quad m' \geq 0,$$

2. **Durable adjustment.** The household chooses how much durables to purchase

$$W_t^D(m,y) \equiv \max_{d',m'} W_t^C(d', m', y) \tag{A.2}$$
$$\text{s.t. } \left[P_t^d - (1-\theta) P_{t+1}^d (1-\delta)\right] d' + m' \leq m$$

3. **Discrete choice.** Finally, the household chooses whether to adjust her stock of durables. The value associated to the discrete choice problem is[40]

$$V_t(\mathbf{x}) \equiv \eta \log \left(\sum_{h \in \{D,C\}} \exp\left(\frac{W_t^{\star,h}(\mathbf{x})}{\eta} \right) \right) \tag{A.3}$$

[39] The terminal condition for $V_{t+1}(\cdot)$ is the stationary value when $T_t = 0$ in each period t.
[40] See Artuç et al. (2010) for the derivation.

where

$$W_t^{\star,D}(\mathbf{x}) \equiv W_t^D\left(\, \mathcal{Y}(\mathbf{x};T_t) + \theta P_t^d (1-\delta)\, d, y \,\right) - \kappa \tag{A.4}$$

$$W_t^{\star,C}(\mathbf{x}) \equiv W_t^C\left(\, (1-(1-\iota)\,\delta)\, d, \mathcal{Y}(\mathbf{x};T_t) - \Delta_t d - \iota\delta P_t^d d, y \,\right) \tag{A.5}$$

and

$$\begin{aligned} \mathcal{Y}(\mathbf{x};T_t) \equiv & \left(1-\tau^l\right) y + \left(1 + r_{t-1}^m\right) m \\ & - r_{t-1}^b (1-\theta)\, P_t^d (1-\delta)\, d + T_t \end{aligned} \tag{A.6}$$

is cash-on-hand, and

$$\Delta_t \equiv (1-\theta)\,(1-\delta) \times \left\{ P_t^d - P_{t+1}^d \left(1-(1-\iota)\,\delta\right) \right\} \tag{A.7}$$

captures the debt payment on the principal. The associated adjustment hazard is

$$\mathcal{S}_t(\mathbf{x}) \equiv \frac{\exp\left(\frac{W_t^{\star,D}(\mathbf{x})}{\eta}\right)}{\sum_{h' \in \{D,C\}} \exp\left(\frac{W_t^{\star,h'}(\mathbf{x})}{\eta}\right)} \tag{A.8}$$

In the fully state-dependent limit $\eta \to 0$, the value (A.3) and hazard (A.8) become

$$V_t(\mathbf{x}) \equiv \max_{h \in \{D,C\}} \left\{ W_t^{\star,h}(\mathbf{x}) \right\} \quad \text{and} \quad \mathcal{S}_t(\mathbf{x}) = \begin{cases} 1 & \text{if } W_t^{\star,D}(\mathbf{x}) > W_t^{\star,C}(\mathbf{x}) \\ 0 & \text{otherwise} \end{cases} \tag{A.9}$$

A.2 Numerical Implementation

We now describe how we solve numerically for the value functions defined above, and how we iterate on the associated policy functions to obtain aggregate quantities.

Value functions. We proceed as follows

1. **Guess.** Fix an initial guess for $\mathcal{V}(\mathbf{x}) \equiv \int V(d,z,y')\,\Gamma(dy';y)$. Let $\mathcal{V}_z(\cdot) \equiv \partial_z \mathcal{V}(\cdot)$ for the durable and liquid assets $z \in \{d,m\}$.

2. **Consumption-saving.** Fix the (terminal) states / policies (d,y). Consider sequentially the two cases described below.

   (a) *Borrowing constraint not binding*. If the household's borrowing constraint $m' \geq 0$

is not binding, a necessary condition for an optimum is

$$u_c\left(c,d\right)=\beta P_t^c\mathcal{V}_m\left(d,z',y\right),\tag{A.10}$$

together with the budget constraint $c=m-m'$. These conditions are not sufficient, however, since the problem is typically non-convex.[41,42] To recover policy functions, i.e., maps $z\mapsto(c,m')$, we proceed as follows. We first obtain maps $m'\mapsto(c,m)$ using the endogenous grid method (EGM) of Carroll (2006). The (generalized) inverse of this map (as a function of m) might contain several points since the problem is non-convex. These points define a set of candidates, together with $m'=0$ (and the upper bound of the grid for m). The optimum is found by comparing the values of the objective in (A.1) associated to each candidate. We recover the policy functions using an approach similar Druedahl and Jørgensen (2017). Fix some m on the grid of interest. Find the couples (m_0',m_1') such that the couple (m_0,m_1) recovered by EGM are such that $m_0\leq m\leq m_1$. Then, interpolate linearly the value of m' at m using (m_0,m_1) and (m_0',m_1') and compare the value of the objective for this value of m'. The policy function $m\mapsto m'$ is the one that provides the highest value, and $m\mapsto c$ is recovered using the budget constraint. Whenever this policy violates the borrowing constraint $m'\geq 0$, consider instead the next case. Otherwise, proceed to Step 3.

(b) *Borrowing constraint binding*. If the household's borrowing constraint $m'\geq 0$ is binding, holdings of the liquid asset are $m'=0$ and non-durable consumption equals cash-on-hand $c=m$.

Using the resulting policy function $m'(\cdot)$, compute the value $W^C(\mathbf{x})$ using (A.1), and the marginal values

$$\partial_d W^C(\mathbf{x})=u_d\left(m-m'(\cdot),d\right)+\beta\mathcal{V}_d\left(d,m'(\cdot),y\right)\tag{A.11}$$

$$\partial_m W^C(\mathbf{x})=1/P_t^c u_c\left(m-m'(\cdot),d\right)\tag{A.12}$$

[41] The reason is that the continuation value involves the upper envelopes (A.3) and (A.9). Random fixed adjustment costs for durables can make continuation value *smooth* (i.e. no kinks) but not necessarily *concave*.

[42] Condition (A.10) is still necessary for an optimum. To see this, consider a simplified version of the problem of interest: $\max_c f(c)+G(-c)$ with $f(\cdot)$ and $G(\cdot)$ smooth except for a convex kink in $G(\cdot)$ at $\bar{c}\in\mathbb{R}$. Suppose (by contradiction) that the optimizer is $c^\star=\bar{c}$. Then, $f'(\bar{c})\geq G_+'(-\bar{c})$ and $f'(\bar{c})\leq G_-'(-\bar{c})$. However, $G_+'(-\bar{c})>G_-'(-\bar{c})$ since $G(\cdot)$ admits a convex kink at $\bar{c}$. This leads to the desired contradiction. Therefore, the optimizer cannot be the point where the kink occurs. The argument generalizes immediately to multiple kinks and multiple financial assets.

for the durable, the liquid asset and the illiquid asset.

3. **Durable adjustment.** A necessary condition for an optimum is[43]

$$\partial_d W^R\left(d', m', y\right) - \left[P_t^d - (1-\theta) P_{t+1}^d (1-\delta)\right] \partial_m W^R\left(d', m', y\right) = 0 \tag{A.13}$$

where

$$m' = m - \left[P_t^d - (1-\theta) P_{t+1}^d (1-\delta)\right] d' \tag{A.14}$$

Again, (A.13) is typically not sufficient for an optimum. We thus define a set of candidates d' that satisfy either (A.13) or $d' = \bar{d}$ where $\bar{d}$ is the upper bound of our numerical grid for durables. We compute the value (A.2) associated to these candidates. The policy function for d' is the one that provides the highest value. We compute the value $W^D(\mathbf{x})$ using (A.2), and the marginal value

$$\partial_m W^D(z, y) = \partial_m W^C\left(d'(\cdot), z'(\cdot), y\right), \tag{A.15}$$

and proceed to Step 4.

4. **Continuation values.** Compute the values (A.4)–(A.5) and the marginal values

$$\partial_d W_t^{\star,D}(\mathbf{x}) = \left\{-r_{t-1}^b (1-\theta) P_t^d (1-\delta) + \theta P_t^d (1-\delta)\right\} \partial_z W_t^D(\cdot) \tag{A.16}$$

$$\begin{aligned}\partial_d W_t^{\star,C}(\mathbf{x}) = {} & (1-(1-\iota)\delta)\, \partial_d W_t^C(\cdot) + \\ & \left\{-r_{t-1}^b (1-\theta) P_t^d (1-\delta) - \Delta_t - \iota\delta P_t^d\right\} \partial_z W_t^C(\cdot)\end{aligned} \tag{A.17}$$

for the durable asset, with Δ_t defined by (A.7), and

$$\partial_m W_t^{\star,k}(\mathbf{x}) = \left(1 + r_{t-1}^m\right) \partial_m W_t^k(\cdot) \quad \text{for each choice } k \in \{C, D\} \tag{A.18}$$

for the liquid asset.

5. **Discrete choice.** Compute the value (A.3) and the marginal values[44]

$$\partial_x V(\mathbf{x}) = \sum_{k \in \{D,C\}} \mathcal{S}(\mathbf{x})\, \partial_x \overline{W}^z(\mathbf{x}) \tag{A.19}$$

for the durable and liquid asset $x \in \{d, m\}$, where $\mathcal{S}(\mathbf{x})$ is the adjustment hazard (A.8)..

[43] The solution is necessarily interior in this case, i.e., $d' = 0$ cannot be optimal.
[44] We omit the arguments on the right-hand side of (A.19) for concision.

6. **Update.** Update the expected utility $\mathcal{V}(\mathbf{x}) \equiv \int V(d, m, y') \Gamma(dy'; y)$ and the marginal utilities $\mathcal{V}_x(\mathbf{x}) \equiv \int \partial_x V(d, m, y') \Gamma(dy'; y)$ for the durable and liquid asset $x \in \{d, m\}$. Finally, repeat Step 1 until convergence.

Computational details. We use 100 points for the grids for the durable and liquid assets. We discretize the income process $\Gamma(y'; y)$ on a 7-point grid using the method of Rouwenhorst (1995). To iterate on the distribution, we use the policy functions computed above together, together with the income process Γ and we randomly assign households between adjustment (D) and no adjustment (C) according the adjustment hazard (A.8). For numerical reasons, we endow new generations with a small stock of durables $\left(\underline{d} \equiv 10^{-4}\right)$. In our partial equilibrium exercises, we start with a random sample of 15,000 households and simulate them for 3,200 periods, including 400 burn out periods. In our general equilibrium exercises, we randomly draw 250,000 households from the stationary distribution we obtained in partial equilibrium and simulate them for 125 periods.

A.3 Price Indices, Trade Balance and Exchange Rate

This appendix provides the expressions for the price indices faced by the households and the trade balance, and explains how the exchange rate is determined in equilibrium.

Price indices. The domestic prices and price indices, the exchange rate, and the trade balance are all expressed relative to the price of the domestic non-durable good. The real exchange rate is expressed as the cost of acquiring a non-durable good from the foreign country. The price indices at home for non-durables and durables are

$$P_t^c \equiv \left[\alpha_c + (1-\alpha_c)(e_t)^{1-\rho}\right]^{\frac{1}{1-\rho}} \quad \text{and} \quad P_t^d \equiv \left[\alpha_d \left(p_t^d\right)^{1-\rho} + (1-\alpha_d)(e_t)^{1-\rho}\right]^{\frac{1}{1-\rho}}, \tag{A.20}$$

where e_t is the real exchange rate and p_t^d is the price of the domestic durables. Similarly, the price indices abroad are

$$P_t^{c,\star} \equiv \left[\alpha_c + (1-\alpha_c)(1/e_t)^{1-\rho}\right]^{1-\rho} \quad \text{and} \quad P_t^{d,\star} \equiv \left[\alpha_d + (1-\alpha_d)\left(p_t^d/e_t\right)^{1-\rho}\right]^{1-\rho} \tag{A.21}$$

The *level* of the domestic price is

$$P_t^{\text{dom}} = \prod_{s=0}^{t} (1+\pi_s), \tag{A.22}$$

where the inflation rate π_t is given by the Phillips curve (5.2). The CPI price index is

$$\text{CPI}_t \equiv \left\{ \omega^c P_t^c + (1-\omega^c) P_t^d \right\} P_t^{\text{dom}}, \tag{A.23}$$

where ω^c is the spending share on non-durables at the stationary equilibrium. In turn, the monetary policy (5.5) depends on CPI inflation $\pi_t^{\text{CPI}} \equiv \text{CPI}_t / \text{CPI}_{t-1} - 1$.

Budget constraints. It is convenient to express all the budget constraints in real terms.[45] We now use m to denote real cash-on-hand (in terms of domestic goods). The budget constraints in (A.1)–(A.2) now become

$$P_t^c c + m' \leq \tilde{m}^c \tag{A.24}$$

and

$$\left[P_t^d - (1-\theta) P_{t+1}^d (1+\pi_t)(1-\delta) \right] d' + m' \leq \tilde{m}^d, \tag{A.25}$$

In turn, $\tilde{m}^c$ and $\tilde{m}^d$ are the real cash-on-hand after the adjustment decision (A.4)–(A.5). That is,

$$\tilde{m}^c \equiv \mathcal{Y}(\mathbf{x}; T_t) + \theta P_t^d (1-\delta) d \tag{A.26}$$

or

$$\tilde{m}^d \equiv \mathcal{Y}(\mathbf{x}; T_t) - \Delta_t d - \iota \delta P_t^d d \tag{A.27}$$

depending on the option, where

$$\begin{aligned} \mathcal{Y}_t(\mathbf{x}; T_t) \equiv (1-\tau_t)\, y\, (Y_t + \text{Div}_t) + \frac{(1+r_t^m)}{1+\pi_{t-1}} m \\ - r_t^b (1-\theta) P_t^d (1-\delta) d + t_t \end{aligned} \tag{A.28}$$

where Y_t is real output, Div_t is real dividends, t_t are real stimulus checks, and

$$\Delta_t \equiv (1-\theta)(1-\delta) \times \left\{ P_t^d - P_{t+1}^d (1+\pi_t)(1-(1-\iota)\delta) \right\} \tag{A.29}$$

The envelope conditions (A.11)–(A.12), (A.15) and (A.16)–(A.18) are modified accordingly.

[45] We originally opted for a nominal formulation in Appendix A.1 to simplify the exposition.

Trade balance. The trade balance is

$$\mathrm{TB}_t \equiv -\, e_t \left\{ (1-\alpha_c) \left(\frac{e_t}{P_t^c} \right)^{-\rho} c_t + (1-\alpha_d) \left(\frac{e_t}{P_t^d} \right)^{-\rho} x_t \right\} + \left\{ (1-\alpha_c) \left(\frac{1/e_t}{P_t^{c,\star}} \right)^{-\rho} c^\star + (1-\alpha_d)\, p_t^d \left(\frac{p^d/e_t}{P_t^{d,\star}} \right)^{-\rho} x^\star \right\}, \tag{A.30}$$

where consumption $c^\star$ and investment $x^\star$ in the rest of the world are constant and equal to the steady state levels at home, i.e., $c^\star = c$ and $x^\star = x$, so there is no net imports initially.

Exchange rate. The nominal exchange rate satisfies uncovered interest parity. Therefore, the real exchange rate satisfies

$$e_t = e_T \prod_{s=t}^{T-1} (1+\pi_{s+1}) \frac{1+r^\star}{1+r_s} \tag{A.31}$$

where $r^\star$ is the foreign interest rate, which is constant and equal to the steady state level at home. The terminal condition is $\lim_{t\to+\infty} e_t = 1$ by purchasing power parity.[46]

A.4 Firm's Problem

Investment. The firm's investment problem is

$$\max_{\{I_t, K_t\}} \sum_t Q_t p_t^d \{AK_{t-1} - I_t\} \tag{A.32}$$

$$\text{s.t. } K_t \le \left\{ 1 - \delta^K + \Phi(I_t/K_{t-1}) + z_t \right\} K_{t-1} \quad \text{and} \quad K_t \ge 0$$

with the initial condition $K_{-1} \equiv K$ where K is steady state capital and Q_t is the firm's stochastic discount factor. At optimum,

$$\frac{1}{\Phi'(x_t)} \frac{1+r_t}{1+\pi_{t+1}} \frac{p_t^d}{p_{t+1}^d} = A + \frac{1}{\Phi'(x_{t+1})} \left\{ 1 - \delta^K + \Phi(x_{t+1}) - x_{t+1}\Phi'(x_{t+1}) + z_{t+1} \right\} \tag{A.33}$$

with terminal condition $\lim_{T\to+\infty} x_{T+1} = \Phi^{-1}(\delta^K)$, where $x_t \equiv I_t/K_{t-1}$ and where we have used that the firm's stochastic discount factor satisfies $Q_{t+1}/Q_t \equiv (1+\pi_{t+1})/(1+r_t)$. This initial value problem (i.e., finding x_0) can be solved using a standard shooting algo-

[46] This terminal condition uses the fact that the foreign price is normalized to 1 (in level). We work with a finite horizon in our simulation and assume that $E_t = P_t^H$ after 20 years.

rithm.[47] The sequence of capital can then be constructed recursively using the law of motion of capital

$$\frac{K_t}{K_{t-1}} = 1 - \delta^K + \Phi\left(x_t\right) + z_t, \tag{A.34}$$

with initial condition $K_{-1} \equiv K$.

Dividends. The firm's dividends are $\text{Div}_t = \text{Div} + \Psi_t \widehat{\text{Div}}$, where Div is the steady state dividends, $\widehat{\text{Div}}$ parametrizes the change in dividends, and $\{\Psi_t\}$ takes the value 1 over 15 years and then decreases linearly to 0 over the next 5 years. The change $\widehat{\text{Div}}$ ensures that $\sum_t Q_t \text{Div}_t = \sum_t Q_t \Pi_t$ where Π_t is real profits. Therefore,

$$\text{Div}_t = \text{Div} + \Psi_t \frac{\sum_s Q_s \left\{\Pi_s - \overline{\text{Div}}\right\}}{\sum_s Q_s \Psi_s} \tag{A.35}$$

A.5 Investment Shocks

In Section 5, we consider recessions of various magnitudes induced by firm investment shocks. We are interested in constructing a sequence of investment shocks $\{z_t\}$ that produces a particular recession, i.e., a path of equilibrium outputs $\{Y_t\}$. In this appendix, we show that this sequence of shocks can be constructed in a straightforward way despite the non-linearities inherent to our economy. In the following, we let $C_t\left(\{E_t\}\right)$, $X_t\left(\{E_t\}\right)$ and $\text{TB}_t\left(\{E_t\}\right)$ denote total (real) demands for non-durables and durables and the trade balance given pre-tax incomes $\{E_t\}$.

Lemma 1. *Consider a sequence of real outputs $\{Y_t\}$ with $Y_t \to 1$ as $t \to +\infty$. There exists a (unique) sequence of investment shocks $\{z_t\}$ that induces $\{Y_t\}$ in equilibrium. It can be contructed in four steps. First, fix an initial guess for dividends, e.g., $Div_t = \overline{Div}$ for every period t. A sequence of net investment $\{Z_t\}$ is backed out residually from the resource constraint*

$$Z_t \equiv \frac{Y_t - P_t^c C_t\left(\{Y_t + Div_t\}\right) - P_t^d X_t\left(\{Y_t + Div_t\}\right) - G - TB_t\left(\{Y_t + Div_t\}\right)}{p_t^d}, \tag{A.36}$$

Second, dividends, tax and prices are updated: dividends Div_t are given by (A.35) with $\Pi_t \equiv -p_t^d Z_t$; taxes are backed out from the government's budget constraint (5.6)–(5.7); and prices are computed using the pricing equations (5.2) and (A.20). Updating the guess for dividends and iterating on the first step after until converge allows to recover the equilibrium sequence of net investment $\{Z_t\}$. Third, the sequence of investment rates $\{x_t\}$ is obtained from the firm's Euler

[47] Expression (A.33) defines a unique map $x_t \mapsto x_{t+1}$ since the right-hand side of (A.33) is increasing in $x \geq 0$ when the expression itself is positive, given our choice $\Phi\left(x\right) = 1/\kappa\left(\sqrt{1+2\kappa x} - 1\right)$ with $\kappa \equiv 2$.

equation by solving the second-order difference equation

$$\frac{1}{\Phi'(x_t)}\frac{1+r_t}{1+\pi_{t+1}}\frac{p_t^d}{p_{t+1}^d} = A + \frac{1}{\Phi'(x_{t+1})}\left\{\frac{Z_{t+2}}{Z_{t+1}}\frac{x_{t+1}-A}{x_{t+2}-A} - x_{t+1}\Phi'(x_{t+1})\right\} \tag{A.37}$$

with initial condition $x_0 \equiv A + Z_0^\star/K$ *where* K *is steady state capital, and terminal condition* $\lim_t x_{T+1} = \Phi^{-1}(\delta^K)$. *This initial value problem (i.e., finding* x_1*) can again be solved using a standard shooting algorithm.*[48] *Finally, the investment shocks* $\{z_t\}$ *are backed out residually from the law of motion of capital*

$$\frac{Z_{t+1}}{Z_t}\frac{x_t-A}{x_{t+1}-A} = 1 - \delta^K + \Phi(x_t) + z_t \tag{A.38}$$

Proof. The sequence of investment $\{I_t\}$ induces incomes $\{Y_t\}$ in equilibrium if and only if it satisfies the resource constraint (5.8) or

$$P_t^c C_t + P_t^d X_t + \mathrm{TB}_t + G + p_t^d Z_t = Y_t \tag{A.39}$$

where

$$Z_t \equiv I_t - AK_{t-1} \tag{A.40}$$

is the effective investment shock. Combining the firm's Euler equation for investment (A.33) and the law of motion of capital (A.34),

$$\frac{1}{\Phi'(x_t)}\frac{1+r_t}{1+\pi_t^d}\frac{p_t^d}{p_{t+1}^d} = A + \frac{1}{\Phi'(x_{t+1})}\left\{\frac{K_{t+1}}{K_t} - x_{t+1}\Phi'(x_{t+1})\right\} \tag{A.41}$$

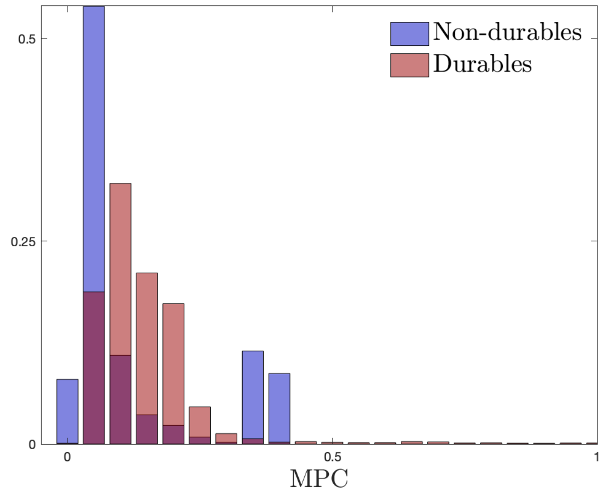
Expression (A.37) is obtained using the definition (A.40) and the Euler equation (A.41). Similarly, expression (A.36) is obtained using the same definition and the law of motion of capital (A.34). The rest of proof follows immediately. □

A.6 Fiscal Policy

The tax intercept is $\psi_{0,t} = \psi_0 + \Psi_t\hat{\psi}_0$, where ψ_0 is the intercept at steady state, $\hat{\psi}_0$ parametrizes the change in the intercept, and $\{\Psi_t\}$ was defined in Appendix A.3. The change $\hat{\psi}_0$ ensures that the government's debt converges to its steady state level in the long-run. Therefore,

[48] Note that the initial value problem consists here of solving for x_1 — not x_0 contrary to the problem (A.33). The reason is that $x_0 \equiv I_0/K_{-1}$ is predetermined in period $t = 0$ *given* $Z_0^\star$.

Figure B.1: Distribution of MPCs



Notes: This figure plots the distribution of MPC in our full model, and in a model of non-durable spending (our model specialized with $\vartheta_c = 0$).

$$\hat{\psi}_0 = \frac{\sum_t Q_t \left\{ \int yE_t d\mu_{t-1} + \Sigma_t - t_t - G_t - \psi_0 \int (yE_t)^{1-\psi_1} d\mu_{t-1} \right\}}{\sum_t Q_t \Psi_t \int (yE_t)^{1-\psi_1} d\mu_{t-1}} \tag{A.42}$$

A.7 Computational Details

We use 125-point grids for the financial and durable assets. We discretize the income process on a 7-point grid using the method of Rouwenhorst (1995). Given the non-convexities inherent to our model, we use a stochastic simulation.[49] When computing our stationary moments (Section 3), we simulate 15,000 households over 3,000 quarters with a burn of 400 quarters. In our general equilibrium experiments, we sample 200,000 households from this stationary distribution and simulate them over 125 quarters.

B Additional Quantitative Results

Figure B.1 plots the distribution of MPCs in our model, and in a model of non-durable spending (our model specialized with $\vartheta_c = 0$).

[49] A non-stochastic simulation (e.g., Young, 2010) would produce a different stationary distribution in presence of non-convexities.