Durables and Size-Dependence in the Marginal Propensity to Spend[*]

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Abstract

Stimulus checks have become an increasingly important policy tool in recent U.S. recessions. How does the households' marginal propensity to spend (MPX) vary with the size of these checks? To quantify the size-dependence in the MPX, we augment a canonical model of durable spending by introducing a smooth adjustment hazard. We discipline this hazard by matching a rich set of micro-level moments. We find that the MPX declines slowly with the size of checks. The MPX is much flatter in a purely state-dependent model of durables, whereas it declines sharply in a canonical two-asset model of non-durables. Finally, we embed our spending model into an open-economy heterogeneous-agent New-Keynesian model. We use the model to compute the size of the checks that close the output gap in various recessions driven by demand and supply shocks; checks exceeding this amount overheat the economy.

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1 Introduction

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

How does the households' marginal propensity to spend (MPX) vary with the size of stimulus checks?[1] Measuring the *size-dependence* in the MPX is challenging. The few empirical studies available obtain a wide range of estimates: the marginal propensity to spend can be decreasing (Coibion et al., 2020), essentially flat (Sahm et al., 2012), or even increasing (Fuster et al., 2021).[2] State-of-the-art models of the MPX focus on non-durables and predict that the marginal propensity to spend falls rapidly with the size of stimulus checks (Kaplan and Violante, 2014). However, a government that sends stimulus checks cares about the response of total household spending, including durables. Indeed, durable spending accounts for a large share of the MPX (Souleles, 1999; Parker et al., 2013).[3] The literature has 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).[4]

To quantify the size-dependence in the MPX, we augment a canonical incomplete mar-

[1] We use the term "marginal propensity to spend" (MPX) to refer to the average spending response (across individuals) divided by the size of the income change (e.g., the check). The empirical counterpart is what Kaplan and Violante (2014) refer to as the "rebate coefficient." The MPX includes spending in non-durables and durables (Auclert, 2019; Laibson et al., 2022), in contrast to the marginal propensity to consume (MPC) which only includes non-durables.

[2] The MPX is notoriously difficult to estimate even in *levels.* Part of the reason is that the MPX 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 MPX 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).

[3] A large empirical literature also documents large responses of durable spending to wealth shocks (Maggio et al., 2020; Mian et al., 2013), changes in social security (Wilcox, 1989), and minimum wage increases (Aaronson et al., 2012).

[4] For instance, Parker et al. (2013) write: "[...] *we find larger total spending in 2008 due to significant spending on durable goods*. [...] *some prior research finds that larger payments can skew the composition of spending towards durables, which is consistent with our findings given that the 2008 stimulus payments were on average about twice the size of the 2001 rebates*" (pp. 2531–2532).

kets 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, or increasing MPX, 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.[5]

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 quarterly marginal propensity to spend on durables relative to non-durables out of small checks; (ii) generates a realistic short-run price elasticity; (iii) replicates the distribution of adjustment sizes 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 untargeted moments well; for example, the annual MPX out of small lottery gains in Fagereng et al. (2021), the fraction of hand-to-mouth agents in Kaplan and Violante (2022) and Aguiar et al. (2020), the skewed distribution of MPXs (with many above 1) in Misra and Surico (2014) and Lewis et al. (2022), and the conditional probability of adjustment since the last purchase.

We find that the MPX declines slowly with the size of stimulus checks. The quarterly MPX 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 MPXs in our model lie between those of canonical models of non-durables and durables spending, both in terms of levels and size-dependence. A canonical two-asset model of non-durables (Kaplan and Violante, 2022) produces smaller MPXs 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 MPXs which are essentially flat at first and then decline. Overall, the MPX neither surges as sometimes conjectured (Parker et al., 2013), nor does it fall sharply as in a canonical models of non-durables.

The extensive margin of durable adjustment plays an important role in this result. As

[5] 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). The down payment requirement allows our model to generate a skewed distribution of MPXs (with large responses by some households) as in the data. Our specification ensures that households cannot continuously refinance and extract equity against their stock of durables This is realistic for consumer durables (cars, furniture, etc.) which our calibration focuses on.

stimulus checks become bigger, a larger and larger share of households adjusts its stock of durables, consistently with survey evidence (Fuster et al., 2021). This effect offsets the usual precautionary savings motive 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 compared to a purely state-dependent models of durables: our calibration implies a substantial degree of time-dependence. In turn, the marginal propensity to spend on durables is both lower compared to purely state-dependent models and never increases with the size of stimulus checks.

We conclude the paper with an application. We embed our spending model into an open-economy heterogeneous-agent New-Keynesian model. This allows us to account for forces that can dampen the spending response to checks in general equilibrium, such as inflation and relative price movements, the response of monetary policy, or international leakages through imports. We use the model to compute the size of the checks that close the output gap in various recessions driven by different combinations of demand and supply shocks. Larger checks overheat the economy and raise inflation.[6]

We first consider a purely demand-driven recession where output falls by 4% over three quarters and later recovers over two years. Starting from this recession, the government sends a stimulus check in the first quarter to elegible households. We find that large checks remain effective at stimulating output in our model, whereas their effect wears off rapidly in the canonical two-asset model of non-durables. A check of \$2,400 closes the output gap in the first quarter of the recession, which amounts to three times the fall in average quarterly income of \$800. A larger check of \$5,500 is needed to close the cumulative output gap over the recession and recovery, but pushes output above potential in the short run. For comparison, we also consider a recession that is coupled with an adverse supply shock and a non-linear Phillips curve. A government that misdiagnoses the recession as being purely demand-driven could send a large check to close its perceived output gap; this would overheat the economy and raise inflation substantially.

Methodologically, our paper advances the literature on durables demand in incomplete markets economies. Berger and Vavra (2015) developed the canonical model that spearheaded this literature. Most notably, McKay and Wieland (2021) extend this canonical model to study monetary policy. They introduce several features to dampen the interest rate elasticity of durables, including operating costs, exogenous adjustment shocks, and limited attention. Gavazza and Lanteri (2021) build on the canonical model to study

[6] In presence of distortionary taxation or inflation, the government would not fully close the output gap even in a purely demand-driven recession. How close the government gets to closing the gap (or whether it stimulates output beyond potential) also depends on its preference for redistribution and insurance (McKay and Wolf, 2023).

the effect of credit shocks, and Berger et al. (2023) analyze policies that subsidize durable purchases. Relative to these papers, we augment the canonical model by introducing a smooth adjustment hazard in the tradition of Caballero and Engel (1999) and more recently Beraja et al. (2019) and Alvarez et al. (2020). We show how to discipline this hazard by matching a rich set of micro level moments. We also study different questions compared to this literature: the size-dependence in the MPX and the effect of stimulus checks.

While the existing literature has used random fixed costs 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.[7] An important body of work in industrial organization 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 heterogeneous-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 key for the shape of the adjustment hazard and the size-dependence in the MPX.

Our paper also adds to a literature that studies the effect of stimulus checks in general equilibrium. The existing work on tax rebates (e.g., Wolf, 2021; Wolf and McKay, 2022) or transfers in fiscal unions (e.g., Farhi and Werning, 2017; Beraja, 2023) abstracts from durables altogether and uses first order approximations in the aggregates. In contrast, durable spending is central to our analysis, and we show that it generates substantial non-linearities in the aggregate. Our general equilibrium application is also related to Orchard et al. (2022), who use a linearized two-agent model to show that changes in the relative price of durables can dampen the response to stimulus checks in general equilibrium. We allow for relative price changes in equilibrium, and we focus on the non-linearities generated by our heterogeneous-agent model with lumpy durables.

Finally, our analysis is related to a literature that explores how behavioral frictions affect the MPX. Laibson et al. (2021) find that MPXs can remain elevated for large shocks when households are present-biased. In an extension that builds on Laibson et al. (2022), they allow for a durable good whose adjustment is frictionless. In contrast, non-convex

[7] 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 monetary fixed costs of adjustment do not have a clear empirical counterpart.

adjustment costs are key to our mechanism. Fuster et al. (2021) find that non-convex costs of attention or re-optimization can generate an MPX 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) show 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 $t \geq 0$.

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 ϑ 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 ϵ are independent over time and distributed according to a logistic distribution $\mathcal{E}$.[8] The mean and variance of this distribution are controlled by $\kappa > 0$

[8] This specification is common in the literature, as discussed in our introduction. Additional references include Berkovec (1985), Rust (1985), and Gillingham et al. (2022) who focus on the demand for automobiles.

and $\sigma^2 > 0$, respectively.[9] The resulting durable adjustment hazard is

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

where V^{adjust} and V^{not} denote the continuation values when adjusting and not adjusting, respectively, and $\mathbf{x}$ denotes the household's idiosyncratic state (which we define formally later in this section).

The scale parameter η controls the *shape* of the adjustment hazard while the location parameter κ controls its *position*. 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 this case.[10] Figure 2.1 provides an illustration of two such hazards. The first (solid curve) 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 curve) is a much flatter hazard, which results from allowing for time-dependent adjustments (Alvarez et al., 2016a). As we discuss after presenting the remaining elements of the model, the shape of this adjustment hazard plays a key role for the size-dependence in the MPX (Section 2.6).

2.3 Investment, Saving, and Down Payment

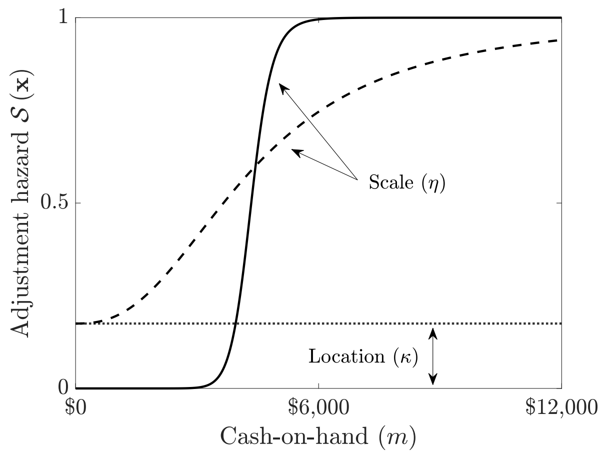
Households invest in durables. Their stock depreciates at rate δ and requires a mandatory maintenance rate ι between adjustments so $d_t = (1-(1-\iota)\delta)\, d_{t-1}$ when the household does not adjust. Households also save in a liquid asset $m \geq 0$ (i.e., cash, deposits) with return r^m and borrow with credit $b \leq 0$ with return $r^b \geq r^m$. They make a down payment when they purchase a durable, and borrow the rest with credit. Households face the following credit constraint when purchasing a durable of size d_t

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

[9] The literature typically normalizes the mean of these shocks to zero (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.

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

Figure 2.1: Adjustment hazard (fixing d)



where $\theta \in (0,1)$ captures the down payment share.[11] This formulation differs from existing models of durables, which make no distinction between cash and credit (Jose Luengo-Prado, 2006; Berger and Vavra, 2015; McKay and Wieland, 2021). These models assume instead a single, liquid asset that is subject to a loan-to-value constraint similar to (2.4). This presumes that households can refinance their debt *continuously* and extract equity from their durables. As a result, the effective supply of liquidity in the economy (i.e., the average distance to the borrowing constraint) is much larger than in the data and the households' marginal propensity to spend is implausibly small (McKay and Wieland, 2021) particularly for non-durables.[12] In practice, refinancing is virtually nonexistent for consumer durables (which we focus on), and auto loan prepayments are relatively rare too (Heitfield and Sabarwal, 2004). Our specification with cash and credit addresses that; it ensures that the effective supply of liquidity in the economy matches conventional estimates (Kaplan et al., 2018).

In the following, we assume that the constraint (2.4) holds with equality at origination, and that is remains binding at any point while the household holds the durable. This assumption allows us not to introduce credit as an additional state variable. It is also fairly realistic in the context of cars and consumer durables, which our calibration focuses on. In practice, the vast majority of down payments for cars do not exceed the minimum

[11] In our partial equilibrium analysis, we normalize the price of durables and non-durables $P_t^d = P_t^c \equiv 1$ as in Berger and Vavra (2015). This is without loss of generality, as a different price of durables would translate in a different spending weight on non-durables ϑ in our calibration (Section 3). We allow for relative price changes in our general equilibrium analysis (Section 5).

[12] For instance, Kaplan et al., 2018 report that the average stock of *net* durables equals 22% of annual GDP. Assuming a down payment share of $\theta = 20\%$ as in our calibration (Section 3), the conventional formulation in the literature would imply that the average household can draw liquidity at any point to roughly $88\% = 22\%/\theta \times (1-\theta)$ of their average income. This figure is much larger than conventional values in the literature (e.g., Kaplan et al., 2018).

level required (Green et al., 2020); and most car loans are repaid within 5–6 years and cars depreciate at roughly 20% so outstanding credit b effectively tracks durables d.[13] With this assumption, households make pre-determined credit repayments while they hold their stock (Laibson et al., 2021), which mimicks the rule out thumb they appear to follow in practice (Argyle et al., 2020).[14] Households repay their outstanding credit when they sell their old durable and purchase a new one.[15]

2.4 Earnings and Income

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 denote the associated transition kernel by $\Gamma\left(dy';y\right)$. Households' net income before interest rate payments is $\mathcal{Y}_t \equiv \psi_0 \left(e_t Y_t\right)^{1-\psi_1}$, where ψ_0 and ψ_1 parametrize progressive taxation (Heathcote et al., 2017). Total income is after interest rate payments is

$$\mathcal{Y}_t\left(\mathbf{x};T_t\right) \equiv \psi_{0,t}\left(yY_t^{\text{inc}}\right)^{1-\psi_1} + \left(1+r_{t-1}^m\right)m - r_{t-1}^b\left(1-\theta\right)\left(1-\delta\right)d + T_t,$$

where T_t are potential lump sum transfers the government.[16]

2.5 Recursive Formulation

We now state the household's problem recursively. Each household is indexed by the states $\mathbf{x} \equiv \left(d,m,y\right)$, i.e., its holdings of the durable and liquid assets and its idiosyncratic income shock, as well as the independent taste shock ϵ described in Section 2.2. The household first chooses whether to adjust its stock of durables or not. The value associated

[13] An *even* richer model could allow for refinancing between purchases (Berger et al., 2021; Laibson et al., 2021). Introducing refinancing in addition to lumpy durables would make the program numerically intractable.

[14] 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.

[15] In our model, we can equivalently assume that: (i) households sell their entire stock of durables before purchasing a new one, repay their outstanding credit at that point, and then face the constraint (2.4) when buying the new stock; or (ii) they add durables do their existing stock when they adjust, and the borrowing constraint (2.4) applies to new flows of credit and durables.

[16] Given our focus on the marginal propensity to spend, we assume for now that the stimulus check in the first period $T_0 \geq 0$ is the same for all households. It acts as a one-time, unanticipated income shock. We allow for an asymmetric incidence of stimulus checks in our general equilibrium model (Section 5).

to the discrete choice problem is

$$\mathcal{V}_t(\mathbf{x};\epsilon) = \max\left\{V_t^{\text{adjust}}(\mathbf{x}) - \epsilon, V_t^{\text{non}}(\mathbf{x})\right\},$$

This discrete choice problem yields the adjustment hazard (2.3). When the household adjusts its stock of durables, it solves

$$\begin{aligned} V_t^{\text{adjust}}(\mathbf{x}) = \max_{c,d',m'} \; & u(c,d') + \beta \int \mathcal{V}_{t+1}(d',m',y';\epsilon')\, d\mathcal{E}(\epsilon')\,\Gamma(dy';y) \\ \text{s.t. } & [1-(1-\theta)(1-\delta)]\,d' + m' + c \le \mathcal{Y}_t(\mathbf{x};T_t) + \theta(1-\delta)\,d \\ & m' \ge 0, \end{aligned}$$

The households' cash-on-hand consists of its total income $\mathcal{Y}_t(\mathbf{x};T_t)$ plus the value of the durable its sells net of the credit it still own on it. It chooses its new stock of durables subject to the binding down payment constraint (2.4), and it decides how much to spend on non-durables. When holding on to its existing stock of durables, the household maintains this stock at rate ι and then solves

$$\begin{aligned} V_t^{\text{non}}(\mathbf{x}) = \max_{c,m'} \; & u(c,d') + \beta \int \mathcal{V}_{t+1}(d',m',y';\epsilon')\, dG(\epsilon')\,\Gamma(dy';y) \\ \text{s.t. } & m' + c \le \mathcal{Y}_t(\mathbf{x};T_t) - \iota\delta d - (1-\theta)\left[(1-\delta)\,d - d'\right] \\ & m' \ge 0 \end{aligned}$$

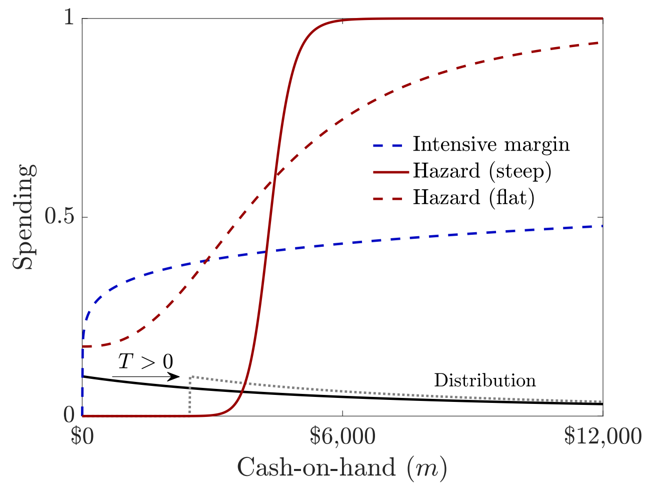
where $d' = (1-(1-\iota)\,\delta)\,d$ is the stock after maintenance. We explain how to solve this recursive problem in Appendix A.

2.6 Adjustment Hazard and Size-Dependence in the MPX

Having presented the model, we are now ready to discuss the role that the adjustment hazard plays in the size-dependence in the MPX. Following the literature, we will compute the MPX as the average spending response divided by the size of the check. The empirical counterpart of this MPX is what Kaplan and Violante (2014) refer to as a "rebate coefficient." We focus momentarily on the MPX on durables since our adjustment hazard is particularly important for durables. Let T be a one-time unanticipated transfer and $\text{MPX}^d(T)$ be the associated average marginal propensity to spend on durables

$$\text{MPX}^d(T) \equiv \frac{1}{T}\int\int \underbrace{\mathcal{S}(m,d)}_{\text{extensive}}\,\underbrace{x(m+d)}_{\text{intensive}}\,\{d\pi(m-T,d) - d\pi(m,d)\}\,, \tag{2.5}$$

Figure 2.2: Spending Functions (fixing d and y)



where $\mathcal{S}(m, d)$ is the adjustment hazard, $x(m+d)$ is spending conditional on adjustment for a household with cash-on-hand m and durable stock d, and π is the associated distribution. The expression abstracts from the households' idiosyncratic productivity y to save on notation. 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

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

when the intensive margin 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 with m (as in the data). The reason is that proportionately more and more households are pushed over their adjustment threshold as the transfer T becomes larger. 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. After a simple change of variable, the marginal propensity to spend on durables becomes

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

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. These two polar cases illustrate that the shape of the adjustment hazard is key for the size-dependence in the marginal propensity to spend on durables, and hence the MPX on total spending generally (which includes spending on non-durables too). 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. We discuss alternative parametrizations in Section 4.1. We explain how to solve the model in Appendix A.

3.1 External Calibration

External parameters are set to standard values in the literature. The inverse elasticity of intertemporal substitution is $\sigma = 2$, 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 for cars (Berry et al., 2004; Orchard et al., 2022). The quarterly depreciation rate is $\delta = 5\%$. We set the down payment parameter to θ so the downpayment is 20%, 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

Table 3.1: External calibration

Parameter	Description	Value	Target / Source
Preferences			
σ	Inverse EIS	2	Berger and Vavra (2015)
ν	CES parameter	1	Long-run price elasticity
Durables			
δ	Depreciation rate	5%	NIPA
Earnings process			
ρ	Persistence	0.977	Floden and Lindé (2001)
γ	Volatility	0.198	Auclert et al. (2018)
τ	Distorsionary taxation	0.3	Kaplan and Violante (2014)
Financial asset			
θ	Down payment	0.15	Adams et al. (2009); Attanasio et al. (2008)
r^m	Return on cash	1%	Real annual Fed funds rate
$r^b - r^m$	Borrowing spread	3.5%	Fed board (G.19 Consumer Credit)

Table 3.2: Internal Calibration

Parameter	Description	State-dependent	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

Notes: The purely state-dependent model is a version of our model with $\eta \to 0$. We calibrate $\eta = 0.2$ in our model as we discuss in Section 3.2.

assume that idiosyncratic productivity follows an AR(1) process as in Berger and Vavra (2015) and McKay and Wieland (2021). 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 $\gamma = 0.197$ to match an annual standard deviation of 0.92 in log-earnings (Auclert et al., 2018). We normalize the earnings process so that aggregate income 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% at the stationary equilibrium.

3.2 Internal Calibration

We calibrate five parameters internally: (i) the discount factor β; (ii) the relative weight on non-durables ϑ_c; (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.[17] We set the maintenance rate to obtain a ratio of maintenance spending to gross investment of 32.6% for cars as in the CEX. We choose the location parameter κ to match an annual frequency of adjustment of 23.8% for vehicles in the PSID, which is in line with conventional estimates (Attanasio et al., 2022; McKay and Wieland, 2021).[18] The rest of this section describes the calibration of the scale parameter η since it plays an important role in our analysis.

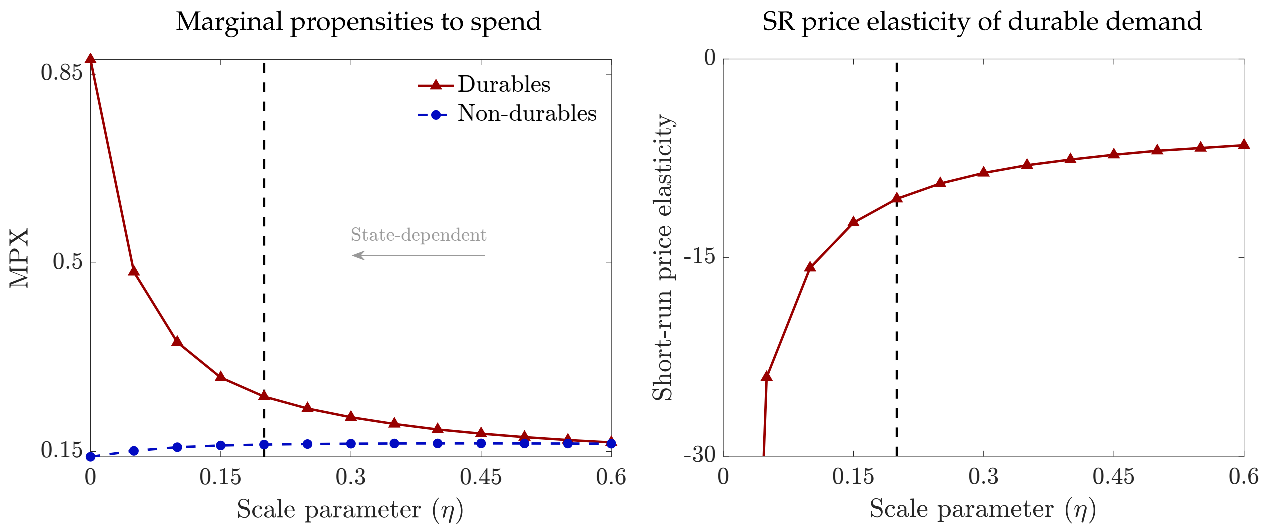
Bounding the scale parameter. The scale parameter η controls the shape of the hazard (2.3). Two moments are particularly informative about this parameter, and they are nature targets for our calibration. The households' marginal propensities to spend on durables and non-durables control the partial equilibrium effect of stimulus checks. In turn, the elasticity of durable demand with respect to changes in the user cost determines how much subsequent changes in the interest rate and prices dampen the general equilibrium response. As we will see, these moments provide upper and lower bounds for the scale parameter η.

The left panel of Figure 3.1 shows the marginal propensity to spend on durables and

[17] As discussed, we exclude housing from both durables and non-durables. 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.

[18] 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 marginal propensities to spend out of a \$500 check on durables and non-durables for various values of the scale parameter η in (2.3). These are 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 ($\eta = 0.2$).

non-durables out of a \$500 check for different values of η. All other parameters are re-calibrated to match the moments described above. The model becomes more state-dependent as η decreases, and it eventually converges to the canonical model with (s, S) bands as $\eta \to 0$. The marginal propensity to spend on durables declines monotonically as η increases and the model becomes more time-dependent. The literature offers a wide range of estimates of the marginal propensities to spend on durables and non-durables.[19] However, it is generally agreed that the MPX 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 marginal propensity to spend on durables relative to the one on non-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 ($\eta \to 0$) pre-

[19] For instance, Souleles et al. (2006) find a small MPX on durables, while Parker et al. (2013) find a large one.

dicts an implausibly high elasticity of -90. Introducing a smooth adjustment hazard is a parsimonious way to dampen this elasticity.[20] There is much uncertainty about the precise elasticity in the empirical literature. Bachmann et al. (2021) find an elasticity of -12 among households who were aware of a short-run decrease in the VAT in Germany. Gowrisankaran and Rysman (2012) estimate a short-run elasticity of -2.55 for camcoders. 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 $\eta = 0.2$ which is in between the lower and upper bounds. This value delivers a marginal propensity to spend 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 total MPX 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 upon adjustment, and the conditional probability of adjustment — which highlight the importance of allowing for a smooth adjustment hazard. We also examine the distribution of MPXs.

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. An adjustment ($\text{Adj}_w = 1$) occurs in two cases. Either the number of vehicles owned by the household changes. Or the household reports that the vehicle that was last purchased (vehicle "#1") was acquired more recently than the one reported in the previous wave $\text{Purchase}^{\#1}_{w} > \text{Purchase}^{\#1}_{w-1}$, and at most two years before the interview date $\text{Purchase}^{\#1}_{w} \geq t_w - 2$ (since the PSID waves are bi-annual). We denote the year of the most recent purchase by Year_w. We measure net investment upon a purchase

[20] 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.

as $\log(d_w) - \log(d_{w-1})$ when $\text{Adj}_w = 1$, where d_w is the value of the stock of vehicles *net* of liabilities reported by the household.[21] 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 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). 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. The value of the stock of durables net of liabilities is $d_w \equiv \{1 - (1-\theta)(1-\delta)\}\, d_{T(w)}$ 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.[22] In Appendix D.2, we show that having a *smooth* adjustment hazard (as opposed to a discontinuous hazard with some exogenous, time-dependent adjustments) is important to match the empirical distribution of adjustments.

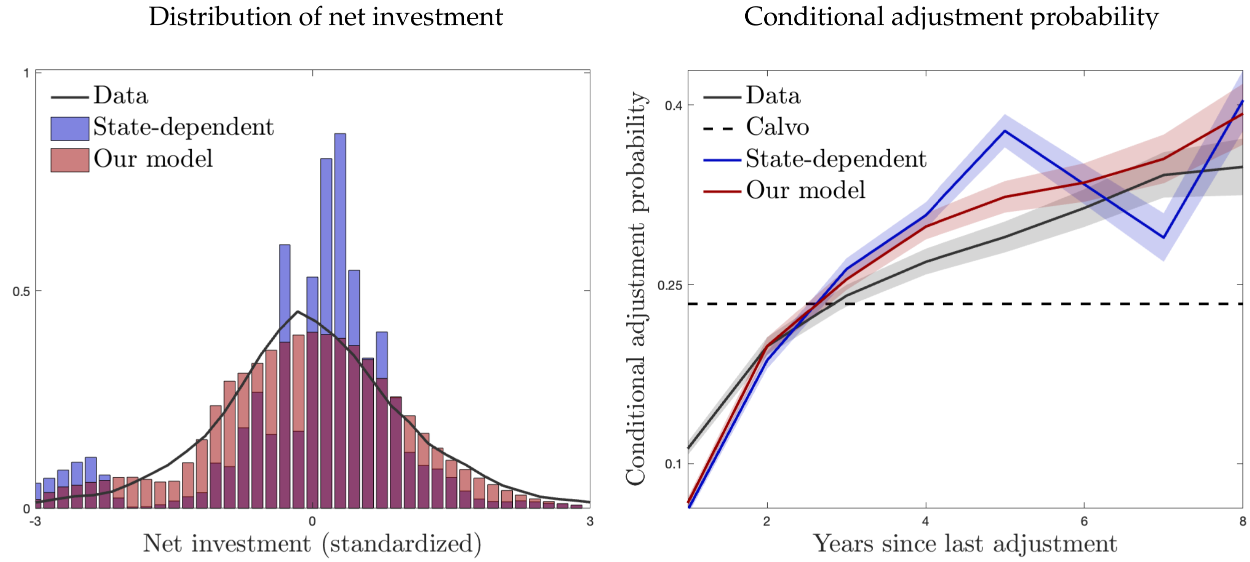
Probability of adjustment. The right panel of Figure 3.2 plots (in black) the empirical probability that a household adjusts its stock of vehicles after a certain number of years *conditional* on not having adjusted so far (Alvarez et al., 2021), which is also known as the Kaplan-Meier hazard. We construct 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 an adjustment occurs ($\text{Adj}_w = 1$). We restrict attention to the first purchase by a given household.[23] This yields an empirical probability

[21] We do not attempt to back out the gross value of the stock by using imperfect information on liabilities, which would add another layer of measurement error. Instead, we directly compute the changes in the net stock, and we treat the model-generated data identically. Note that $\log(d_w) - \log(d_{w-1})$ is exactly equal to net investment in the model.

[22] The empirical distribution might capture some measurement error, i.e., households over- or under-estimating the value of their cars for instance. To account for this possibility, we conducted an experiment where we introduced a measurement error of 10% in the model-generated investment sizes. The overall shapes of the resulting distributions are essentially unchanged compared to the left panel of Figure 3.3.

[23] The reason is that subsequent purchases, if observed in the PSID's short time dimension, are more likely to be of shorter duration and would bias our estimates. Focusing on the first adjustment allows us to

Figure 3.2: Untargeted moments



Notes: The left panel plots the distribution of net investment (standardized) across two consecutive PSID waves where households adjusted their stock. The black curve is the data, while the red and blue bars are our calibrated model ($\eta = 0.2$) and its version with purely state-dependent adjustments ($\eta \to 0$), respectively. The right panel plots the adjustment probability conditional on a household not having adjusted so far. The black, red and blue curves are the same models as on the left panel. The dashed curve is a version of our model with purely time -dependent adjustments ($\eta \to +\infty$).

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 (in black) to the one implied by our model ($\eta = 0.2$, in red) and two alternative calibrations with, respectively, purely time-dependent adjustments ($\eta \to +\infty$, dashed) and 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. This is intuitive: the longer a households owns a car and the more it depreciates, the more likely it is that the household will adjust next period. The model with $\eta = 0.2$ matches the empirical profile quite well.[24] The overall pattern is roughly similar in the purely state-dependent model ($\eta \to 0$), although the fit becomes somewhat poorer as the horizon in-

circumvent this issue.

[24] 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.

creases. 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 marginal propensity to spend on durables (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 (the right panel of Figure 3.1) as well as the evidence on the distribution of net investments (the left panel of Figure 3.2).

Annual MPX. The model delivers an annual marginal propensity to spend of 0.40 on durables, and 0.52 on non-durables out of a $500 check. The total MPX is 0.92, which is similar to the estimates of Fagereng et al. (2021) out of small lottery gains in Norway (most gains are much larger). We obtain an annual MPX of 0.67 out the mean lottery gain in their sample ($9,240). This value lies between their benchmark (truncated) estimate of 0.51 and their untracated estimate of 0.72.[25] The latter is more comparable to our value since we do not trim the distribution of MPXs in the model. We report the dynamic responses (or intertemporal MPXs in the language of Auclert et al., 2021) in Figure C.1 in Appendix C.1.

Share of hand-to-mouth. We find that 42% of households are hand-to-mouth, i.e., their holdings of liquid assets are less than half of their monthly (gross) income (Kaplan et al., 2014). 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).

Secondary market. Households who adjust their stock of durables (upward or downward) first *sell* their existing stock. Part of households' gross purchases are thus fulfilled effectively by old cars on the secondary market.[26] In our calibrated model, used cars make 53% of gross purchases. For comparison, used cars represent roughly 55% of total spending on cars in the US (DoT, 2023).[27]

[25] For comparison, Golosov et al. (2021) find an annual MPX of roughly 0.6 in their sample of US lottery winnings of at least $30,000.

[26] New and old durables are indistinguishable 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.

[27] 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.

Distribution of MPX. Figure C.2 in Appendix C plots the distribution of total MPXs produced by our model. We also compare this distribution to the ones produced by a purely state-dependent version of our model and by a two-asset model of non-durable spending similar to one in Kaplan and Violante (2022).[28] The distribution of MPXs is skewed in our model and has a relatively long right tail. The overall shape of the distribution is consistent with the evidence in Lewis et al. (2022) and Fuster et al. (2021). A non-negligible share of households displays an MPX close to (or above) 1, which is also 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 MPXs possible. Turning to the purely state-dependent version of our model, the distribution of MPXs is bi-modal (with a second mode around 0.5), which is expected in a model with (s, S) adjustment bands. Finally, the two-asset model of non-durables struggles to generate MPXs larger than 1 as observed in the data.

3.4 State- *vs*. Time-Dependent Adjustments

The previous section showed that our calibrated model has both state- and time-dependent features. Having calibrated the model, we can now quantify the degree of state-dependence more formally.

In a purely state-dependent 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 with 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 occurs $\mathcal{A}(\mathbf{x};\psi) = 0$ otherwise.

We introduce the following measure of state-dependence

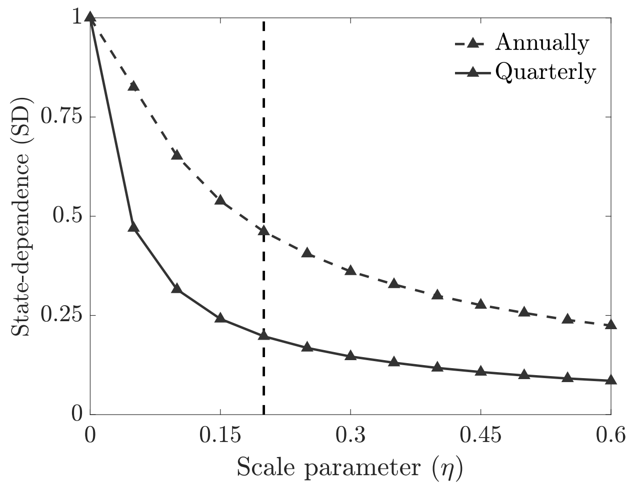
$$\text{State-dependence (SD)} \equiv \frac{\text{share with } \mathcal{A}(\mathbf{x}';\psi\ ) = 1 \text{ and } \mathcal{A}(\mathbf{x};\psi) = 0}{\text{share with } \mathcal{A}(\mathbf{x}';\psi') = 1 \text{ and } \mathcal{A}(\mathbf{x};\psi) = 0} \tag{3.2}$$

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'.[29] Households decide to adjust for two reasons: either because they moved to $\mathbf{x}'$ or because they got a particular draw ψ'. Our mea-

[28] We describe the two-asset model of non-durables in Appendix D.1.

[29] 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.

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 $\eta = 0.2$.

sure 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 frequencies. 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 MPX is not very sensitive to changes in the scale parameter around this value.

4 Size-Dependence in the MPX

We now quantify the size-dependence in the MPX 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 4.3), and how aggregate conditions affect MPXs (Section 4.4).

4.1 Size-Dependence: Durables, Non-Durables, and the MPX

The left panel of Figure 4.1 plots the marginal propensities to spend on durables and non-durables (at the quarterly level) following stimulus checks of varying sizes.[30] 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 durables is virtually flat over the range \$100 to \$600, and then declines slowly. In contrast, the marginal propensity to spend on non-durables declines more rapidly. 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. For comparison, a canonical two-asset model of non-durables (similar to Kaplan and Violante, 2022) produces a marginal propensity to spend on non-durables that declines much faster compared to our model: the response is essentially halved when comparing a \$100 and \$2,000 check.[31] The response of non-durables remains robust in our model partly because of the complementarity between durables and non-durables. As stimulus checks become larger, households spend more on durables; and this raises the marginal utility of consuming non-durables and the associated marginal propensity to spend.

The right panel plots the MPX (which adds durables and non-durables spending) as a function of the size of stimulus checks. We find that the MPX 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). The MPX is both higher in our model, and declines more slowly, compared to the canonical two-asset model of non-durables. We elaborate on this point in Figure 4.2 below.

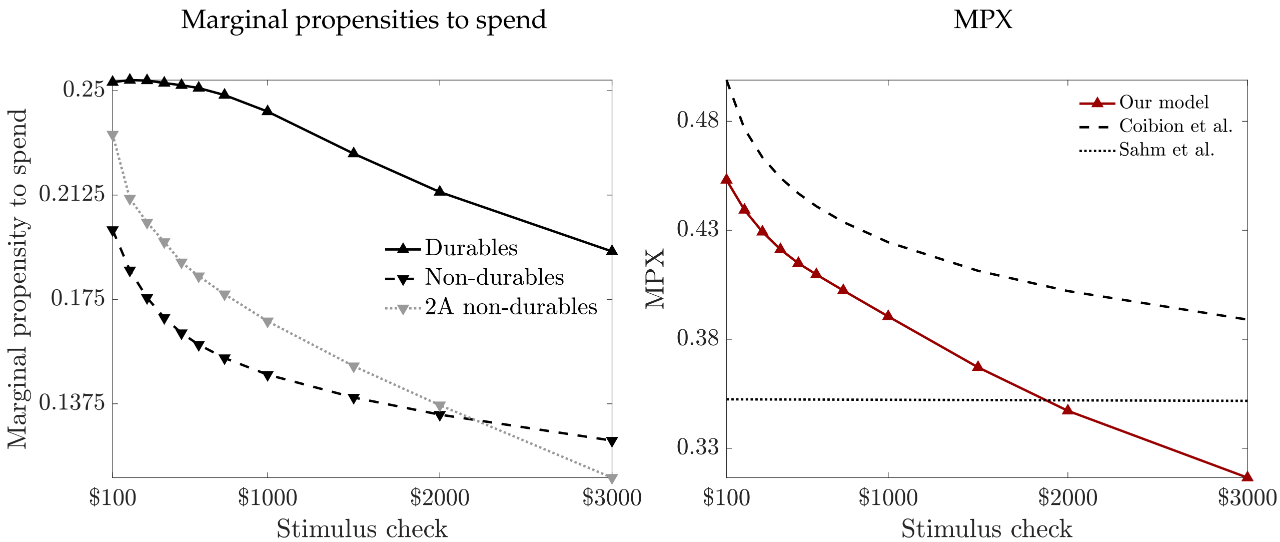
Sensitivity. Finally, we perturbate various parameters to explore how they affect our results. Figure C.4 in Appendix C reports the marginal propensities to spend on durables and non-durables as a function of the size of stimulus checks for four alternative calibrations. To make sure that all the models are comparable, we calibrate the scale parameter η to match the same short-run price elasticity (Figure 3.1). All other parameters are re-calibrated to match the targets discussed in Section 3.2.

The first alternative calibration decreases the amount of liquidity to 58% of quarterly income (as in Kaplan and Violante, 2014) instead of 104% in our baseline calibration. The

[30] Stimulus checks are used to stimulate the economy in the short-run. The recessions during which they are are sent can be relatively short. For instance, the 2001 recession lasted only 8 months, and the 2020 recession lasted 2. This explains our focus on quarterly responses. Figure C.1 in Appendix C plots the dynamic responses, i.e., beyond the first quarter. Annual responses also exhibit a meaningful degree of size-dependence (Figure C.3 in Appendix C), as discussed in Section 3.3. All responses are computed starting from the stationary equilibrium. We explore the role of aggregate conditions in Section 4.4.

[31] Again, we describe the two-asset model of non-durables in Appendix D.1.

Figure 4.1: Size-dependence in the MPX



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 MPX as a function of the size of this checks in our model, and compares it to existing estimates in the literature.

marginal propensities to spend on both durables and non-durables are higher in levels (as expected) but the overall profile is mostly unchanged. The second calibration increases the down payment to 30% instead of 20%. Unsurprisingly, the marginal propensity to spend on durables declines much more slowly, as larger stimulus checks provide households with the down payment to purchase durables. In fact, the marginal propensity to spend on durables actually increases (albeit slowly) at the beginning in this alternative parametrization, as conjectured by Fuster et al. (2021). The third calibration increases the frequency of adjustment to 35% instead of 25%. The marginal propensities to spend on durables and non-durables are very similar to our benchmark calibration. The fourth calibration increases the inverse elasticity of intertemporal substitution to $\sigma = 4$ (as in McKay and Wieland, 2021) instead of $\sigma = 2$. The marginal propensities to spend are higher in levels, in particular for durables. The marginal propensity to spend on durables again increases slightly for small checks, but the overall profile thereafter is unchanged compare to our baseline.

4.2 Aggregate Spending and the Role of the Smooth Hazard

What does the size-dependence in the MPX imply for aggregate spending? The left panel of Figure 4.2 plots the response of aggregate spending as a function of the size of stimulus checks in the three models that we discussed so far.[32] The concavity of these functions reflects the size-dependence in the MPX in these models. To summarize and compare this size-dependence across models in a conveninent and parsimonuous way, we compute the elasticity β of the change in aggregate spending ΔSpending with respect to the size of checks T over the range \$100 to \$3,000 (by ordinary least squares). The lower β, the more concave the spending function as ΔSpending is proportional to T^{β}. The left panel also indicates the elasticity associated with each model.

Our model (in red) predicts that even large checks remain effective in stimulating aggregate spending. The elasticity is $\beta = 0.87$ in our preferred parameterization with $\eta = 0.2$: the spending function is somewhat concave but the spending response remains robust as stimulus checks become larger. In contrast, the two-asset model of non-durables model (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. The spending function is very concave in the size of checks, with an elasticity $\beta = 0.73$. That is, the MPX declines at a rate that is twice as high in the non-durables model relative to ours.[33] Finally, a purely state-dependent model of durables (in blue) predicts a much stronger response of spending and less size-dependence in the MPX. The elasticity $\beta = 0.94$ is much closer to unity in this model with $\eta \to 0$.[34]

What role does the smooth adjustment hazard play in the size-dependence in the MPX in our model? The right panel of Figure 4.2 reports the elasticity β as we vary the scale parameter (η) in our model. Aggregate spending becomes more concave as the scale parameter η (and hence time-dependence) increases. As mentioned, the elasticity β is lower in our preferred calibration with $\eta = 0.2$ compared to a purely state-dependent model with $\eta = 0$, and the MPX declines more rapidly. Moreover, it is worth noting that the elasticity β is relatively insensitive to changes in the scale parameter between the lower bound ($\eta = 0.1$) and the upper bound ($\eta = 0.45$) bounds that we discussed in Section 3.2. In other words, the degree of size-dependence is robust to changes in η within these bounds.[35]

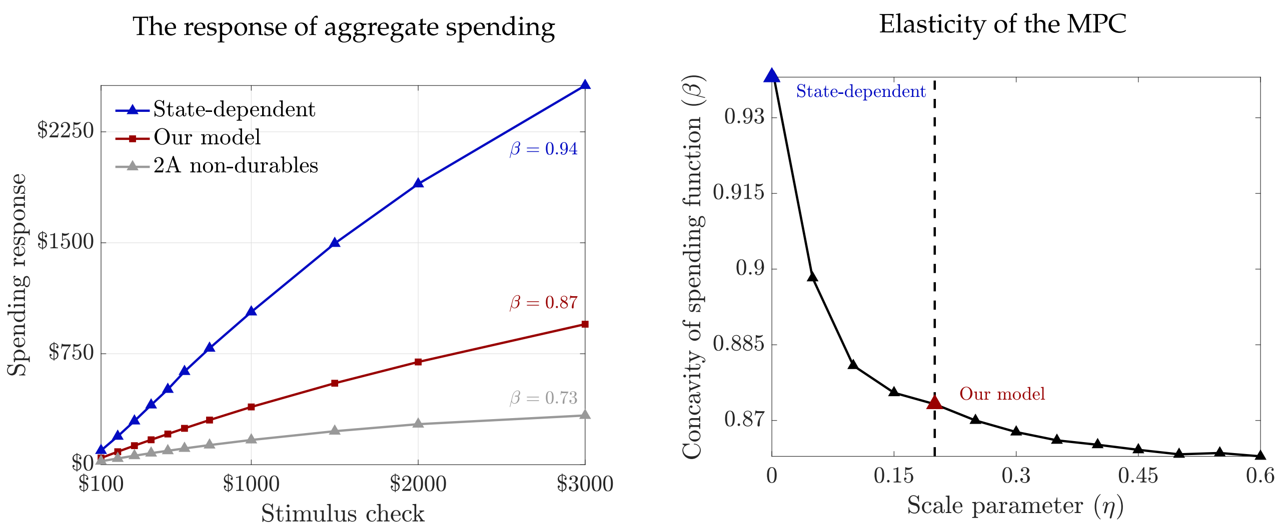
[32] This exercise serves as an intermediate, partial equilibrium step to our dynamic general equilibrium analysis where we quantify the effect of stimulus checks of varying size (Section 5).

[33] By construction, the elasticity of the MPX with respect to the size of checks T is equal to $\beta - 1$ since $\text{MPX} \equiv \Delta\text{Spending}/T$.

[34] Berger et al. (2023) build a purely state-dependent model of housing purchases. To compute total spending, they add non-durable spending and the imputed service flow from housing. While not the focus of their paper, they find in a numerical experiment that the marginal propensity to consume declines more slowly compared to a canonical model of non-durables.

[35] That said, changes in the scale parameter within these bounds still affect the level of the MPX and the other moments discussed in Section 3. We prefer $\eta = 0.2$ for the reasons discussed in that section.

Figure 4.2: Aggregate spending



Notes: The left panel plots the response of aggregate spending as a function of the size of stimulus checks. The red curve is our model. The blue curve is a purely state-dependent version of our model. The grey curve is a canonical two-asset model of non-durables. The right panel reports the elasticity of the MPX with respect to the size of stimulus checks, 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 $\eta = 0.2$.

4.3 Decomposing the MPX on Durables

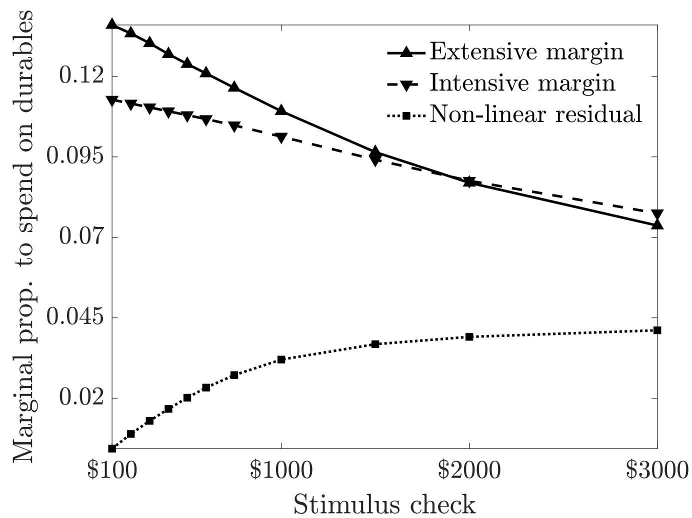
The smooth adjustment hazard in our model dampens the extensive margin of adjustment. To understand how it affects the size-dependence in the MPX, we decompose the marginal propensity to spendon durables into its extensive and intensive margins as follows

$$
\begin{aligned}
\text{MPX}^d(T) = & \underbrace{\frac{\int \overbrace{\{\mathcal{S}_0(d, m+T, y) - \mathcal{S}_0(d, m, y)\}}^{\#\text{ of marginal adjusters}} \times \overbrace{x(d, m, y)}^{\text{selection}} \times d\pi(\mathbf{x})}{T}}_{\text{Extensive margin}} \\
& + \underbrace{\frac{\int \mathcal{S}_0(d, m, y) \times \{x(d, m+T, y) - x(d, m, y)\} \times d\pi(\mathbf{x})}{T}}_{\text{Intensive margin}} + \text{res} \qquad (4.1)
\end{aligned}
$$

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. The residual res captures the non-linear interaction between the two margins.

Figure 4.3 plots these three components as a function of the size of stimulus checks in our model. The intensive and extensive margins contribute to the marginal propen-

Figure 4.3: Intensive and extensive margins



Notes: The solid and dashed curves decompose the response of durable spending into its extensive and intensive margins. The dotted curve is the non-linear residual that captures the interaction between the two margins.

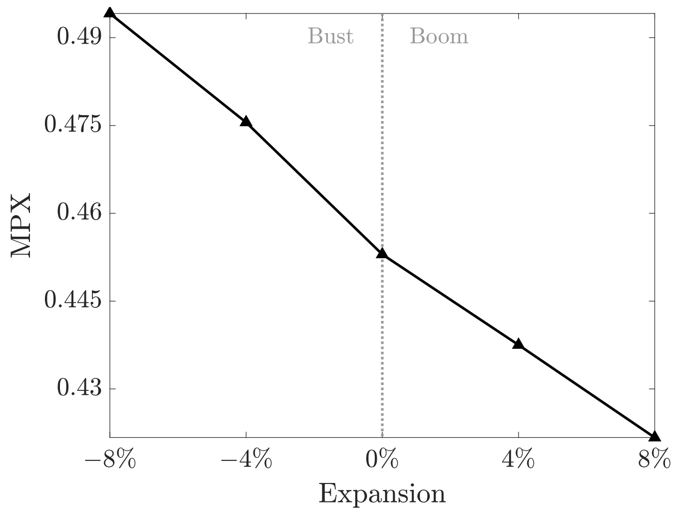
sity to spend on durables in roughly the same proportions in our model. This contrasts with a purely state-dependent model where the extensive margin dominates.[36] The intensive margin declines as the stimulus checks become larger due a standard precautionary savings motive. Perhaps surprisingly, the extensive margin declines as well. Figure C.5 in Appendix C shows that more and more households are pushed into adjustment as stimulus checks become larger, initially at a constant rate and eventually at a lower pace. Overall we find that increasing the size of stimulus checks from $100 to $3,000 increases the mass of adjusters by 2.5% or so, which is broadly consistent with the survey evidence from Fuster et al. (2021). The decline in the pace at which households adjusts accounts for most, but not all the decrease in the extensive margin. There is a selection effect too: late adjusters who wait until they receive a large check to adjust were originally less likely to purchase a durable and thus buy a smaller one.[37] The residual is smaller than the other components. However, its contribution rises with the size of stimulus checks as late adjusters are poorer on average and have a higher marginal propensitites to spend.

4.4 Aggregate Conditions

Finally, we explore how aggregate conditions affect the MPX in our model. Figure 4.1 plots the MPX out of $500 at various points of the business cycle. The stimulus checks

[36] Figure C.6 in Appendix C conducts the same exercise for the purely state-dependent model.
[37] This type of selection effect is well known in the price setting literature (Golosov and Lucas, 2007).

Figure 4.4: Aggregate conditions (MPC out of \$500)



Notes: This figure plots the total MPC in our model at various points of the business cycle. The stimulus checks are received unexpectedly after three quarters of constant expansion (or contraction), following by a linear mean-reversion over eight quarters.

are received unexpectedly after three quarters of constant expansion (or contraction), followed by a linear mean-reversion over eight quarters. The MPX is mildly countercyclical: it tends to be larger in recessions, and even more so in deeper ones. This prediction is in line with the evidence of Gross et al. (2020) and Baker et al. (2018). In contrast, a purely state-dependent model predicts a sharp decline in the MPX in deeper recessions (Figure C.7 in Appendix C) through the mechanism proposed by Berger and Vavra (2015).

5 Stimulus Checks in General Equilibrium

In the rest of this paper, we evaluate the effect of stimulus checks in general equilibrium. We start by embedding our model of households' spending into an open-economy heterogeneous-agent New-Keynesian model (Section 5.1). Our model accounts for various forces that could mitigate the spending response to stimulus checks. We describe the parameterization in Section 5.2. We quantify the general equilibrium response to stimulus checks in Section 5.3, and compare our results to those of a canonical two-asset model of non-durables. We allow for supply shocks and richer inflation dynamics in Section 5.4. We provide more details in Appendix B.

5.1 Environment

The economy has two sectors. The first produces a non-durable good and the second an investment good. The non-durable good can be used for consumption or as an intermediate for producing the investment good. The investment good can be used to build up the stock of durables or capital. The non-durable good is produced with labor. The investment good is produced by combining non-durables and a fixed factor (as in McKay and Wieland, 2021), or with capital.

Households. The household block of the economy is identical to the one introduced in Section 2. The only difference is that we allow for relative price movements over time, and across durables and non-durables, as well as imports and exports of goods.

Households import part of their non-durable and investment goods.[38] Households' non-durable 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 home and foreign non-durable goods, respectively, and the weights $\alpha_H^c + \alpha_F^c = 1$ capture the corresponding spending shares. The terms x_t^j and α_j^d are defined similarly for investment in durables. 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 home non-durable good. The households' credit constraint (2.4) is now indexed by the future expected price of durables $\mathbb{E}_t \left[P_{t+1}^d\right]$ as in Gavazza and Lanteri (2021).[39] All other prices and real quantities are also expressed in terms of the home non-durable good.

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 equal to the steady state levels at home so there are no net imports initially. Capital flows are unrestricted during the transition. Finally, the price of the foreign good is fixed throughout. The nominal exchange rate is pinned down by uncovered interest rate parity during the transition, and purchasing power parity in the long-run (Appendix B.1). Domestic and foreign prices are normalized to 1 at the initial stationary equilibrium.

Non-durable goods. A firm produces non-durables using only labor. Inflation in the price

[38] For instance, a fourth of durable expenditure is spent on foreign goods in the US. Allowing for imports dampens the equilibrium response of output to stimulus checks as part of the extra spending leaks abroad.
[39] See Appendix A.1 for details.

of the non-durable good (π_t) follows a standard Phillips curve

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

where Y_t^{dom} is the aggregate demand for the non-durable good, Y_t^{potent} is potential output in that sector, and $\kappa > 0$ is the slope of the Phillips curve.[40]

Investment goods. Following McKay and Wieland (2021, 2022), a firm produces the durable good using an amount M of non-durables and produces $F(M) = A_0 M^{\frac{\zeta}{1+\zeta}}$ investment goods, where $1/\zeta > 0$ governs the decreasing returns in production and $A_0 > 0$ is productivity.

We assume that the firm can also produce the investment good using capital. This allows us to introduce investment shocks that act as aggregate demand shifters in a tractable way.[41] Specifically, we assume that the firm can use K_{t-1} units of capital to produce $A_1 K_{t-1}$ units of the investment good, where $A_1 > 0$ is productivity. New capital is produced with investment goods too. The stock of capital evolves as

$$K_t = \left\{1 - \delta^K + \Phi\left(I_t/K_{t-1}\right) + z_t\right\} K_{t-1}, \tag{5.3}$$

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 investment technology which is increasing and concave.[42] As in Brunnermeier and Sannikov (2014), the shocks $\{z_t\}$ are a source of aggregate fluctuations in our economy.

The firm maximizes its value (Appendix B.2) and smoothes the dividends Div_t that it disburses to households (Leary and Michaely, 2011). This ensures that investment shocks affect households' incomes in (5.9) and hence their aggregate spending.[43] Profit maxi-

[40] See McKay and Wieland (2021) for the derivation of the price setting equations (5.2) and (5.4). The Phillips curve can result from sticky prices or wages. Workers claim the revenue of the firm producing non-durables in proportion to their idiosyncratic productivity. Distinguishing between sticky prices and sticky wages (or wages and profits in the non-durable sector) would require taking a stance on workers' labor supply, which is not the focus of this paper.

[41] Firms investment shocks are the main driver of US business cycle fluctuations (Justiniano and Primiceri, 2008; Auclert et al., 2020). Beyond their importance in the data, investment shocks also allow us to compute efficiently the sequence of shocks that produce a given recession of interest despite the non-linearities inherent to our model (Appendix B.3).

[42] This specification with a linear production function and a concave investment technology is common in the asset pricing literature (Jermann, 1998; Brunnermeier and Sannikov, 2014).

[43] Absent dividend smoothing, an increase in investment raises output but not incomes when output is demand-determined, as is evident from (5.9). We describe the dividend smoothing in more detail when we discuss the parametrization (Section 5.2).

mization implies that, in equilibrium, the relative price of the investment good is

$$p_t^d \equiv \left(\frac{X_t^{\text{dom}}}{X_t^{\text{potent}}} \right)^{1/\zeta} \tag{5.4}$$

where X_t^{dom} is the aggregate demand for durables produced domestically and X_t^{potent} is potential output in that sector. The potential outputs Y_t^{potent} and X_t^{potent} in (5.2) and (5.4) capture sectoral productivities (Appendix B.2). In Section 5.4, we allow for shocks to these potential outputs which can be inflationary. In the following, we let $\hat{y}_t \equiv \log(Y_t^{\text{dom}}/Y_t^{\text{potent}})$ and $\hat{x}_t \equiv \log(X_t^{\text{dom}}/X_t^{\text{potent}})$ denote the output gaps in the two sectors relative to potential.

Policy. Monetary policy follows a standard rule

$$r_t^m = \max \left\{ r^m + \phi_\Pi \pi_t, \underline{r} \right\}, \tag{5.5}$$

where r^m is the steady state interest rate on the liquid asset m, ϕ_Π is the coefficient on inflation, and $\underline{r}$ is the effective lower bound.[44]

The government levies progressive income taxes (Heathcote et al., 2017). It also claims the net payments on credit from the households.[45] The government's flow budget constraint is

$$B_t^g = \frac{1 + r_t}{1 + \pi_t} B_{t-1}^g + \mathcal{T}_t + \Sigma_t - t_t - G_t, \tag{5.6}$$

where B_t^g is the government's real asset holdings, $\mathcal{T}_t \equiv \int \left(yE_t - \psi_{0,t}(yE_t)^{1-\psi_1} \right) d\mu_{t-1}$ is tax revenues with E_t denoting households' total real income, t_t is real stimulus checks to households, Σ_t is the net payments on the credit (Appendix B.4), and G_t is the government spending on non-durables.[46]

Stimulus checks are sent in the first period to eligible households. We assume that households who have earned less than \$75,000 in the previous year are eligible to receive a check. The check decreases linearly with income after that and reaches 0 at \$80,000.[47]

As in our baseline calibration, the government maintains a constant ratio of debt to output at the stationary equilibrium. Its real spending $G > 0$ on domestic goods balances

[44] We assume that the Taylor coefficient on the output gap is zero, as in Auclert et al. (2021). We have experimented with a version where the rule (5.5) depends on CPI (or PPI inflation) instead of non-durable inflation π_t, and obtained similar results in this case.

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

[46] We assume that the government spends G_t on domestic and foreign varieties using the same aggregator (5.1) as the households.

[47] This distribution of checks mimicks the one observed in 2020–2021. We assume that mean annual income is \$67,000 at the steady state, as in Kaplan and Violante (2022).

the budget (5.6) in steady state. In period $t = 0$, the government sends a one-time nominal stimulus check $T_0 > 0$ to every household. It borrows $(\Delta B_0 < 0)$ to finance these checks. In later periods $t > 0$, the government maintains a constant spending $G_t = G > 0$ and repays its new debt over time by raising the tax intercept $\psi_{0,t}$ as we explain in Section 5.2.

Outputs and incomes. Market clearing requires that the amounts spent on the non-durable and durable goods equal the value of the production in these sectors

$$P_t^c \left(C_t + G_t\right) + F^{-1}\left(X_t^{\text{dom}}\right) + \text{NX}_t^{c,\text{real}} = Y_t^{\text{dom}}, \tag{5.7}$$

and

$$P_t^d X_t + p_t^d I_t + \text{NX}_t^{d,\text{real}} = p_t^d \left(X_t^{\text{dom}} + A_1 K_{t-1}\right), \tag{5.8}$$

where C_t and X_t are the households' aggregate demands for the non-durable and investment good, respectively, $F^{-1}\left(X_t^{\text{dom}}\right)$ is the demand for non-durables used to produce X_t^{dom} units of the investment good, $\text{NX}_t^{c,\text{real}}$ and $\text{NX}_t^{d,\text{real}}$ are net exports in real terms (Appendix B.1), and Y_t^{dom} and $X_t^{\text{dom}} + A_1 K_{t-1}$ are the outputs in the two sectors.[48] The price indices P_t^c and P_t^d are given by (5.9) and the relative price p_t^d is given by (5.4).

Households' aggregate income before interest and tax payments Y_t^{inc} is

$$Y_t^{\text{inc}} = Y_t^{\text{dom}} + \text{Div}_t, \tag{5.9}$$

where Y_t^{dom} corresponds to the payments of the firm producing the non-durable good (footnote 40) and Div_t corresponds to the dividends disbursed by the firm producing the investment good. Households' real net income before interest payments is

$$E_t^{\text{net}}(\mathbf{x}) = \psi_{0,t}\left(y Y_t^{\text{inc}}\right)^{1-\psi_1}, \tag{5.10}$$

where y still captures idiosyncratic income shocks, and $\psi_{0,t}$ and ψ_1 parametrize the non-linear tax schedule.

Finally, we will compute aggregate output as a quantity index

$$Y_t^{\text{GDP}} \equiv C_t + X_t + G_t + I_t + \text{TB}_t \tag{5.11}$$

using steady state prices ("chained dollars"), where TB_t is the quantity index for the trade

[48] Households' consumption C_t and investment in durables X_t and government spending G use both the local and foreign goods. On the contrary, the firm's investment I_t uses local goods only. Hence the different price indices in (5.9).

balance (Appendix B.1).

5.2 Parametrization

As in our baseline calibration (Section 3), the real 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 the tax intercept ψ_0 ensures that the marginal tax rate is 30% in the long-run. Households import 23% of their durable spending at the steady state, and 19% of their non-durable spending (Hale et al., 2019). We set the elasticity of substitution between home and foreign varieties to $\rho \to 1$. This value lies between the short-run and long-run estimates of Boehm et al. (2023). We normalize the productivity A_0 in the sector producing the investment good so the relative price of durables is $p^d \equiv 1$ at the initial steady state. The investment technology is $\Phi(x) = 1/\phi\left(\sqrt{1+2\phi x} - 1\right)$ with $\phi \equiv 2$ as in Brunnermeier and Sannikov (2014). The productivity of the investment firm A_1 is chosen so there is no long-run growth.[49] The slope of the Phillips curve is $\kappa = 0.0031$ based on Hazell et al. (2022).[50] For now, we focus on the case $\zeta \to +\infty$ where the relative price of durables is acyclical.[51] We allow for relative price movements in Section 5.4. The Taylor coefficient is $\phi_\Pi = 1.5$ as in Auclert et al. (2021). The effective lower bound on the interest rate is 3 percentage points lower than the steady state interest rate r, assuming a 3% nominal return on the liquid asset. Therefore, we set the effective lower bound to $\underline{r} = -2\%$. The government slowly repays the debt that it contracts to finance the stimulus checks by raising tax rate $\psi_{0,t}$ uniformly over 15 years. After that, the government lets $\psi_{0,t}$ decay to its long-run value ψ_0 over the next 5 years. Similarly, we assume that the firm producing the investment good disburses dividends Div_t uniformly over 15 years, and then lets the dividends decay back to their steady state level over the next 5 years.

5.3 The Response to Stimulus Checks

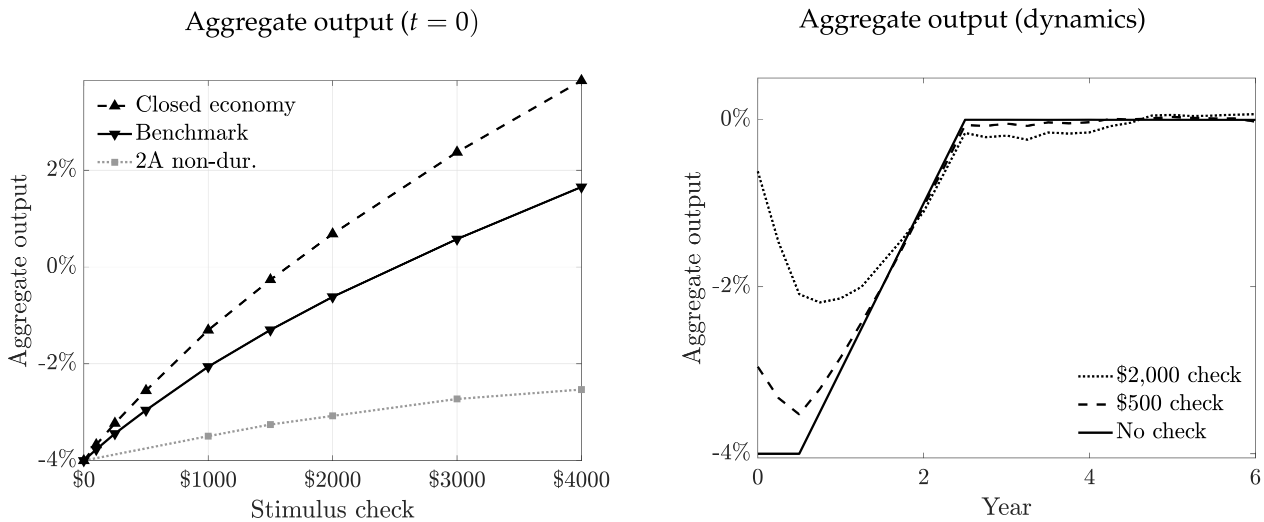
We are now ready to quantify the effect of stimulus checks in general equilibrium. The economy experiences a demand-driven recession due to investment shocks $\{z_t\}$ in (5.3). We engineer these shocks so that aggregate output falls by 4% over three quarters, and then recovers linearly over the next two years (Appendix B.3). Starting from this reces-

[49] This is standard in models with AK technology. We normalize the level of capital in steady state to $K \equiv 1$.

[50] Hazell et al. (2022) find that the slope of the Phillips curve is -0.0062 in terms of unemployment since 1980. The semi-elasticity of unemployment with respect to output is roughly -0.5 over the same period.

[51] Empirically, the relative price of new consumer durables is essentially acyclical, even when using transaction prices instead of sticker prices (as in CPI data). In particular, this relative price does not respond to monetary policy shocks (McKay and Wieland, 2021; Cantelmo and Melina, 2018).

Figure 5.1: General equilibrium responses to stimulus checks



Notes: The left panel plots the response of aggregate output (in deviations from steady state) as a function of the size of stimulus checks. The solid curve is our benchmark general equilibrium model. The dotted curve is a closed-economy version of our model. The grey curve is a canonical two-asset model of non-durables. The right panel reports the dynamic response of aggregate output in our benchmark general equilibrium model for stimulus checks of various sizes.

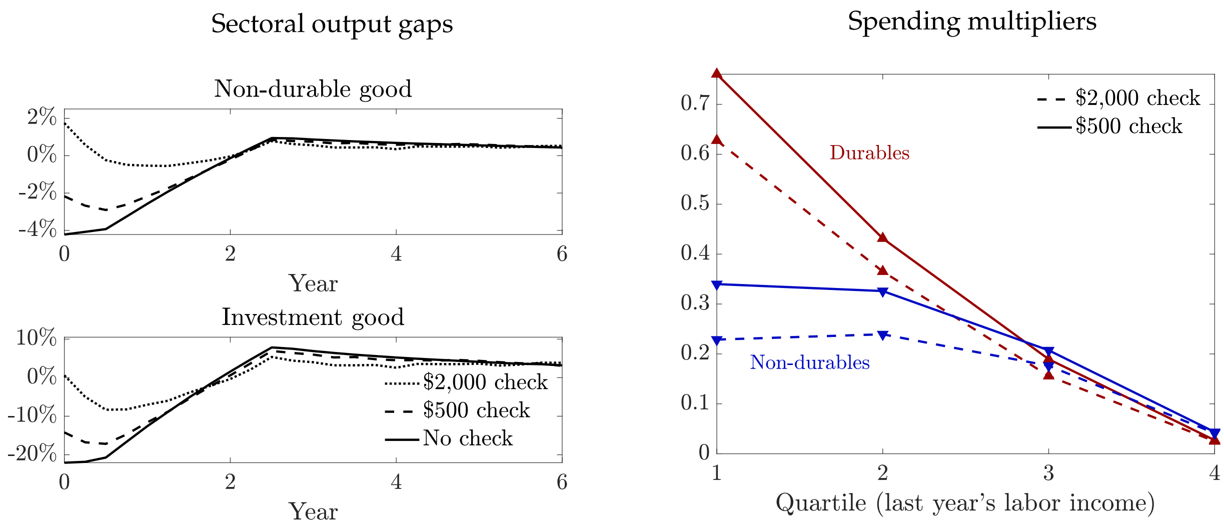
sion, the government sends a (nominal) stimulus check T_0 in the first quarter. We repeat this experiment for checks of various sizes.

Aggregate output. The left panel of Figure 5.1 plots the response of aggregate output (in deviations from steady state) in the first quarter for various sizes of stimulus checks. We first consider the benchmark general equilibrium model that we presented in Sections 5.1–5.2 (solid black curve). Output is 4% below potential initially, which amounts to a roughly $800 decrease in average quarterly income A $500 check closes about a fourth of the output gap. Doubling the check achieves twice as much: $1000 closes one half of the output gap. Beyond that amount, the size-dependence in the MPX starts kick in, as the aggregate spending function becomes more concave (Figure 4.2). A more than twice as large ($2,400) is needed to fully close the output gap — about three times the $800 fall in average quarterly income. Checks beyond this amount are too much in a typical demand-driven recession in that they stimulate output beyond potential.

To assess the strength of international leakages through imports, we report the same response in a closed economy (dashed black curve).[52] The bang-for-the-buck is larger in the closed economy: a smaller stimulus check of roughly $1,600 suffices to fully close the output gap. For comparison, we also plot the output response for the canonical two-asset

[52] In this version of the model, households only consume the domestic varieties so $\alpha_d^F = \alpha_c^F = 0$.

Figure 5.2: Durables and non-durables



Notes: The left panel plots the output gaps over time in the sectors producing the non-durable and investment goods, respectively, for various stimulus checks. The right panel plots the general equilibrium spending multipliers on durables (in red) and non-durables (in blue), i.e., the average equilibrium response of spending (across individuals) divided by the size of stimulus checks.

model of non-durables (dashed grey curve). In this case, a large check of $4,000 is barely more effective than a smaller check of $2,000 as the MPX decreases sharply (Figure 4.2),

The right panel of Figure 5.1 plots aggregate output over time in our benchmark general equilibrium model for various sizes of stimulus checks. A $2,000 check closes most of the output gap in the first period, and about half of the cumulative output gap. A $4,000 check closes 75% of the cumulative output gap but stimulates output above potential in the short run; an even larger check of roughly $6,000 is required to fully close this cumulative gap (not shown).

Durables and non-durables. We now turn our attention to sectoral responses. The left panel of Figure 5.2 plots the response of the output gaps in the sectors producing the non-durable and investment goods for various stimulus checks.[53] The sector producing the investment good contracts proportionately more in the recession, both because households' durable spending is much more cyclical and because of the demand shock that lowers the firm's investment. The two sectors recover roughly simultaneously. The right panel of Figure 5.2 plots the average equilibrium response of spending (across individuals) divided by the size of stimulus checks. These "spending multipliers" account for general equilibrium changes in incomes and prices. We report this measure for each quartile of the

[53] Note that these output gaps do not exactly average to the aggregate output gap reported in Figure 5.1 since intermediaries $F^{-1}\left(X_t^{\text{dom}}\right)$ are counted in sectoral output (5.7) but not in aggregate output (5.11).

distribution of average labor income in the previous year (i.e., the basis of eligibility for checks). As expected, low-income households account for most of the spending response, both because they have higher MPXs and because they are more likely to be eligible for checks.[54] This effect is particularly strong for durables.

5.4 Supply Shocks and Inflation

We conclude the paper with an exercise that creates a larger role for supply side effects. The goal is to quantify the extent to which these forces could dampen the equilibrium response to stimulus checks. Our motivation is twofold. First, some recessions entail changes in the productive capacity of the economy, in addition to shifts in aggregate demand (which we have focused on far). Second, the Phillips curve may become steeper when output is above potential, and the supply of investment goods could be less elastic in certain recessions. These effects would contribute to stronger inflationary pressures.

With this in mind, we now allow for contractions in potential outputs Y_t^{potent} and X_t^{potent}, we introduce a non-linear Phillips curve

$$\pi_t = \kappa \hat{y}_t + \kappa^{\star} \max\left\{\hat{y}_t, 0\right\}^2 + \beta \pi_{t+1}, \tag{5.12}$$

when output is above potential, and we allow for relative price movements between durables and non-durables by lowering the supply elasticity compared to our benchmark ($\zeta < \infty$). This is a rather extreme scenario: a "perfect storm" with both demand and supply shocks, and strong inflationary pressures. While not representative of the typical recession, this scenario resembles perhaps the 2020-2021 recession and its recovery.[55]

We choose the shocks to potential outputs Y_t^{potent} and X_t^{potent} to reduce the output gaps $\hat{y}_t$ and $\hat{x}_t$ by 50% in the first period absent stimulus checks; after that, the output gaps mean revert linearly over the next 2 years. Regarding the non-linear Phillips curve, there is much uncertainty in the literature about the appropriate value for $\kappa^{\star}$.[56] We purposefully choose a high value to allow inflation to play an important role. We set $\kappa^{\star}$ so the average slope of the Phillips curve is steep (0.1) as $\hat{y}_t$ rises from zero to 2%.[57] This slope lies

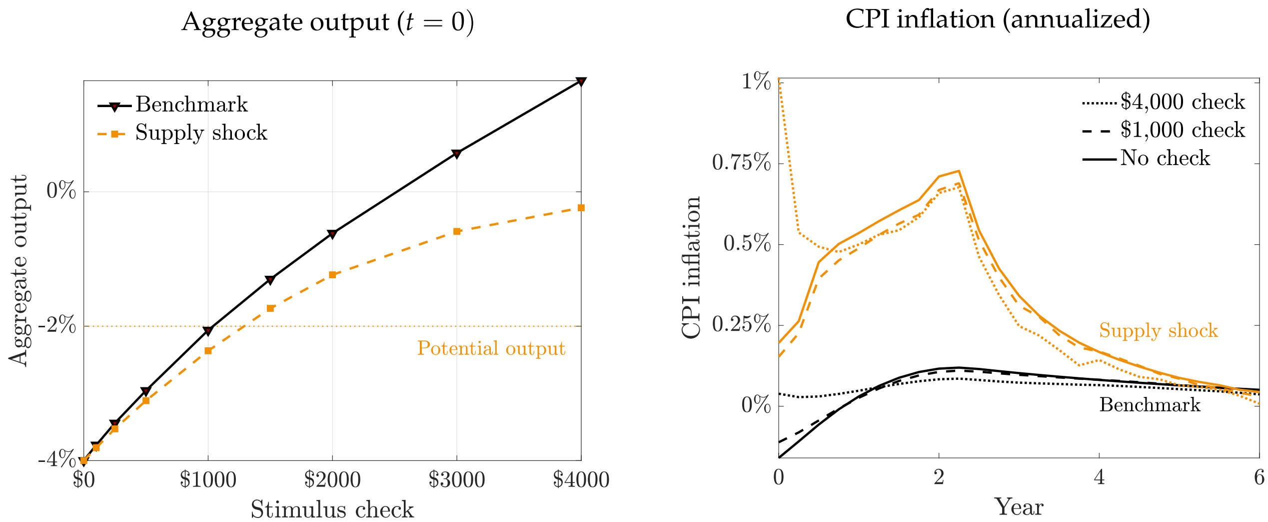
[54] About 66% of households are eligible for checks, i.e., quartiles 1–2 receive the full check.

[55] For instance, US inflation was very low during the 2001 recession and the Great recession, and there was no meaningful change in the relative price of durables; whereas inflation rose in 2021 in particular for durables.

[56] In fact, there is little consensus as to whether the Phillips curve actually steepened or just shifted up in the aftermath of the 2020 recession (Hobijn et al., 2023; Ari et al., 2023). Higgins (2021) argues that the Phillips curve actually *flattened* early on around the time when stimulus checks checks were sent. Cerrato and Gitti (2022) reach the same conclusion, but find that the Phillips curve steepened subsequently during the 2021-2022 recovery.

[57] This output gap is similar to what we observed in the US in 2023 when inflation peaked. Unemployment

Figure 5.3: General equilibrium responses with supply shock



Notes: The left panel plots the response of aggregate output (relative to steady state) as a function of the size of stimulus checks. The black curve is our benchmark model with a demand shock only. The orange curve is our model with both a demand and supply shock. The right panel reports CPI inflation in these two models with and without a stimulus check.

at the upper end of conventional estimates in the literature (Mavroeidis et al., 2014) and is consistent with the findings of Cerrato and Gitti (2022) for the 2021-2022 recovery.[58] Finally, we set the relative supply elasticity of durables to $\zeta \equiv 1/0.049$ as in McKay and Wieland (2021, 2022).

Figure 5.3 plots aggregate output in the first quarter (left panel) and CPI inflation (right panel) in this model and in our benchmark model with only demand shocks.[59] The response of output is nearly indistinguishable for small checks. Supply shocks reduce potential output, and a check of roughly \$1,200 closes the smaller output gap. Inflation is higher, even absent stimulus checks, as sectoral demands eventually exceed potential outputs during the recovery (Figure C.8 in Appendix C).[60] Stimulus checks are more inflationary as they become larger and stimulate output above potential, which dampens the response of output substantially. A government that misdiagnoses the recession as being entirely demand-driven could be tempted to send checks as large as \$4,000 to close its perceived output gap (the full 4% decline in output from steady state) when the true gap is smaller. Inflation would increase, albeit modestly compared to the 2021-2022 episode.

was 1% lower than its NAIRU level in the second part of 2023 (CBO). This corresponds to an output gap of 2% (footnote 50).

[58] Cerrato and Gitti (2022) estimate that the slope of annualized inflation with respect to the unemployment rate was -0.85 during 2021-2022 recovery. Expressing this estimate in terms of quarterly inflation and output gap leads to a slope of roughly 0.1, assuming an unemployment elasticity of -0.5 (footnote 50).

[59] The CPI price index weights sectoral prices by the households' steady state spending shares.

[60] *Future* positive output gaps raise current inflation as the Phillips curve is forward-looking.

6 Conclusions

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

We find that the MPX declines with the size of income changes, albeit slowly. The MPX neither surges as sometimes conjectured in the empirical literature, nor does it decline sharply as in a canonical two-asset model of non-durable spending.

As an application, we quantify the effect of stimulus checks in general equilibrium by embedding our spending model into an open-economy heterogeneous-agent New-Keynesian setting. Large checks remain effective at stimulating output in our model, whereas their effect wears off quickly in a canonical two-asset model of non-durables. We compute the size of the checks that close the output gap in recessions driven by different combinations of demand and supply shocks. Larger checks overheat the economy and raise inflation.

The size of the check that closes the output gap provides a useful, though incomplete answer when it comes to choosing how large stimulus checks should be in a given recession. In presence of distortionary taxation or inflation, the government would not fully close the output gap. Moreover, governments send checks not only to stimulate output but also to provide insurance to households in downturns. As such, the optimal size of stimulus checks depends on the government's tolerance for inflation as well as its preference for insurance and redistribution. Future work can build on the model that we have developed here to provide a more complete answer when choosing how large stimulus checks should be.

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A Consumption and Investment Problem

In this appendix, we discuss how to solve the households' consumption and investment problem. Section A.1 states the problem recursively for the full model. Section A.2 discusses the numerical implementation. Finally, Section A.3 provides details about our numerical implementation.

A.1 Households' Problem

We now state the household's problem recursively. Relative to Section 2.5, the formulation below allows for movements in the price indices for the investment good $\left(P^d\right)$ and the non-durable good (P^c) to anticipate our general equilibrium analysis (Section B). We also formulate the problem in a way that lends itself better to numerical implementation (Appendix A.2). Households are still indexed by three idiosyncratic states: their holdings of durables (d); their holdings of liquid asset (m); and their idiosyncratic income (y). We let $\mathbf{x} \equiv (d, m, y)$ to save on notation. All prices and real quantities are expressed relative to the domestic non-durable good.

Continuation values. The continuation values $\{V_t(\cdot)\}$ can be characterized recursively.[61]

1. **Discrete choice.** The household chooses whether to adjust its stock of durables. The value associated to the discrete choice problem is

$$V_t(\mathbf{x}) \equiv \max\left\{\hat{W}_t^D(\mathbf{x}) - \epsilon, \hat{W}_t^C(\mathbf{x})\right\},$$

where $\hat{W}_t^D(\mathbf{x})$ is the value of adjusting the stock of durables, $\hat{W}_t^C(\mathbf{x})$ is the value of not adjusting, and ϵ is a taste shifter that follows a logistic distribution whose mean and variance are controlled by $\kappa > 0$ and $\eta > 0$, respectively.[62] Therefore,

$$V_t(\mathbf{x}) \equiv \eta \log\left(\sum_{h\in\{D,C\}} \exp\left(\frac{\hat{W}_t^h(\mathbf{x})}{\eta}\right)\right) \tag{A.1}$$

[61] The terminal condition for $V_{t+1}(\cdot)$ is either an initial guess when solving for the stationary equilibrium, or the stationary value function without stimulus checks when solving for transitions. We let $t = T$ denote the terminal period.

[62] An equivalent formulation consists of introducing two additive taste shifters ϵ^D and ϵ^C (one for each option) which are distributed according to a generalized extreme value distribution of type-I. See Artuç et al. (2010) for the derivation of (A.1) and (A.2).

The adjustment hazard associated to the discrete choice problem is

$$\mathcal{S}_t(\mathbf{x}) \equiv \frac{\exp\left(\frac{\hat{W}_t^D(\mathbf{x})-\kappa}{\eta}\right)}{\exp\left(\frac{\hat{W}_t^D(\mathbf{x})-\kappa}{\eta}\right)+\exp\left(\frac{\hat{W}_t^C(\mathbf{x})}{\eta}\right)} \tag{A.2}$$

The continuation values are given by

$$\hat{W}_t^D(\mathbf{x}) \equiv W_t^D\left(\mathcal{Y}_t(\mathbf{x};T_t)+\Delta_t^D d, y\right)-\kappa \tag{A.3}$$

$$\hat{W}_t^C(\mathbf{x}) \equiv W_t^C\left((1-(1-\iota)\delta)d, \mathcal{Y}_t(\mathbf{x};T_t)-\Delta_t^C d-\iota\delta P_t^d d, y\right) \tag{A.4}$$

The households gets to choose a new stock of durables if it adjusts, and maintains its stock otherwise by offsetting a share ι of the depreciation (Bachmann et al., 2013; Berger and Vavra, 2015). These continuation values depend on the household's initial cash-on-hand after interest payment and stimulus check

$$\begin{aligned}\mathcal{Y}_t(\mathbf{x};T_t) \equiv & \psi_{0,t}\left(yY_t^{\text{inc}}\right)^{1-\psi_1}+\frac{1+r_{t-1}^m}{1+\pi_t}m \\ & -r_{t-1}^b(1-\theta)\hat{P}_t^d(1-\delta)d+t_t\end{aligned} \tag{A.5}$$

where Y_t^{inc} is real aggregate income and t_t are real stimulus checks. The interest rate on credit is r_{t-1}^b is equal to the return on the liquid asset r_{t-1}^m plus a spread of 3.5% (Section 3.1). The inflation rate π_t accounts for the fact that the budget constraints are expressed in real terms, i.e., all prices are expressed relative to the one of the non-durable domestic good. The price $\hat{P}_t^d \equiv \mathbb{E}_{t-1}\left[P_t^d\right] \times (1+\mathbb{E}_{t-1}[\pi_t]) / (1+\pi_t)$ accounts for two effects. First, the credit constraint (2.4) is indexed by the expected nominal price of durables (as in Gavazza and Lanteri, 2021) when allowing for relative price movements in our general equilibrium analysis. Second, the expected *real* price of durables $\mathbb{E}_{t-1}\left[P_t^d\right]$ depends on the *expected* price level (and hence inflation $\mathbb{E}_{t-1}[\pi_t]$) which might differ from the *realized* one (π_t) when the aggregate shock occurs in the first period. In turn, the two terms

$$\Delta_t^D \equiv \left\{P_t^d-(1-\theta)\hat{P}_t^d\right\} \times (1-\delta) \tag{A.6}$$

$$\Delta_t^C \equiv (1-\theta) \times \left\{\hat{P}_t^d - P_{t+1}^d(1+\pi_{t+1})(1-(1-\iota)\delta)\right\} \times (1-\delta) \tag{A.7}$$

capture, respectively, the net profit that the household makes when selling its old durable (after repaying the credit owed on it) in the case of Δ_t^D, and the debt payment on the principal (after borrowing up to the new LTV) in the case of Δ_t^C.[63] In the fully state-dependent limit $\eta \to 0$, the value (A.1) and the hazard (A.2) become

$$V_t(\mathbf{x}) \equiv \max_{h \in \{D,C\}} \left\{ W_t^h(\mathbf{x}) \right\} \quad \text{and} \quad \mathcal{S}_t(\mathbf{x}) = \begin{cases} 1 & \text{if } \hat{W}_t^D(\mathbf{x}) > \hat{W}_t^C(\mathbf{x}) \\ 0 & \text{otherwise} \end{cases} \tag{A.8}$$

2. **Durable adjustment.** If the household opts for adjusting its stock of durables, it chooses how much durables to purchase

$$\begin{aligned} W_t^D(m,y) \equiv \max_{d',m'} \; & W_t^C(d',m',y) \\ \text{s.t. } & \left[P_t^d - (1-\theta) P_{t+1}^d (1+\pi_{t+1})(1-\delta)\right] d' + m' \leq m, \end{aligned} \tag{A.9}$$

   where m is real cash-on-hand before the household purchases its new stock of durables. The down payment constraint depends on the expected price of durables next period.[64] The price index for durables P_t^d is expressed relative to the price of the domestic non-durable, which grows at rate π_{t+1} over time.

3. **Consumption-saving.** Finally, the household chooses how much to consume and save in liquid asset

$$\begin{aligned} W_t^C(d,m,y) \equiv \max_{c,m'} \; & u(c,d) + \beta \int V_{t+1}(d,m',y')\, \Gamma(dy';y) \\ \text{s.t. } & P_t^c c + m' \leq m \quad \text{and} \quad m' \geq 0, \end{aligned} \tag{A.10}$$

   where m is real cash-on-hand when the household chooses non-durable consumption c, and m' is the real holdings of financial assets for next period.

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:

[63] The new LTV depends on next period's undepreciated part $(1-\delta)$ of the capital stock at the end of today's period $(1-(1-\iota)\delta)\,d$.

[64] The expected price of durables appears in (2.4). Note that $\mathbb{E}_t[E_{t+1}] = E_t$ for all $t \geq 0$ in our perfect foresight economy, except in the very first period $(t=-1)$ where the relative price of durables (5.4) can jump after an aggregate shock. Expressions (A.5)–(A.7) account for that.

1. **Guess.** Fix $\mathcal{V}_{T+1}(\mathbf{x}) \equiv \int V_{T+1}(d,m,y')\,\Gamma(dy';y)$. Let $\partial_z \mathcal{V}_t(\cdot) \equiv \partial_z \mathcal{V}_t(\cdot)$ for the durable and liquid assets $z \in \{d,m\}$.

2. **Consumption-saving.** Fix the (terminal) states (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

   $$u_c(c,d) = \beta P_t^c \mathcal{V}_m(d,m',y), \tag{A.11}$$

   together with the budget constraint $c = m - m'$. These conditions are not sufficient, however, since the problem is typically non-convex.[65,66] To recover policy functions, i.e., maps $m \mapsto (c,m')$, 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 for m' 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.10) associated to each candidate. More specifically, we recover the policy functions $m \mapsto (c,m')$ using an approach similar to 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 brackets m so $m_0 \leq m \leq m_1$. 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 $c = m - m'$. Whenever the policy $m \mapsto m'$ violates the borrowing constraint $m' \geq 0$, consider instead the case (b) below. 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 $c = m$.

[65] The reason is that the continuation value involves the upper envelope (A.1). Random preference shocks for adjustment, i.e., the smooth hazard (A.2), can make continuation value *smooth* (i.e. no kinks) but not necessarily *concave*.

[66] Condition (A.11) 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, and condition (A.11) is necessary. The argument generalizes immediately to multiple kinks and multiple assets.

Using the resulting policy function $m'(\cdot)$, compute the value $W_t^C(\mathbf{x})$ using (A.10), and the marginal values

$$\partial_d W_t^C(\mathbf{x}) = u_d\left(m - m'(\cdot), d\right) + \beta \partial_d \mathcal{V}_{t+1}\left(d, m'(\cdot), y\right) \tag{A.12}$$
$$\partial_m W_t^C(\mathbf{x}) = 1/P_t^c u_c\left(m - m'(\cdot), d\right) \tag{A.13}$$

for the durable and the liquid asset.

3. **Durable adjustment.** A necessary condition for an optimum is[67]

$$\begin{aligned}&\partial_d W_t^C\left(d', m', y\right)\\ &\quad - \left[P_t^d - (1-\theta) P_{t+1}^d (1+\pi_{t+1})(1-\delta)\right] \partial_m W_t^C\left(d', m', y\right) = 0\end{aligned} \tag{A.14}$$

where

$$m' = m - \left[P_t^d - (1-\theta) P_{t+1}^d (1+\pi_{t+1})(1-\delta)\right] d' \tag{A.15}$$

Again, (A.14) is typically not sufficient for an optimum. We thus define a set of candidates d' that satisfy either (A.14) or $d' = \bar{d}$ where $\bar{d}$ is the upper bound of our numerical grid for durables. We compute the value (A.9) 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.9), and the marginal value

$$\partial_m W_t^D(m, y) = \partial_m W_t^C\left(d'(\cdot), m'(\cdot), y\right), \tag{A.16}$$

and proceed to Step 4.

4. **Continuation values.** Compute the values (A.3)–(A.4) and the marginal values

$$\partial_d \hat{W}_t^D(\mathbf{x}) = \left\{-r_{t-1}^b (1-\theta) \hat{P}_t^d (1-\delta) + \Delta_t^D\right\} \partial_m W_t^D(\cdot) \tag{A.17}$$
$$\begin{aligned}\partial_d \hat{W}_t^C(\mathbf{x}) = &(1-(1-\iota)\delta)\, \partial_d W_t^C(\cdot) + \\ &\left\{-r_{t-1}^b (1-\theta) \hat{P}_t^d (1-\delta) - \Delta_t^C - \iota\delta P_t^d\right\} \partial_m W_t^C(\cdot)\end{aligned} \tag{A.18}$$

for the durable stock, with Δ_t^D and Δ_t^C defined by (A.6)–(A.7), and

$$\partial_m \hat{W}_t^k(\mathbf{x}) = \frac{1 + r_{t-1}^m}{1+\pi_t} \partial_m W_t^k(\cdot) \quad \text{for each choice } k \in \{C, D\} \tag{A.19}$$

for the liquid asset.

[67] The solution is necessarily interior in this case, i.e., $d' = 0$, cannot be optimal.

5. **Discrete choice.** Compute the value (A.1) and the marginal values

$$\partial_z V_t(\mathbf{x}) = \mathcal{S}_t(\mathbf{x}) \partial_z \hat{W}_t^D(\mathbf{x}) + \{1 - \mathcal{S}_t(\mathbf{x})\} \partial_z \hat{W}_t^C(\mathbf{x}) \tag{A.20}$$

for the durable stock and the liquid asset $z \in \{d, m\}$, where $\mathcal{S}_t(\mathbf{x})$ is the adjustment hazard (A.2).

6. **Update.** Compute the expected utility $\mathcal{V}_t(\mathbf{x}) \equiv \int V_t(d, m, y') \Gamma(dy'; y)$ and the marginal utilities $\partial_z \mathcal{V}_t(\mathbf{x}) \equiv \int \partial_z V(d, m, y') \Gamma(dy'; y)$ for the durable stock and the liquid asset $z \in \{d, m\}$. Finally, repeat Step 1 until convergence when solving for the stationary equilibrium, or until $t = 0$ when solving for transitions.

A.3 Computational Details

Numerical parameters. We use 175-point grids for the liquid asset and the durable stock. We discretize the income process on a 7-point grid using the method of Rouwenhorst (1995). We use a stochastic simulation given the non-convexities inherent to our model.[68] To iterate on the distribution, we use the policy functions computed above, together with the income process Γ and we randomly assign households between adjustment (D) and no adjustment (C) according the adjustment hazard (A.2). The hazard and the policy functions are interpolated linearly between grid points. 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 after a burn of 400 quarters.

Smoothing the responses. In Sections 3–4, we compare the properties of our model with a purely state-dependent version $(\eta \to 0)$. To obtain slightly smoother responses, we introduce a very small variance $\eta = 0.0025$. The difference with our model and baseline calibration is that this variance is arbitrarily small, whereas we discipline this parameter empirically to match a rich set of micro moments.

[68] A non-stochastic simulation (e.g., Young, 2010) typically produces a different stationary distribution in presence of non-convexities. To understand why, consider a simplified example. Suppose that durables d is the only state and that there is no depreciation $\delta = 0$. The household choose yesterday a level that lies between two grid points $\underline{d} \leq d \leq \bar{d}$. Suppose that, the hazards are $\mathcal{S}(\underline{d}) = 0$ and $\mathcal{S}(\bar{d}) = 1$, and conditional on adjustment, $d'(\underline{d}) < \bar{d}$ and $\bar{d} \leq d'(d) \leq d'(\bar{d})$. The stochastic and non-stochastic simulations produce the same probability of adjustment today $(\bar{d} - d) / (\bar{d} - \underline{d})$. However, the probability of adjustment *tomorrow* should be 1 for those who adjusted today (as with the stochastic simulation) since their state tomorrow is $d'(d) \geq \bar{d}$. However, this probability is less than 1 for these households with the non-stochastic simulation since $d'(\underline{d}) < \bar{d}$ for some of them.

B General Equilibrium

In this appendix, we provide details about the general equilibrium setup. Section B.1 describes the price indices and the open economy features of our model (net exports, the real exchange rate, etc.). Section B.2 states and characterizes the firm's investment problem. Section B.3 explains how we construct efficiently the sequence of investment shocks that generates any particular recession of interest. Finally, Section B.4 discusses fiscal policy.

B.1 Price Indices, Trade Balance and Exchange Rate

This appendix provides details about the price indices, the trade balance, and the equilibrium exchange rate.

Price indices. We express the domestic prices and price indices, the exchange rate, and the trade balance relative to the price of the domestic non-durable good.[69] The real exchange rate is the cost of acquiring a non-durable good from the foreign country. The price indices at home for the non-durable and investment goods baskets are

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

where e_t is the real exchange rate and p_t^d is the price of the domestic investment good.[70] Similarly, the price indices abroad are

$$P_t^{c,\star} \equiv \left[\alpha_c + (1-\alpha_c)\,(1/e_t)^{1-\rho}\right]^{1-\rho} \quad \text{and} \quad P_t^{d,\star} \equiv \left[\alpha_d + (1-\alpha_d)\left(p_t^d/e_t\right)^{1-\rho}\right]^{1-\rho} \tag{B.2}$$

The *level* of the price of the domestic non-durable good is

$$P_t^{\text{dom}} = \prod_{s=0}^{t}(1+\pi_s)\,, \tag{B.3}$$

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

$$\text{CPI}_t \equiv \left\{\omega^{c,\text{CPI}} + \left(1-\omega^{c,\text{CPI}}\right)p_t^d\right\} P_t^{\text{dom}}, \tag{B.4}$$

[69] Similarly, we express the foreign price indices (B.2) relative to the foreign final good.
[70] The nominal prices of foreign goods are normalized to 1 (Section 5.1).

where $\omega^{c,\text{CPI}} \equiv 1/\left(1+X/C\right)$ is the spending share of domestic households on the non-durable good at the stationary equilibrium. Similarly, the PPI price index is

$$\text{PPI}_t \equiv \left\{\omega^{c,\text{PPI}} + \left(1-\omega^{c,\text{PPI}}\right) p_t^d\right\} P_t^{\text{dom}}, \tag{B.5}$$

where $\omega^{c,\text{PPI}} \equiv 1/\left(1+\{X+Z\}/\{C+G+F^{-1}\left(X+Z\right)\}\right)$ is the output share of the non-durable good at the stationary equilibrium.

Net exports and trade balance. Let

$$\text{IM}_t^c \equiv \left(1-\alpha_c\right)\left(\frac{e_t}{P_t^c}\right)^{-\rho}\left(C_t+G_t\right) \quad \text{and} \quad \text{IM}_t^d \equiv \left(1-\alpha_d\right)\left(\frac{e_t}{P_t^d}\right)^{-\rho} X_t$$

denote the quantities imported of the non-durable and investment good, respectively, where we have used the fact that the price of foreign goods is normalized to 1. Similarly, let

$$\text{EX}_t^c \equiv \left(1-\alpha_c\right)\left(\frac{1/e_t}{P_t^{c,\star}}\right)^{-\rho}\left(C^\star+G^\star\right) \quad \text{and} \quad \text{EX}_t^d \equiv \left(1-\alpha_d\right)\left(\frac{p^d/e_t}{P_t^{d,\star}}\right)^{-\rho} X^\star$$

denote the quantities exported, where consumption $C^\star$, government spending $G^\star$ and investment $X^\star$ in the rest of the world are constant and equal to the steady state levels at home, i.e., $C^\star = C$, $G^\star = G$ and $X^\star = X$, so there is no net imports initially. The quantity indices for net exports are $\text{NX}_t^z \equiv \text{EX}_t^z - \text{IM}_t^z$ for the non-durable and investment goods $z \in \{c,d\}$. The quantity index for the trade balance is $\text{TB}_t \equiv \text{NX}_t^c + \text{NX}_t^d$. Net exports in real terms are $\text{NX}_t^{z,\text{real}} \equiv p_t^z \text{EX}_t^z - e_t \text{IM}_t^z$ for the non-durable and investment goods $z \in \{c,d\}$. Finally, the trade balance in real terms is $\text{TB}_t^{\text{real}} \equiv \text{NX}_t^{c,\text{real}} + \text{NX}_t^{d,\text{real}}$.

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

$$e_t = \left(1+\pi_{t+1}\right)\frac{1+r^\star}{1+r_t} e_{t+1} \tag{B.6}$$

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 and using the fact that the foreign nominal price is normalized to 1.[71]

[71] We work with a finite horizon in our simulation and assume that $e_t = 1$ after 20 years.

B.2 Firm's Problem

The firm producing the investment good chooses how much to produce with intermediate (non-durable) goods, and how much to invest in capital to produce in the following period. These two problems are separable, so we characterize them sequentially.

Intermediates. The firm solves

$$\max_{X_t^{\text{dom}}} p_t^d X_t^{\text{dom}} - \left(\frac{X_t^{\text{dom}}}{A_0}\right)^{\frac{1+\zeta}{\zeta}}$$

since the production function is $X_t^{\text{dom}} = A_0 M_t^{\frac{\zeta}{1+\zeta}}$ where M_t is intermediates. Therefore,

$$p_t^d = \left(\frac{X_t^{\text{dom}}}{X^{\text{potent}}}\right)^{1/\zeta},$$

which is expression (5.4) in the text, where $X^{\text{potent}} \equiv \left(\frac{\zeta}{1+\zeta}\right)^{\zeta} A_0^{1+\zeta}$ is potential output.

Investment. The firm's investment problem is

$$\begin{aligned}
&\max_{\{I_t, K_t\}} \sum_t Q_t p_t^d \{A_1 K_{t-1} - I_t\} \\
&\text{s.t. } K_t \leq \left\{1 - \delta^K + \Phi\left(I_t / K_{t-1}\right) + z_t\right\} K_{t-1} \quad \text{and} \quad K_t \geq 0
\end{aligned} \tag{B.7}$$

with initial condition $K_{-1} \equiv K$ where K is steady state capital. The price of the investment good p_t^d is expressed relative to the price of the non-durable good (Section B.1). The firm's stochastic discount factor Q_t is expressed in real terms and satisfies $Q_{t+1}/Q_t \equiv (1 + \pi_{t+1}) / (1 + r_t)$ and $Q_0 \equiv 1$. At optimum,

$$\begin{aligned}
&\frac{1}{\Phi'(x_t)} \frac{1 + r_t}{1 + \pi_{t+1}} \frac{p_t^d}{p_{t+1}^d} \\
&\quad = A_1 + \frac{1}{\Phi'(x_{t+1})} \left\{1 - \delta^K + \Phi(x_{t+1}) - x_{t+1}\Phi'(x_{t+1}) + z_{t+1}\right\}
\end{aligned} \tag{B.8}$$

with terminal condition $\lim_{T \to +\infty} x_T = \Phi^{-1}\left(\delta^K\right)$, where $x_t \equiv I_t / K_{t-1}$ and where we have used the definition of the firm's stochastic discount factor. This initial value problem (i.e., finding x_0) associated to this difference equation can be solved using a standard shooting algorithm.[72] The sequence of capital can then be constructed recursively using the law of motion of capital

$$\frac{K_t}{K_{t-1}} = 1 - \delta^K + \Phi\left(x_t\right) + z_t, \tag{B.9}$$

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

Dividends. The firm's dividends are $\mathrm{Div}_t = \mathrm{Div} + \Psi_t \widehat{\mathrm{Div}}$, where Div is the steady state dividend, $\{\Psi_t\}$ takes the value 1 over 15 years and then decreases linearly to 0 over the next 5 years (Section 5.2). The change in dividends $\widehat{\mathrm{Div}}$ over that period ensures that $\sum_t Q_t \mathrm{Div}_t = \sum_t Q_t \Pi_t$ where

$$\Pi_t \equiv p_t^d X_t^{\mathrm{dom}} - \left(\frac{X_t^{\mathrm{dom}}}{A_0}\right)^{\frac{1+\zeta}{\zeta}} + p_t^d \left(A_1 K_{t-1} - I_t\right) \tag{B.10}$$

is real profits, using the fact that $p_t^c \equiv 1$ in the non-durables sector (Appendix B.1). Therefore,

$$\mathrm{Div}_t = \mathrm{Div} + \Psi_t \frac{\sum_s Q_s \left\{\Pi_s - \mathrm{Div}\right\}}{\sum_s Q_s \Psi_s} \tag{B.11}$$

B.3 Investment Shocks

We are interested in constructing a sequence of investment shocks $\{z_t\}$ that produces a particular recession, i.e., a path for aggregate output

$$Y_t^{\mathrm{GDP}} \equiv C_t + X_t + I_t + G + \mathrm{TB}_t \tag{B.12}$$

as defined in Section 5.1. We show below that this sequence of shocks can be constructed in a straightforward way despite the non-linearities inherent to the demand side of our economy. In the following, we let $C_t\left(\cdot\right)$, $X_t\left(\cdot\right)$ and $\mathrm{TB}_t\left(\cdot\right)$ for denote total demands and the quantity index for the trade balance as a function of households' aggregate income before interest and tax payments $\left\{Y_t^{\mathrm{inc}}\right\}$.

Lemma 1. *Consider a sequence of aggregate output $\left\{Y_t^{GDP}\right\}$ that converges to its steady state level $Y_t^{GDP} \to Y^{GDP}$ as $t \to +\infty$. There exists a (unique) sequence of investment shocks $\{z_t\}$ that induces this output in equilibrium. It can be contructed in four steps.*

[72] Expression (B.8) defines a unique map $x_t \mapsto x_{t+1}$ since the right-hand side of (B.8) is increasing in $x \geq 0$ as $\Phi\left(x\right) - x\Phi'\left(x\right)$ is increasing given our choice $\Phi\left(x\right) = 1/\kappa\left(\sqrt{1+2\kappa x} - 1\right)$ with $\kappa \equiv 2$ and $1 - \delta^K + z_{t+1} > 0$ when z_{t+1} is positive (during a recession) or sufficiently small. This is the case in our numerical simulations (Appendix B.3).

Step 1 (Net investments). *Fix an initial guess for incomes* $\{Y_t^{inc}\}$, *e.g.,* $Y_t^{inc} = Y^{inc}$ *for each period* $t \geq 0$. *Back out the sequence of investments* $\{I_t\}$ *residually from the resource constraint*

$$I_t \equiv Y_t^{GDP} - C_t\left(\left\{Y_t^{inc}\right\}\right) - X_t\left(\left\{Y_t^{inc}\right\}\right) - G - TB_t\left(\left\{Y_t^{inc}\right\}\right) \tag{B.13}$$

Step 2 (Investment shocks). *Fix an initial guess for capital* $\{K_t\}$, *e.g.,* $K_{t-1} = K$ *for each period* $t \geq 0$. *Compute the investment rates* $x_t \equiv I_t/K_{t-1}$ *using the sequence of investment from the previous step. Back out the sequence of investment shocks* $\{z_t\}$ *from the firm's Euler equation*

$$z_{t+1} = \frac{\Phi'(x_{t+1})}{\Phi'(x_t)} \frac{1+r_t}{1+\pi_{t+1}} \frac{p_t^d}{p_{t+1}^d} - (A_1 - x_{t+1})\,\Phi'(x_{t+1}) - \left\{1 - \delta^K + \Phi(x_{t+1})\right\} \tag{B.14}$$

with the normalization $z_0 \equiv 0$.[73] *Given this sequence of investment rates and investment shocks, compute a new sequence of capital* $\{K_t'\}$ *with* $K_{-1}' = K$ *and*

$$\frac{K_t'}{K_{t-1}'} = 1 - \delta^K + \Phi(x_t) + z_t, \tag{B.15}$$

for each $t \geq 0$. *Update the initial guess for capital* $\{K_t\}$ *using* $\{K_t'\}$ *and repeat Step 2 until convergence. This yiels a sequence of investment shocks* $\{z_t\}$ *such that the firm chooses investments* $\{I_t\}$ *given equilibrium prices.*

Step 3 (Incomes and prices). *Update incomes, prices, taxes, and the interest rate: households' aggregate income* Y_t^{inc} *is given by (5.9) where* Div_t *is given by (B.11); prices are computed using equations (5.2), (5.4) and (B.1); taxes are given by constraint (B.18)–(B.19); and the interest rate satisfies the rule (5.5). Repeat the previous steps until convergence. The resulting sequence of investment shocks* $\{z_t\}$ *in Step 2 is the one that implements the sequence of aggregate output* $\left\{Y_t^{GDP}\right\}$ *in equilibrium.*

Proof. The sequence of shocks $\{z_t\}$ induces aggregate outputs $\left\{Y_t^{\mathrm{GDP}}\right\}$ in equilibrium if and only if the following conditions are satisfied: (i) the firm's Euler equation (B.8); (ii) the law of motion of capital (B.9); (iii) incomes, prices and taxes are given by the expressions described in Step 2; and (iv) aggregate output is defined by (B.12).[74] The result simply uses these equilibrium conditions. □

[73] The investment rates $\{x_t\}$ depend on the *expected* shocks $\{z_{t+1}\}$, as is apparent from the firm's Euler equation (B.8). Because we are interested in investment shocks, we abstract from any unexpeted depreciation in the first period and normalize $z_0 \equiv 0$.

[74] Necessity uses the fact that the firm's problem (B.7) is convex.

B.4 Fiscal Policy

Budget constraint. The government's budget constraint is

$$B_t^g + P_t^c G + t_t = \frac{1+r_{t-1}}{1+\pi_t} B_{t-1}^g + \int \left(yE_t - \psi_{0,t} \left(yE_t \right)^{1-\psi_1} \right) d\mu_{t-1} + \Sigma_t \tag{B.16}$$

Instead of introducing (passive) financial intermediaries, we suppose that the government claims

$$\Sigma_t \equiv (1-\theta) \times \left\{ \left(1 + r_{t-1}^b \right) \hat{P}_t^d D_{t-1} - P_{t+1}^d \left(1 + \pi_{t+1} \right) D_t \right\} \times (1-\delta) \tag{B.17}$$

is the net payments on credit from households to the government. The pre-determined stock of durables is $D_{t-1} \equiv (1-\delta) \int d \times \mu_{t-1} (d\mathbf{x})$. The interest rate on credit r_{t-1}^b and the price $\hat{P}_t^d$ were defined in Appendix A.1.

Taxes. The tax intercept is $\psi_{0,t} = \psi_0 + \Psi_t \hat{\psi}_0$, where ψ_0 is the intercept at steady state, $\{\Psi_t\}$ was defined in Appendix B.1. The change $\hat{\psi}_0$ ensures that the government's tax revenues are equal to its spending in present discounted value. Therefore, the tax intercept is

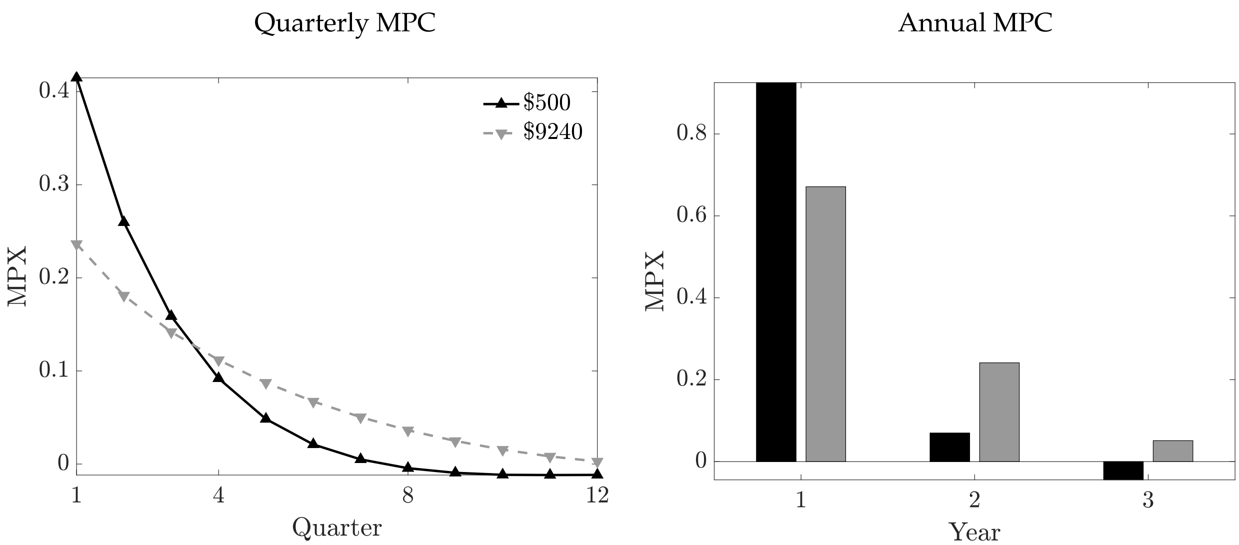
$$\psi_{0,t} = \psi_0 + \Psi_t \frac{\sum_t Q_t \Omega_t + \frac{1+r_{-1}}{1+\pi_0} B_{-1}^g}{\sum_t Q_t \Psi_t \int \left(yE_t \right)^{1-\psi_1} d\mu_{t-1}} \tag{B.18}$$

where

$$\Omega_t \equiv \int yE_t d\mu_{t-1} - \psi_0 \int \left(yE_t \right)^{1-\psi_1} d\mu_{t-1} + \Sigma_t - t_t - P_t^c G_t \tag{B.19}$$

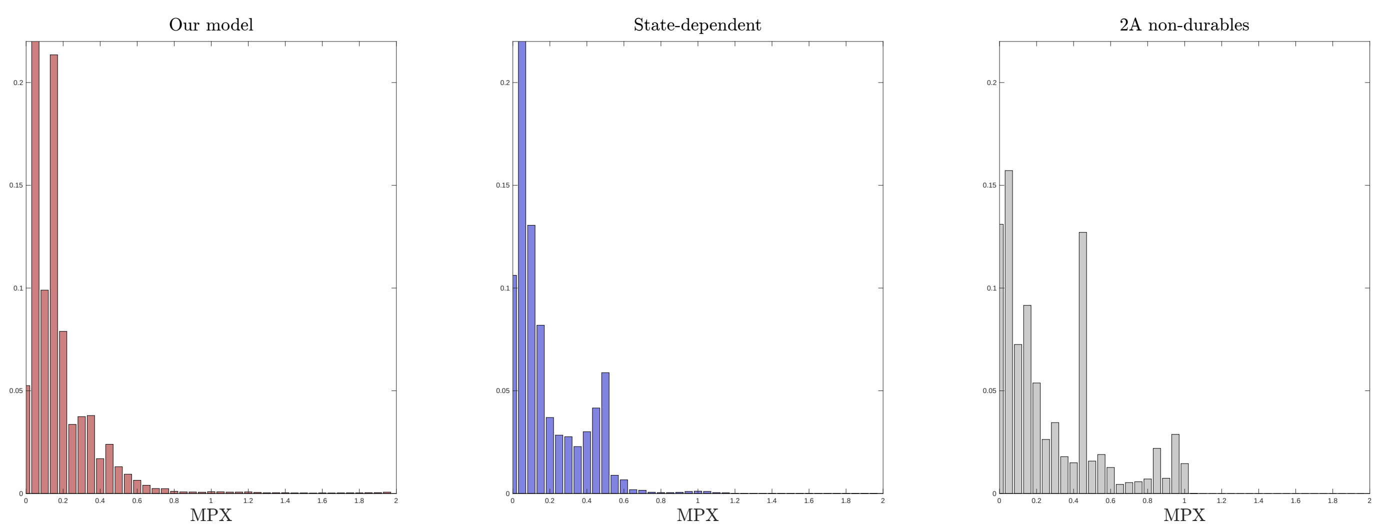
C Additional Quantitative Results

Figure C.1: Dynamic responses in our model



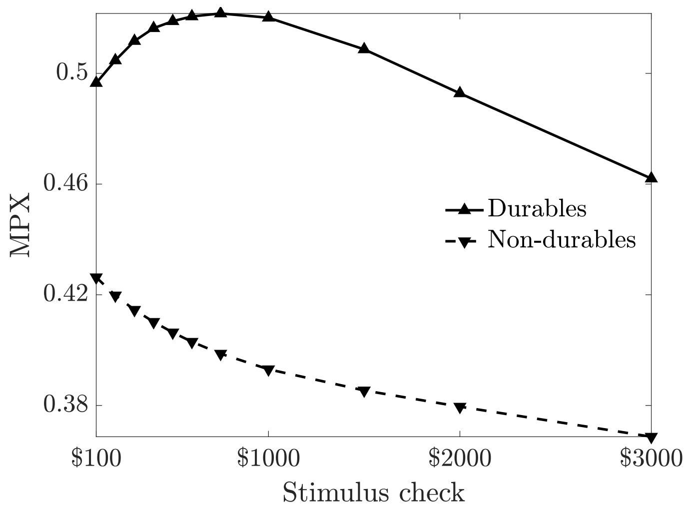
Notes: The left panel plots the total MPC over time to a check received in the first quarter. We repeat this experiment for checks of \$500 and \$9,240 (the average lottery gain in Fagereng et al., 2021). The right panel reports the associated annual MPCs.

Figure C.2: Distribution of MPXs



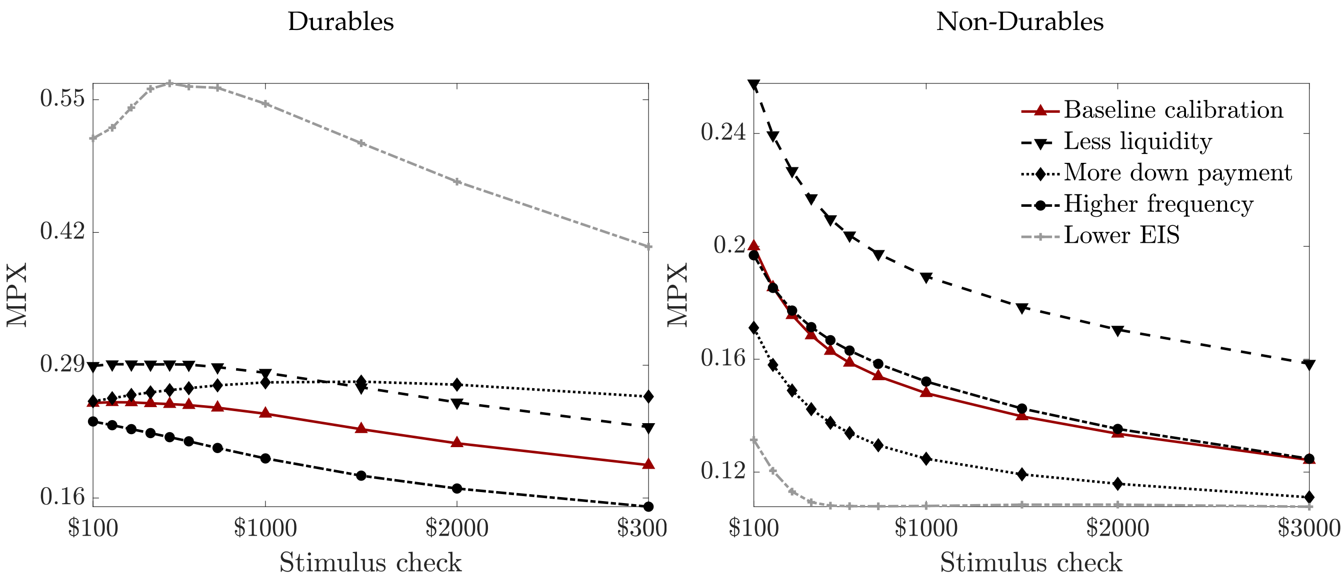
Notes: This figure plots the distribution of MPXs in our model, in the fully state-dependent model, and in the two-asset model of non-durables.

Figure C.3: Size-dependence in the MPX



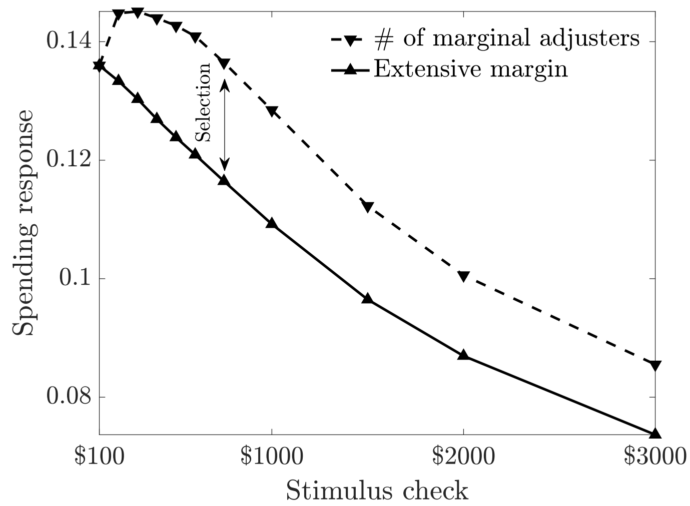
Notes: This figure plots the annual marginal propensity to spend on durables and non-durables as a function of the size of the stimulus checks.

Figure C.4: The role of various parameters in our model



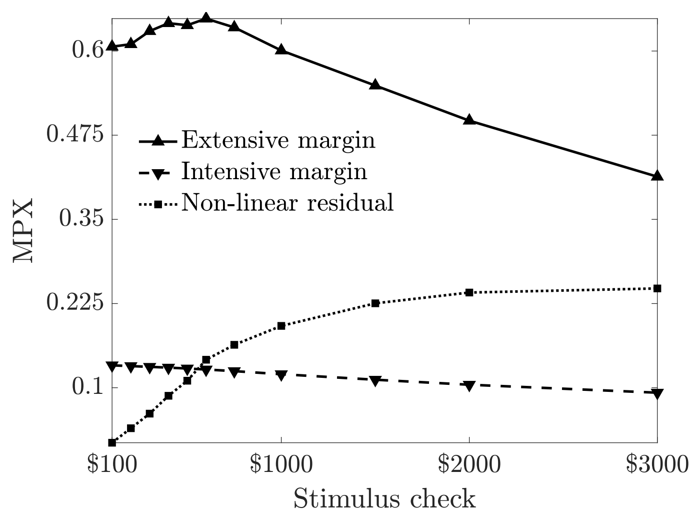
Notes: This figure plots the MPX on durables (left) and non-durables (right) in our model (red) and in four alternative calibrations with lower liquidity (58% of quarterly income instead of 104%), more down payment ($\theta = 30\%$ instead of $\theta = 20\%$), higher frequency of adjustment (35% instead of 25%), or lower EIS ($\sigma = 4$ instead of $\sigma = 2$).

Figure C.5: Decomposing the extensive margin in our model



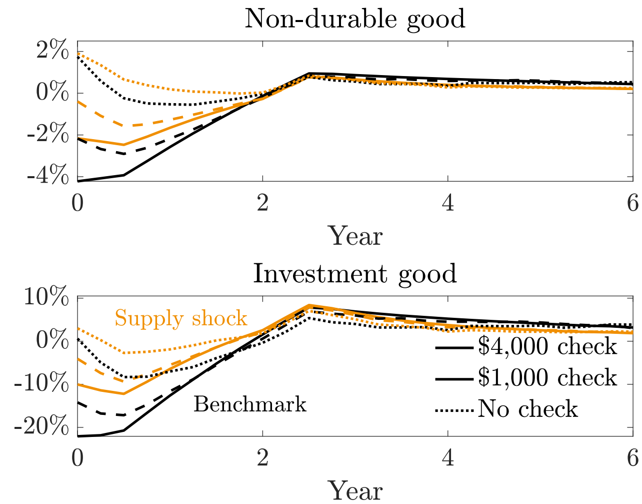
Notes: This figure decomposes the extensive margin into the two components in the first term of expression (4.1). The solid curve is the extensive margin. The dashed curve captures the rate at which households adjust $\{S(d, m+t, y) - S(d, m, y)\}\, X/T$. The scale X is chosen so that the two curves coincide for a check of \$100. By construction, the difference between these two curves captures the selection effect.

Figure C.6: Intensive and extensive margins in the purely state-dependent model



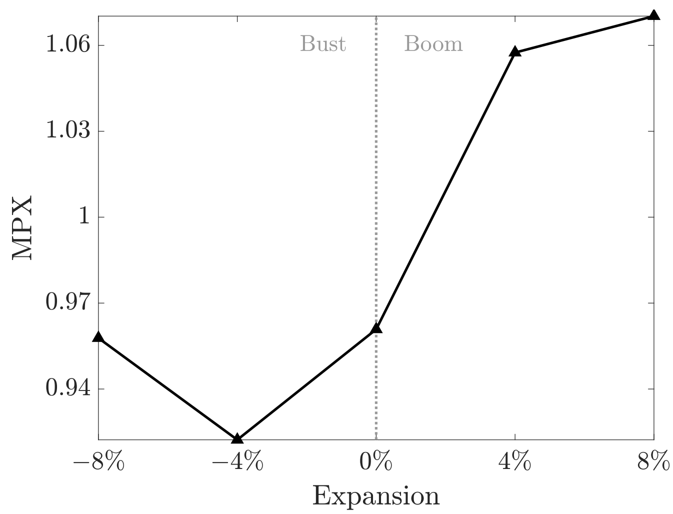
Notes: The solid and dashed curves decompose the response of durable spending into its extensive and intensive margins. The dotted curve is the non-linear residual that captures the interaction between the two margins.

Figure C.8: Sectoral output gaps with a supply shock



Notes: This figure plots the output gaps over time in the sectors producing the non-durable and investment goods, respectively, for various stimulus checks. The black curves are our benchmark general equilibrium model with a demand shock only. The orange curves are our model with both a demand and supply shock.

Figure C.7: Aggregate conditions (MPC out of $500) in the purely state-dependent model



Notes: This figure plots the total MPC in the purely state-dependent model at various points of the business cycle. The stimulus checks are received unexpectedly after three quarters of constant expansion (or contraction), following by a linear mean-reversion over eight quarters.

D Alternative Models

This appendix describes the two alternative models that we discuss in the paper. Section D.1 presents a two-asset model of non-durables. Section D.2 presents a Calvo-Plus model.

D.1 Two-Asset Model of Non-Durables

In Sections 3–5, we compare the predictions of our model to those of a two-asset model of non-durable spending similar to Kaplan and Violante (2022) or Kaplan and Violante (2014). We state the household's problem recursively and discuss the calibration. Households are indexed by three idiosyncratic states: their holdings of illiquid financial asset (b); their holdings of liquid asset (m); and their idiosyncratic income (y). As before, we let $\mathbf{x} \equiv (b, z, y)$ denote the vector of states.

Continuation values. The continuation values $\{V_t(\cdot)\}$ can be characterized recursively as follows:[75]

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

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

2. **Illiquid asset adjustment.** The household chooses how much to adjust its stock of illiquid asset

$$W_t^R(m, y) \equiv \max_{b',m'} W_t^C(b', m', y) \tag{D.2}$$
$$\text{s.t. } b' + m' \leq m \ , \ b' \geq 0$$

3. **Discrete choice.** Finally, the household chooses whether to adjust her stock of illiquid asset. The value associated to the discrete choice problem is[76]

$$V_t(\mathbf{x}) \equiv \max \left\{ W_t^R(b + m, y) - \kappa, W_t^C(b, m, y) \right\} \tag{D.3}$$

where $\kappa > 0$ is the adjustment cost.

Calibration. The calibration strategy follows Kaplan and Violante (2022) closely. We set $u(c) = 1/(1-\sigma) c^{1-\sigma}$ with inverse elasticity of intertemporal substitution to $\sigma \to 1$, as is usual in models of non-durable spending. We set the (real) return on cash to -2% per year

[75] Again, the terminal condition for $V_{t+1}(\cdot)$ is the stationary value when $T_t = 0$ in each period t.

[76] Households face a constant adjustment cost κ as in Kaplan and Violante (2022). As explained in Appendix A.3, we actually introduce a random cost with an arbitrarily small variance to smooth out the responses.

and the spread to 6% per year.[77] We discipline internally two parameters: the discount factor (β); and the adjustment cost (κ). We use them to match a share of total hand-to-mouth households of 41%, and a share of wealthy hand-to-mouth (with positive holdings of b) of 27% as in Kaplan and Violante (2022).

D.2 Calvo-Plus Model

Our smooth adjustment hazard (2.3) can be microfounded by introducing random preference shocks for adjustments (as in McFadden, 1973) to generate some time-dependence in durable adjustment. The distribution of shocks is smooth and has full support. An alternative approach would be to assume that the distribution is degenerate on two points $\{0, \kappa\}$. Either households can adjust freely or they face a constant fixed cost $\kappa > 0$. While a degenerate distribution is harder to justify empirically, this type of "Calvo-Plus" models is sometimes used in the price setting literature (Nakamura and Steinsson, 2010). McKay and Wieland (2021) use a related device for durable spending (amongside other frictions) to study the response to monetary policy shocks.[78] This two-point distribution still generates a discontinuous hazard but the intercept is shifted up (see Figure 2.1). Because it is used in the literature, we find it useful to inspect the ability of this formulation to match the micro level moments discussed in Section 3. To make sure that the models are comparable, we match the same short-run price elasticity of durable demand (Figure 3.1) as in our model, which is informative about the degree of time-dependence (and hence the "Calvo-ness"). All other parameters are re-calibrated to match the targets discussed in Section 3.2.

Figure D.1 plots two untargeted moments for the Calvo-Plus model. Overall, the distribution of adjustments provides a poorer fit to the data compared to our model (Figure 3.2). The distribution is skewed and the model generates a lot of very small adjustments, as is expected in a Calvo-Plus model.[79] The conditional probability of adjustment is somewhat steeper between years 1 and 2, as in our model. After that, the conditional probability is very flat, as expected in a Calvo-Plus model, whereas it increases steadily in the data. In

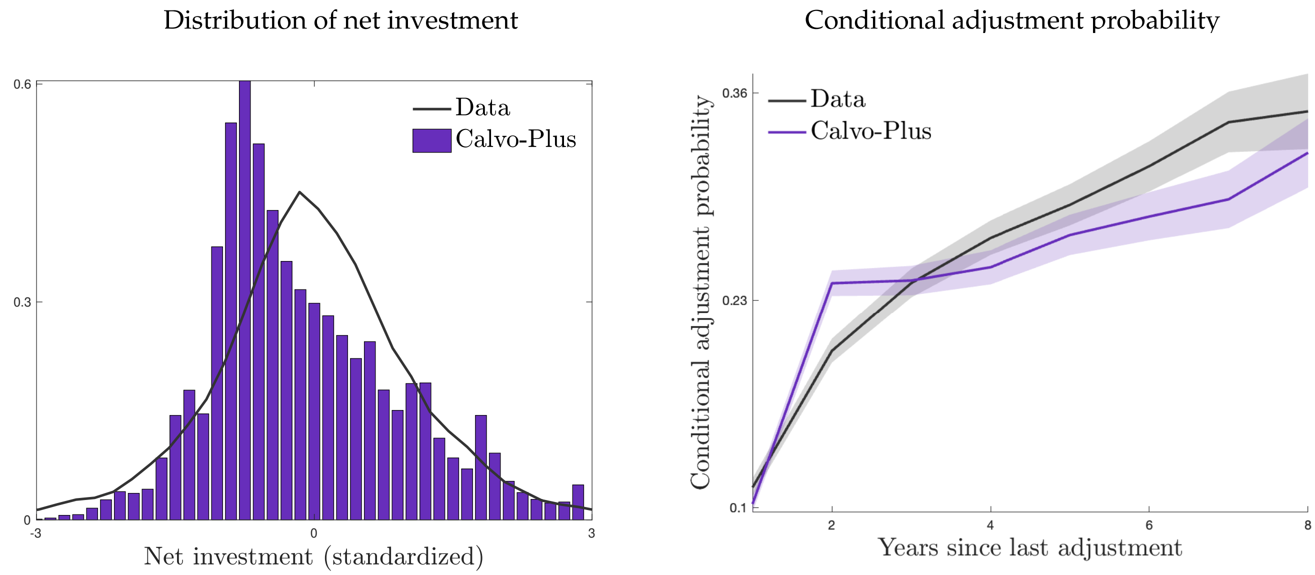
[77] The real effective lower bound on the interest rate is -2% in our durables model (Section 5.2). In the two-asset model of non-durables, this would imply that the lower bound is binding even in steady state. Instead, we assume that monetary policy can decrease the interest rate by 3% in both model before it hits its effective lower bound. Indeed, $r - r^{\star} = 3\%$ in our durables model.

[78] McKay and Wieland (2021) assume that households are *forced* to adjust (e.g., their car breaks down), as opposed to being *allowed* to adjust for free. Effectively, households face a constant adjustment cost κ and occasionally experience an infinite disutility of *not* adjusting. This formulation is equivalent to the Calvo-Plus one: households who are given the choice to adjust freely do so with probability one, which effectively amounts to forcing them to adjust.

[79] This distribution is standardized, as usual (Alvarez et al., 2016b). This explains why the mode (corresponding to very small adjustments) is not located exactly at zero.

fact, the Calvo-Plus is almost purely time-dependent: our measure of state-dependence is 10% quarterly and 11% annually, compared to 18% and 46% in our model (Figure 3.3). Unsurprisingly, the Calvo-Plus model generates a lower MPC on durables out of a $500 check (18%) compared to our model (25%).[80] Figure D.2 plots the size-dependence in the MPC on durables and non-durables. The MPC on durables in not only lower in the Calvo-Plus model, it also declines faster than in our model (Figure 4.1) as a result of its greater time-dependence.

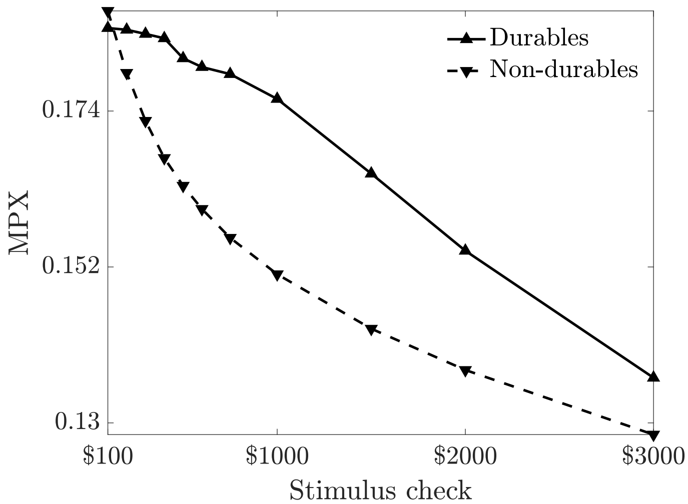
Figure D.1: Untargeted moments in the Calvo-Plus model



Notes: The left panel plots the distribution of net investment (standardized) across two consecutive PSID waves where the household adjusted. The black curve is the data, while the purple bars are the Calvo-Plus model. The right panel plots the adjustment probability conditional on a household not having adjusted so far.

[80] The Calvo-Plus model also predicts a lower share of households with low liquidity (33%) relative to our model (42%), as defined in Section 3.3.

Figure D.2: Size-dependence in the MPC in the Calvo-Plus model



Notes: This figure plots the marginal propensity to spend on durables and non-durables as a function of the size of the stimulus checks in the Calvo-Plus model.