A Simple Framework for MPCs and MPXs*

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Abstract

Standard consumption models assume a notional consumption flow that does not distinguish between nondurable and durable consumption. Such notional-consumption models generate notional marginal propensities to consume (MPC). By contrast, empirical work and policy discussions often highlight marginal propensities for expenditure (MPX), which incorporate spending on durables. We compare the notional-consumption model to an isomorphic model with frictionless durables, and map notional MPCs into MPXs. In its minimal formulation, the mapping is: $\text{MPX} = \left(1 + \frac{s}{r+\delta} \times \frac{1}{\tau}\right) \text{MPC}$, with durable share s, interest rate r, durable depreciation rate δ, and time horizon τ. Our analysis can be extended to incorporate durable-adjustment frictions.

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1 Introduction

The most widely used class of consumption models assumes that households maximize the present discounted value of flow utility, where flow utility is a function of a scalar index, c_t, representing flow consumption. This model simplifies the economy by modeling all consumption as a notional,[1] homogeneous flow. This *notional-consumption model* does not specify the sources of this flow; in particular, it does not distinguish between durable and nondurable consumption. This model is often used to analyze the response of notional consumption to wealth shocks—what we call the *notional* MPC.

In practical macroeconomic policy analysis, it is well known that notional consumption is often not the key variable. Macroeconomic policy attempts to influence the value of personal consumption *expenditures* (C in the national accounts; GDP = C + I + G + NX), not the flow of notional consumption. To illustrate the difference, assume a domestic firm manufactures an automobile in January (using domestic parts and labor) and sells it to a household in February for price p. All else equal, the production/sale of this automobile raises GDP in Q1 by p, but raises notional consumption in Q1 by an amount that is approximately two orders of magnitude smaller because the household's consumption flow from owning the new automobile accrues slowly over time. For most policy applications, economists need to understand the dynamics of consumption *expenditure*. We refer to the response of expenditure to wealth shocks as the marginal propensity for expenditure (MPX).[2]

The relationship between notional consumption and expenditure is complex. The two measures are identical for goods that have no durability (e.g., lettuce) and for services. But the low depreciation rates of consumer durable goods—such as furniture and automobiles—generate a wedge between expenditure on durables and notional consumption of durables.

The discrepancy between notional consumption and expenditure has long been recognized

[1] In this model, consumption is "notional" because it is a theoretical concept without a clear empirical counterpart.

[2] Our MPX terminology is similar to Auclert (2019) and Crawley and Kuchler (2023).

in the household finance literature.[3] Especially in empirical work, economists frequently draw a distinction between the MPX on all consumption expenditures and the MPX on nondurables alone, and commonly find large differences between the two.[4] In theory, the notional MPC lies below the total MPX and above the nondurable MPX.

In this paper, we propose a portable and tractable modeling device for converting notional MPCs into MPXs. In particular, we show how to extend a notional-consumption model to generate predictions about consumption expenditures in an isomorphic model with durable stocks.

Our modeling device can be built in continuous time (main text) and discrete time (appendix). In its minimal formulation, the mapping between MPCs and MPXs is:

$$\text{Total MPX} \approx \left(1 + \frac{s}{r+\delta} \times \frac{1}{\tau}\right) \times \text{Notional MPC},$$

where s is the durable share of notional consumption, r and δ are the interest rate and durable depreciation rate (so that $r+\delta$ is the user cost of durables), and τ is the time horizon (e.g., $\tau = \frac{1}{4}$ for quarterly MPCs/MPXs). The total MPX sums the MPX on nondurables, $(1 - s) \times \text{MPC}$, and the MPX on durables, $\left(s + \frac{s}{r+\delta} \times \frac{1}{\tau}\right) \times \text{MPC}$. MPXs are larger than MPCs—especially over short horizons—but the two measures converge as durable consumption flows are progressively cumulated (i.e., as τ increases).

We use BEA data to calibrate $s = 0.126$ and $\delta = 0.223$, and set $r = 0.01$ (our calibration focuses on consumer durables and excludes housing).[5] This calibration yields a straightforward rule-of-thumb for calculating the quarterly MPX in a model of notional consumption: *multiply the MPC by 3.* For example, the seminal Kaplan and Violante (2014) model predicts a quarterly notional MPC of 15%, so our rule-of-thumb implies a quarterly MPX of 45%.

[3] E.g., Mankiw (1982), Hayashi (1985), Lusardi (1996), Padula (2004), Parker et al. (2013), and Jappelli and Pistaferri (2014). Aguiar and Hurst (2005) emphasize a separate, but related, distinction of consumption versus expenditure, where consumption includes home production.

[4] We review this literature in Section 4.2.

[5] Section 5.4 discusses housing. Appendix C provides calibration details.

Our framework can also be used to compare MPXs on durables and nondurables. We show that our calibrated mapping fits the available data well at quarterly horizons (Section 4.2).

To derive our MPX formula, our extension with durables makes a number of assumptions (see Assumptions 1–3 in Section 3.2). The strongest is that durables are liquid, i.e., households do not face adjustment frictions when buying/selling durables. This assumption is also used in Abel (1990), Auclert (2019), and Auclert et al. (2024) to generate related mappings between various measures of expenditure.[6] Fundamentally, strong assumptions are needed in our framework to maintain an isomorphism between the benchmark notional-consumption model and the extension with durables. Thus, an alternate interpretation of our isomorphic durables extension is as an effort to spell out the assumptions *already implicit* in notional-consumption models.

In light of these strong (and unrealistic) assumptions it is perhaps puzzling that, as mentioned earlier, our frictionless MPX framework broadly fits the available data. To reconcile this apparent tension, we also derive a mapping from MPCs to MPXs for a tractable (S, s)-type model with durable-adjustment frictions. While adjustment frictions matter at the household level, we first present a limiting case where adjustment frictions nevertheless have *no effect* on the aggregate mapping from MPCs to MPXs (Caplin and Spulber, 1987). When we calibrate the lumpy-adjustment model for consumer durables we find that adjustment frictions only slightly lower the aggregate mapping from MPCs to MPXs relative to our frictionless model. This supports our simple, frictionless, mapping when applied to expenditure on consumer durables. However, the frictionless model and the lumpy-adjustment model diverge sharply when calibrated with housing as the durable. This suggests that researchers studying housing expenditures require specialized models with housing-adjustment frictions (e.g., Berger et al., 2018; Chen et al., 2020; Guren et al., 2021; Fonseca et al., 2024).

Both our frictionless model and our lumpy-adjustment model are stylized, and are complementary to models that rigorously characterize durables.[7] The benefit of the stylized

[6]See Appendix B.5 for further discussion of how our paper relates to this research.

[7]Recent examples include Berger and Vavra (2015), Beraja and Wolf (2021), McKay and Wieland (2021),

approach here is that it clarifies the wedge between consumption and expenditure, and triangulates notional-consumption models with the data on consumer spending.

Section 2 discusses the importance of having a framework for MPCs and MPXs. Section 3 presents a notional-consumption model and our isomorphic extension with durables. Section 4 presents our main results about converting notional MPCs into MPXs. Section 5 extends our approach with durable-adjustment frictions. Section 6 concludes.

2 Distinguishing MPCs and MPXs

2.1 Terminology

Whenever we use the term consumption we mean notional consumption, i.e., the utility-generating consumption flows studied in classical consumption models. Accordingly, whenever we use the term MPC we mean a notional MPC.

In contrast to notional consumption, the alternative concept we study is expenditure. We refer to the response of expenditure to wealth shocks as the MPX. The difference between consumption and expenditure derives from durability: a durable purchase generates a one-time burst of expenditure but a long-lasting flow of notional consumption. Unless specified otherwise, MPX refers to the *total* MPX, which includes spending on nondurables and consumer durables.[8]

2.2 The Importance of Mapping MPCs Into MPXs

Given a model of notional consumption, there are two well-known reasons why it is important to develop a mapping between MPCs and MPXs: measurement and policy.

Beraja and Zorzi (2024), and de Silva and Mei (2025).

[8] In practice, almost all of our subsequent analysis focuses on non-housing notional consumption and non-housing consumer durables. We analyze housing in Section 5.4.

We start by discussing measurement. Empirically, quarterly total MPXs are commonly estimated to be *two- to five-times larger* than quarterly nondurable MPXs (reviewed in Section 4.2). That is, durable purchases compose a large part of the expenditure response to wealth shocks. This has two immediate implications for how model-based notional MPCs should be understood in relation to total and nondurable MPXs. For total MPXs, notional MPCs are not the correct tool for measuring the full expenditure response to wealth shocks, since up-front expenditure on durables translates only slowly into cumulated notional consumption. Correspondingly, this also implies that nondurable MPXs alone do not capture the full notional-consumption response to wealth shocks, since households also derive consumption from durable goods. We quantify this discussion in Section 4.

Linking MPCs and MPXs also expands the connections between notional-consumption models and the empirical moments emerging from the household finance literature's expanding use of microdata. For example, administrative data on household balance sheets often enables researchers to impute the total expenditure response to wealth shocks, but not the response of its underlying components (discussed in Di Maggio et al., 2020b; Fagereng et al., 2021; Crawley and Kuchler, 2023; Sodini et al., 2023). One needs a mapping between MPXs and MPCs to evaluate notional-consumption models against such data. Relatedly, data on household spending is often only partial. Automobile-purchase data is a leading example of this (e.g., Di Maggio et al., 2017, 2020a; Cookson et al., 2022; Agarwal et al., 2023; Berger et al., 2025). Account-level and transactions data are others (e.g., Ganong and Noel, 2019; Baugh et al., 2021; Baker and Kueng, 2022; Borusyak et al., 2024; Ganong et al., 2024; Hamilton et al., 2024)—such data provides an accurate measure of a subset of consumer expenditures, but may miss some spending categories (e.g., large durable purchases like automobiles). In these cases, our modeling device can be used to rescale these partial MPXs into model-consistent notional MPCs.[9]

Regarding policy, expenditure and MPXs are what matters for the response of GDP to

[9]For illuminating applications of the sorts of approaches discussed above, see for example Borusyak et al. (2024), Berger et al. (2025), Boehm et al. (2025), and Ganong et al. (2025).

stabilization policy. But notional consumption and notional MPCs are often what is modeled. Our framework provides the needed mapping from notional consumption to expenditure.

3 The Household Balance Sheet

We now develop our modeling device for mapping notional consumption into expenditure. We present this framework in continuous time, and provide a discrete-time analogue in Appendix B. We start in Section 3.1 with a standard consumption-saving model featuring a single notional consumption good. We refer to this model as the *Benchmark*, since economic models often study notional consumption flows and do not decompose notional consumption into durable and nondurable components. Next, in Section 3.2 we introduce an extended model that explicitly models the purchase of durables. This extended model is designed to: (i) be isomorphic to the Benchmark, and (ii) deliver a tractable MPX formula. The isomorphism implies that a researcher can take an existing model of notional consumption and notional MPCs, and use a simple formula to calculate MPXs.

3.1 Benchmark: Single Notional Consumption Good

A household receives income y_t, which follows an arbitrary (positive) Markov process. It saves in a liquid asset b_t that pays interest rate r to finance a notional consumption flow of c_t. The budget constraint is:

$$\dot{b}_t = y_t + rb_t - c_t, \tag{1}$$

subject to the borrowing constraint $b_t \geq \underline{b}$. The state variables are $x_t = (b_t, y_t)$.

Additionally, denote by

$$C_\tau = \int_0^\tau c_t dt \tag{2}$$

the cumulative notional consumption flow over a discrete time interval of length τ, which will play an important role below when we specify MPCs over discrete time intervals.

For simplicity we only model a liquid asset here, since this is the asset used to fund consumption. However, our results do not rely on a single-asset framework. Our modeling tool is portable and applies in richer environments, including those with both liquid and illiquid assets such as housing. Appendix F demonstrates this portability by applying our MPX tool to the model of Maxted et al. (2025), which includes liquid bank deposits, credit cards, and illiquid home equity.

Relatedly, we also emphasize that while our subsequent analysis will generally focus on MPCs and MPXs out of liquid-wealth shocks (e.g., stimulus checks), this is only for exposition. Our framework can be applied in a variety of scenarios, like the spending response to house-price changes (e.g., Campbell and Cocco, 2007; Mian et al., 2013; reviewed in Cloyne et al., 2019), cash-out and rate refinances (e.g., Berger et al., 2021; Eichenbaum et al., 2022), or even shocks to credit card limits (e.g., Gross and Souleles, 2002; Aydin, 2022).

3.2 Extension: An Isomorphic Model with Durables

To bridge the gap between consumption and expenditure we now introduce an isomorphic, extended, model featuring the purchase of durable goods.[10]

Setup with Durables. The household now consumes two different goods: nondurables and durables. Nondurable consumption n_t is purchased as a flow. Durable consumption requires the household to hold a stock of durables D_t, which provides durable consumption as a flow and depreciates at rate δ, with $r + \delta > 0$.[11] In keeping with our partial-equilibrium analysis, the price of durables is exogenous and normalized to one. The household continues to save in a liquid bank account, denoted by ℓ_t.

[10] Appendix E.3 discusses durable rentals.

[11] D_t here can be thought of as an aggregated composite of many durable goods (we provide a CES-based microfoundation in Appendix E.1).

Our extension with durables is isomorphic to the notional-consumption model under three (strong) assumptions which we spell out momentarily. The key idea for establishing the isomorphism is to make assumptions such that

$$c_t = n_t + (r+\delta)D_t, \quad \text{with} \quad n_t = (1-s) \times c_t \quad \text{and} \quad (r+\delta)D_t = s \times c_t, \tag{3}$$

where $s \in [0,1]$. In words, notional flow consumption expenditure c_t is the sum of nondurable flow consumption expenditure n_t and the implied user cost of durables $(r+\delta)D_t$, with the latter equaling a constant share s of the sum. This can be microfounded with the three assumptions below. Alternatively, (3) can be viewed as a direct assumption on household behavior akin to the constant saving rate assumption in a Solow model.

Our first assumption is:

Assumption 1 *The durables market is perfectly liquid. The household can buy and sell durables instantaneously at price $p \equiv 1$; there are no transaction costs or time delays. Further, the household can borrow against durables at the market rate r.*

With Assumption 1, liquid bank holdings ℓ_t and durables D_t evolve as

$$d\ell_t = [y_t + r\ell_t - n_t]\, dt - d\psi_t, \tag{4}$$

$$dD_t = -\delta D_t dt + d\psi_t. \tag{5}$$

Because durable purchases can be lumpy, we introduce process ψ_t to record the household's *cumulative* spending on durables from time 0 to t, and denote by $d\psi_t$ the household's durable purchases at time t.

The absence of adjustment costs in equations (4) and (5) is a direct consequence of Assumption 1. Similarly, because Assumption 1 allows households to borrow against durables, the borrowing constraint now applies to total liquid-wealth holdings $\ell_t + D_t$:

$$\ell_t + D_t \geq \underline{b}. \tag{6}$$

Given Assumption 1 we need only one state variable for household wealth, namely total liquid wealth $b_t = \ell_t + D_t$. Accordingly, summing (4) and (5) gives

$$\dot{b}_t = y_t + rb_t - n_t - (r + \delta)D_t. \tag{7}$$

An implication of Assumption 1 is therefore that a relevant measure of the cost of holding durables is the user cost $(r + \delta)D_t$.

Our next assumption is:

Assumption 2 *The household values total notional flow consumption, given by the CES aggregator*

$$c_t = \left(s^{\frac{1}{\eta}} (fD_t)^{\frac{\eta-1}{\eta}} + (1 - s)^{\frac{1}{\eta}} n_t^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}, \tag{8}$$

where n_t is the nondurable consumption flow, fD_t is the durable consumption flow generated by durable stock D_t, $s \in [0, 1]$ is the utility weight on durable consumption, and $\eta > 0$ is the elasticity of substitution.

Given the CES functional form we obtain:

Lemma 1 *Let $R := (r+\delta)/f$ denote the price of a unit of durable flow consumption. Under Assumptions 1 and 2 the optimal intratemporal choices of nondurables and durables are:*

$$n_t = \frac{1 - s}{sR^{1-\eta} + 1 - s} Pc_t, \qquad fD_t = \frac{sR^{-\eta}}{sR^{1-\eta} + 1 - s} Pc_t, \tag{9}$$

where

$$P = \left(sR^{1-\eta} + 1 - s\right)^{\frac{1}{1-\eta}}. \tag{10}$$

The cost of attaining notional consumption flow c is

$$n_t + (r + \delta)D_t = Pc_t. \tag{11}$$

To complete the derivation of (3) we impose:

Assumption 3 *The consumption flow per unit of durable f equals its user cost, $f = r + \delta$.*

With Assumption 3 we see from Lemma 1 that $R = 1$, and that CES price index $P = 1$. Using this in equations (9) and (11) gives result (3).

To interpret Assumption 3, recall that our paper studies the MPC and MPX over relatively short time horizons, typically one quarter. Over such horizons, it is generally reasonable to hold r and hence the user cost of durables $r + \delta$ constant. Then, the ratio of nondurables and durables in equation (9), and the price index P in equation (10), are constant. Assumption 3 simply sets this price index to one and is therefore a weak assumption.[12]

Isomorphism to Notional-Consumption Model. We now prove the isomorphism between the extension with durables and our benchmark notional-consumption model.

Proposition 2 *Under Assumptions 1 to 3, the extension with durables is isomorphic to the notional-consumption model. In particular, total liquid wealth $b_t = \ell_t + D_t$ evolves as*

$$\dot{b}_t = y_t + rb_t - c_t, \tag{12}$$

subject to the borrowing constraint $b_t \geq \underline{b}$. This is identical to the law of motion and borrowing constraint for b_t in equation (1).

Proof. Assumption 1 implies that equation (7) holds. Assumptions 2 and 3 imply that equation (3) holds. Substituting (3) into (7) yields equation (12). ■

[12]For monetary policy analysis, notional-consumption models may miss effects related to the impact of rate changes on the user cost of durables (see Auclert, 2019; McKay and Wieland, 2021).

Cumulative Expenditure Flows. Define X_τ as cumulative *expenditure* over period τ, which is the sum of cumulative expenditure on nondurables X_τ^n and durables X_τ^D:

$$X_\tau = X_\tau^n + X_\tau^D, \quad \text{where} \quad X_\tau^n = \int_0^\tau n_t dt \quad \text{and} \quad X_\tau^D = \int_0^\tau d\psi_t. \tag{13}$$

Cumulative expenditure X_τ will be used to define the MPX.

For nondurables, equation (3) implies

$$X_\tau^n = (1-s)\int_0^\tau c_t dt, \tag{14}$$

so nondurable spending equals share $1-s$ of total cumulative notional consumption.

For durables, budget constraint (5) gives

$$X_\tau^D = \int_0^\tau \delta D_t dt + D_\tau - D_0. \tag{15}$$

The first term reflects spending to replace depreciated durables; the remainder is net spending to adjust the durable stock from D_0 to D_τ.

4 Results: The MPC and MPX

We now present our main result on tractably calculating MPXs from models with (only) notional consumption.

4.1 Mapping MPCs into MPXs

In the notional-consumption model of Section 3.1, the MPC is the fraction consumed of a liquid-wealth injection over a discrete time interval. More precisely, denote a point in the state space by $x = (b, y)$. The notional marginal propensity to consume (MPC) over a period of length τ for households with initial state $x_0 = x$ is

$$MPC_\tau(x) = \frac{\partial}{\partial b}\mathbb{E}\left[\int_0^\tau c(x_t)dt \;\middle|\; x_0 = x\right], \tag{16}$$

i.e., the expected change in cumulative consumption (see equation (2)) given a change in liquid wealth (Achdou et al., 2022).

Next consider the extended model of Section 3.2: the MPX is the fraction *spent* of a liquid-wealth injection over a discrete time interval. More precisely, the marginal propensity for expenditure (MPX) over a period of length τ for households with initial state $x_0 = x$ is[13]

$$MPX_\tau(x) = \frac{\partial}{\partial b}\mathbb{E}\left[\int_0^\tau n(x_t)dt + \int_0^\tau d\psi(x_t) \;\middle|\; x_0 = x\right], \tag{17}$$

i.e., the expected change in cumulative expenditure (see equation (13)) given a change in liquid wealth.

The extension with durables in Section 3.2 yields a simple formula for converting notional consumption to expenditures and hence MPCs into MPXs:

Proposition 3 (The Marginal Propensity for Expenditure) *The nondurable, durable, and total expenditure over a period τ defined in equation (13) satisfy $X_\tau^n = (1-s)C_\tau$, $X_\tau^D = \frac{s\delta}{r+\delta}C_\tau + D_\tau - D_0$, and $X_\tau = \left(1 - s + \frac{s\delta}{r+\delta}\right)C_\tau + D_\tau - D_0$, with $D_\tau = \frac{s}{r+\delta}c_\tau$. C_τ is the cumulative notional consumption flow defined in equation (2), and c_τ is the consumption flow at time τ.*

Hence, the Marginal Propensity for Expenditure (MPX) over a period τ is:

$$MPX_\tau(x) = \left(1 - s + \frac{s\delta}{r+\delta}\right)MPC_\tau(x) + \frac{s}{r+\delta} \times \frac{\partial}{\partial b}\mathbb{E}\left[c(x_\tau) \mid x_0 = x\right]. \tag{18}$$

Equation (18) has three components: (i) nondurable spending of $(1-s)MPC_\tau(x)$, (ii) spend-

[13]Our notation $\int_0^\tau d\psi(x_t)$ represents cumulative durables spending as the household's state evolves from x_0 to x_τ, always starting from $\psi_0 = \psi(x_0) = 0$.

ing to replace depreciated durables of $\frac{s\delta}{r+\delta} \times MPC_\tau(x)$*, and (iii) spending to increase the durable stock at time* τ *of* $\frac{s}{r+\delta} \times \frac{\partial}{\partial b}\mathbb{E}\left[c(x_\tau) \mid x_0 = x\right]$.

The MPX can be broken down into a nondurable MPX and a durable MPX:

$$MPX_\tau^n(x) = (1-s)MPC_\tau(x), \tag{19}$$

$$MPX_\tau^D(x) = \frac{s\delta}{r+\delta} \times MPC_\tau(x) + \frac{s}{r+\delta} \times \frac{\partial}{\partial b}\mathbb{E}\left[c(x_\tau) \mid x_0 = x\right]. \tag{20}$$

Proof. See Appendix A.2. ■

Proposition 3 provides a tractable formula for converting MPCs into MPXs. Only two additional ingredients are needed: the change in expected notional consumption at time τ, and the parameters s and δ. The former can be calculated numerically from the notional-consumption model (using the Feynman–Kac formula). The latter can be calibrated. Here, we use BEA data to calibrate durable share $s = 0.126$ and depreciation rate $\delta = 0.223$ (Appendix C).

This section defines the MPC and MPX out of infinitesimal liquid-wealth shocks. We extend these definitions to discrete shocks in Appendix E.2.

Implications and Rule-of-Thumb. Returning to Section 2's measurement discussion, Proposition 3 formalizes how empirical estimates of both nondurable and total spending should be evaluated relative to models of notional consumption.

Starting with the nondurable MPX, a common approach for calibrating notional-consumption models is to set the notional MPC to match an empirical estimate of the nondurable MPX. Though reasonable, nondurable MPXs are not quite the correct target. Instead, equation (19) implies that nondurable MPXs should be multiplied by $\frac{1}{1-s}$ to recover the appropriate MPC-target for notional-consumption models. For our calibration of $s = 0.126$, notional MPCs exceed nondurable MPXs by roughly 15%.

Turning to the total MPX, for further intuition we first simplify equation (18) using two approximations: we set $\frac{s\delta}{r+\delta} \approx s$ (which is valid if $r/\delta \approx 0$; i.e., depreciation accounts for most of the user cost), and we assume that $\frac{\partial}{\partial b}\mathbb{E}\left[c(x_\tau) \mid x_0 = x\right]$ is roughly constant in τ so that $MPC_\tau(x) \approx \tau \times \frac{\partial}{\partial b}\mathbb{E}\left[c(x_\tau) \mid x_0 = x\right]$. We can then rewrite (18) as:[14]

$$MPX_\tau(x) \approx \left(1 + \frac{s}{r+\delta} \times \frac{1}{\tau}\right) MPC_\tau(x). \tag{21}$$

Equation (21) clarifies how MPXs and MPCs dynamically relate to one another. MPXs are larger than MPCs, particularly over short horizons when τ is small. Over longer horizons, the two converge. In short, MPXs are more front-loaded than MPCs: durable expenditure is lumpy, whereas the consumption flows provided by these durables takes time to cumulate.

Equation (21) also provides a useful approximation for converting MPCs into total MPXs: multiply the MPC by $\left(1 + \frac{s}{r+\delta} \times \frac{1}{\tau}\right)$ to recover the MPX. Importantly, this mapping requires no additional modeling—durable share s, interest rate r, and depreciation rate δ are empirical objects that can be calibrated.

We highlight this formula's usefulness for the standard case of quarterly MPCs. Our calibration of $s = 0.126$, $r = 0.01$, and $\delta = 0.223$ implies $\left(1 + \frac{s}{r+\delta} \times \frac{1}{\tau}\right) \approx 3$.[15] Thus, a rule-of-thumb for converting quarterly MPCs into quarterly MPXs is:[16]

Remark 1 (The "Quarterly MPC Times 3" Rule-of-Thumb) *The one-quarter MPX is roughly three-times the one-quarter MPC.*

A key implication of this rule-of-thumb is that the notional MPCs generated by notional-consumption models should not be interpreted as predictions regarding the total expenditure response to wealth shocks. For example, a quarterly MPC of 15% can easily be consistent with a household *spending* 45% of a liquidity injection within the quarter. This is not a

[14] We thank Greg Kaplan for this helpful suggestion.

[15] We use BEA data to calibrate s and δ (Appendix C). We set $r = 0.01$ following the notional-consumption model of Maxted et al. (2025), to which we apply our mapping in Appendix F.

[16] We obtain comparable results using the quarterly one-period MPX from our discrete-time framework (see equation (41) and the discussion in Appendix B.3).

critique of notional-consumption models. Rather, our rule-of-thumb simply quantifies the well-known fact that notional consumption is different than expenditure.

4.2 Taking the MPX Mapping to the Data

Our rule-of-thumb is derived using only our extended model and our calibration of s, r, and δ. We now evaluate whether our MPX mapping holds empirically.

Using equations (19) and (21), the total MPX is approximately $\left(\frac{(r+\delta)\tau+s}{(r+\delta)\tau(1-s)}\right)$-times the nondurable MPX, or 3.6 in our quarterly calibration. In the data, Table 1 presents selected studies estimating both the quarterly nondurable and total MPX. The literature is also reviewed in Di Maggio et al. (2020b), who suggest that nondurable MPXs are typically estimated around 20% while total MPXs range from 60-80%. Overall, the available evidence is broadly consistent with our calibrated mapping that the quarterly total MPX is 3.6-times the quarterly nondurable MPX (our mapping is, perhaps, marginally too high; we address this next).

	Nondurable MPX	Total MPX
Souleles (1999)	9%	64%
Parker et al. (2013)	12-30%	50-90%
Kueng (2018)	25%	73%
Parker et al. (2022)[17]	10%	23%
Boehm et al. (2025)[18]	7%	23%
Orchard et al. (2025)	0%	30%

Table 1: Selected Estimates of Quarterly Nondurable and Total MPXs

[17] Table 1 reports the first round of Economic Impact Payments (EIPs). For the second (third) round of EIPs, Parker et al. (2022) estimate a nondurable MPX of 8% (1%) and a total MPX of 25% (1.5%).

[18] Boehm et al. (2025) report one-month MPXs (not quarterly MPXs), but find that spending is concentrated in that month.

5 Durable-Adjustment Frictions

Our mapping in Remark 1 relies on frictionless durable adjustment. A natural question is: how do adjustment frictions affect this mapping? On one hand, durable adjustment is certainly subject to a variety of frictions that should, presumably, affect the mapping from MPCs to MPXs. On the other hand, we just showed in Section 4.2 that our frictionless mapping aligns well with the data. This tension is puzzling. We now propose a resolution.

To do so, we present an (S, s)-type model with durable-adjustment frictions that can be characterized analytically. Our derivation of a lumpy-adjustment model starting from a notional-consumption model broadly parallels Bertola et al. (2005).[19] We stick to a stylized framework to develop sharper insights on how adjustment frictions will, and will not, affect the mapping from MPCs to MPXs.

We caution readers at the outset that the mapping from MPCs in a *frictionless* notional-consumption model to MPXs in a *frictional* lumpy-adjustment model will require simplifications and approximations. The exercise below is intended to build helpful intuitions, and is again complementary to richer models.

5.1 Special Case: Notional-Consumption Model

In Section 3 we presented a general notional-consumption framework, then developed an isomorphic extension with frictionless durables. Here—to incorporate adjustment frictions—we focus on a tractable special case where the equilibrium notional-consumption process follows geometric Brownian motion (GBM):

$$\frac{dc_t}{c_t} = \nu dt + \sigma dB_t, \tag{22}$$

[19] See also Bertola and Caballero (1990), Eberly (1994), and further references therein.

where ν is the growth rate of consumption, σ is the volatility of consumption growth, and B_t is a standard Brownian motion. There are many ways to microfound GBM consumption and we provide two in Appendix D.1, one with labor-income risk and one with asset-price risk (the seminal Merton (1969) model).

5.2 Extension: Adjustment Frictions and Lumpy Adjustment

Setup with Lumpy Durables. We now extend the special-case notional-consumption model of Section 5.1 with durable-adjustment frictions. We follow similar steps as Section 3.2, but generalize Assumption 1 by requiring that households pay a fixed effort (utility) cost of $A \geq 0$ to adjust their durable stock (we maintain Assumptions 2 and 3):[20]

Assumption 1′ *Assumption 1 holds, except that durable adjustment now incurs a fixed utility cost* $A \geq 0$.

When $A > 0$, the household adjusts its durables only occasionally and lumpily. Durable-adjustment frictions imply that we need to track the durable stock as a separate state variable. Because adjustment only incurs utility costs, however, we can still denote the household's total liquid wealth by $b_t = \ell_t + D_t$, which continues to evolve following equation (7): $\dot{b}_t = y_t + rb_t - n_t - (r+\delta)D_t$.

Let $o_t = n_t + (r+\delta)D_t$ denote the household's effective "wealth-outflow" at time t. We showed in Section 3.2 that for any o_t, the optimal durable stock is $D_t^* = \frac{s}{r+\delta}o_t$. With adjustment frictions, welfare losses arise because the household allows its durable stock to deviate from D_t^*. For a given path of o_t we can approximate these welfare losses, and minimize them, to approximate the household's durable adjustment decisions.

[20]Assumption 1 implicitly fixes $A \equiv 0$. Setting $A > 0$ loosely capture some adjustment frictions (like search costs—e.g., Argyle et al., 2023; Agarwal et al., 2024), but not others (like financial constraints that limit durable financing—e.g., Eberly, 1994; Benmelech et al., 2017; Green et al., 2020).

Approximation 1 *Let $h(D_t, n_t)$ denote CES aggregator (8) and assume log period utility $\ln(h(D_t, n_t))$. To approximate the welfare loss from holding a suboptimal level of durables, a second-order approximation in log-deviations around D_t^* (holding o_t constant) gives:*

$$\ln\Big(h(D_t,\ o_t - (r+\delta)D_t)\Big) - \ln\Big(h(D_t^*,\ o_t - (r+\delta)D_t^*)\Big) \approx \frac{\lambda}{2}\Big(\ln(D_t) - \ln(D_t^*)\Big)^2, \quad \textit{where} \ \ \lambda = \frac{-s}{\eta(1-s)}.$$

Since $\lambda < 0$, larger deviations from D^* generate larger welfare losses. See Appendix D.2 for approximation details.

Let $z_t = \ln(D_t/D_t^*)$ denote the log-ratio of durables to their optimal level ("durables gap"). Under Approximation 1, households endogenously time discrete durable-stock adjustments to maximize the flow of $\frac{\lambda}{2}(z_t)^2$ net of cost-A adjustments. That is, the resulting optimization problem is:

$$v(z_0) = \max_{\tau}\ \mathbb{E}_0\left[\int_0^{\tau} e^{-\rho t}\frac{\lambda}{2}z_t^2 dt + e^{-\rho\tau}(v^* - A)\right], \quad \text{where} \qquad (23)$$
$$v^* = \max_{z}\ v(z),$$

where ρ is the household's exponential discount rate, and where o_t and z_t follow the diffusion processes below. At time t, the household's durable stock is $D_t = D_t^* e^{z_t} = \frac{s}{r+\delta} o_t e^{z_t}$, and its nondurable purchases are $n_t = o_t - (r+\delta)D_t = o_t(1 - se^{z_t})$.

We close the model by specifying the evolution of o_t:

Approximation 2 *Wealth-outflow process o_t equals c_t from the underlying special-case notional-consumption model and therefore follows geometric Brownian motion (GBM):*

$$\frac{do_t}{o_t} = \nu dt + \sigma dB_t. \qquad (24)$$

Approximation 2 holds exactly using the frictionless extension of Section 3.2 with $A = 0$.

Once $A > 0$, equation (24) is only an approximation because adjustment frictions can affect the household's desired wealth-outflow path o_t.[21]

Given Approximation 2, the durables gap $z_t = \ln(D_t/D_t^*)$ follows arithmetic Brownian motion between adjustments:

$$dz_t = -\left(\nu + \delta - \frac{\sigma^2}{2}\right) dt - \sigma dB_t, \tag{25}$$

where we have used $dD_t = -\delta D_t dt$ and $D_t^* = \frac{s}{r+\delta} o_t$. Compared to equation (24), the terms νdt and σdB_t now enter with *negative* signs because positive spending growth implies that a household's durable stock is shrinking relative to D^*. Additionally, a $-\delta dt$ term arises in (25) because durables depreciate at rate δ (an Itô-correction term also arises).

Lumpy-Adjustment Model: Characterization. Together, optimization problem (23) and law-of-motion (25) characterize a tractable (S, s)-type model with one state variable, the durables gap z, which can be characterized analytically. For details, see Bertola and Caballero (1990), Eberly (1994), and Bertola et al. (2005). We summarize the solution here, with additional explanation in Appendix D.2.

Each household's optimal strategy is characterized by two "action points" and one "return point." The action points are a lower threshold $\underline{z}$ where the durable stock is too low and the household discretely increases its durables, and an upper threshold $\overline{z}$ where the durable stock is too high and the household discretely decreases its durables. Whenever the household takes action, it adjusts its durables such that z equals return point z' (where $\underline{z} \leq z' \leq \overline{z}$). Between adjustments, z evolves stochastically following equation (25); in our calibrations, z typically drifts downward as durables depreciate.

Under this optimal strategy the ergodic density for z, denoted $g(z)$, is characterized by equation (53) in Appendix D.2. Importantly, the shape of $g(z)$ depends on the ratio $\frac{\nu+\delta}{\sigma^2}$.

[21] A household's desired spending on nondurables will generally depend on whether its durable stock is relatively too high/low. See also Bertola et al. (2024) for a discussion.

As this ratio gets bigger—in particular because σ decreases or δ increases—$g(z)$ converges to a uniform density.

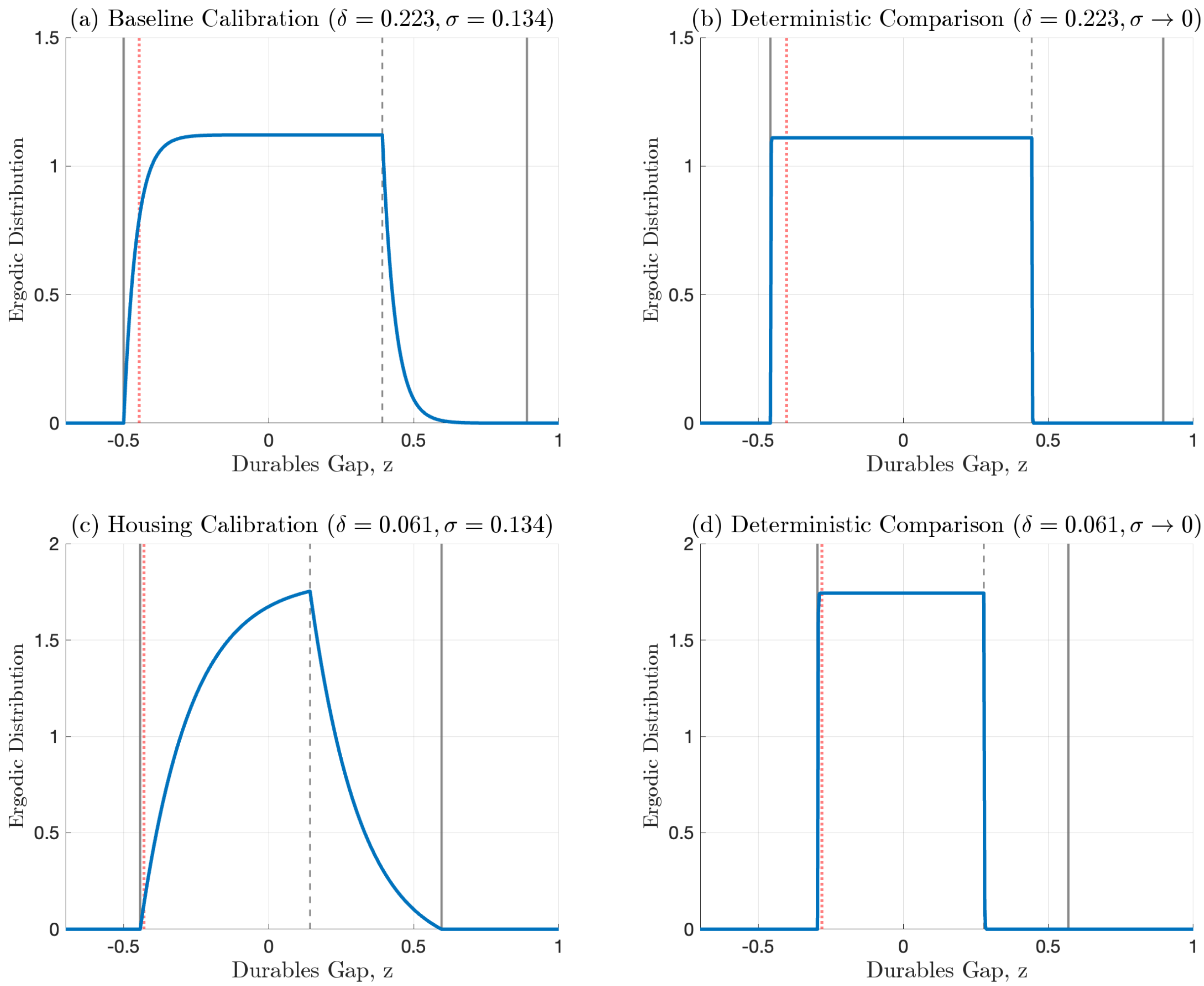

Figure 1: Lumpy-Adjustment Model
Notes: See Appendix D.3 for calibration details.

Figure 1 illustrates our lumpy-adjustment model: the blue curve plots ergodic density $g(z)$, the two solid gray lines mark the action points $\underline{z}$ and $\overline{z}$, and the dashed gray line marks return point z'. Households to the left of the dotted red line will adjust within the next quarter if not hit by offsetting Brownian shocks.

Panel (a) of Figure 1 shows our baseline calibration for consumer durables, which sets $\delta = 0.223$ and $\sigma = 0.134$ (Appendix D.3 provides calibration details and robustness). We also set effort cost $A = 0.039$ to target an annual adjustment probability of 0.24 (Beraja and Zorzi, 2024). For comparison (which will be relevant shortly), Panel (b) shows the model that results from taking $\sigma \to 0$.

In Panel (c), we recalibrate the lumpy-adjustment model to include housing as part of the durable stock. Importantly, this lowers δ from 0.223 to 0.061 (full recalibration details in Appendix D.3). Panel (d) shows the corresponding $\sigma \to 0$ model. We discuss this housing case in Section 5.4.

5.3 Results: The MPX with Lumpy Adjustment

From Lumpy Adjustment to MPXs. Since state variable z is the log-ratio of durables to their optimal level, changes in z do not translate directly into changes in dollars of spending (the relevant concept for MPXs).

To back out the MPX implied by the lumpy-adjustment model, we start from the ergodic distribution $g(z)$ and feed in a small $\epsilon > 0$ wealth shock to each household.[22] For comparison, we also feed this ϵ-shock into the underlying frictionless notional-consumption model of Section 5.1. In the notional-consumption model, denote each household's instantaneous MPC by μ.[23] We can approximately characterize the aggregate MPX implied by the lumpy-adjustment model relative to this μ from the underlying notional-consumption model. Taking o_t from the notional-consumption model (Approximation 2), this means that we consider a shock that increases each household's o_t by $\mu\epsilon$ and hence generates a change in their z_t of $-\frac{\mu\epsilon_t}{o_t}$. We summarize our (heuristic) approximation here, with details in Appendix D.4.

Starting with the nondurable MPX, note that this ϵ-shock alters only a vanishingly small set of households' extensive-margin adjustment processes over a given time period of length

[22]If Brownian shocks are idiosyncratic then ergodic distribution $g(z)$ is also the long-run cross-sectional distribution. If Brownian shocks are partially systematic, however, then any time-specific cross-sectional distribution will not necessarily equal $g(z)$. In this case, our MPX formula in equation (26) should be interpreted as a time-series average. See Appendix D.5 for more.

[23]The instantaneous MPC is $\frac{\partial c(x)}{\partial b}$, where c is the notional consumption rate (Achdou et al., 2022).

τ. For all other households, if τ is relatively short (e.g., one quarter) then additional spending is essentially all on nondurables. Cumulating over τ gives:

$$MPX_{\tau}^{n} \approx \mu \times \tau.$$

For the durable MPX, we calculate four moments from the lumpy-adjustment model: (i) how far households adjust up upon hitting $\underline{z}$, (ii) how far households adjust down upon hitting $\overline{z}$, (iii) how a small wealth shock affects the number of households jumping up per period τ, and (iv) how a small wealth shock affects the number of households jumping down per period τ. Together, (i) and (iii) capture how a wealth shock affects households' durable purchases, while (ii) and (iv) capture how it affects durable sales.

In more detail, assume for now that all households have the same initial wealth-outflow o_t (this drops out later). Then, moment (i) is approximately $D_t^* \left(e^{z'} - e^{\underline{z}}\right) \approx \frac{so_t}{r+\delta} \left(z' - \underline{z}\right)$, and moment (ii) is approximately $D_t^* \left(e^{\overline{z}} - e^{z'}\right) \approx \frac{so_t}{r+\delta} \left(\overline{z} - z'\right)$.

For moments (iii) and (iv), we need some additional notation. First, denote by $\hat{u}_\tau(z)$ the expected number of upward-adjustments that a household starting at z will make over the subsequent period τ, and by $\hat{d}_\tau(z)$ the corresponding downward-adjustment measure. As already discussed, the ϵ-shock generates a change in each household's o_t of $\mu\epsilon$ and hence a change in their z_t of $-\Delta$ with $\Delta = \frac{\mu\epsilon}{o_t}$. Starting from the ergodic density $g(z)$, we therefore consider a leftward-shift in the density to $\tilde{g}(z;\Delta) = g(z+\Delta)$; i.e., a *decrease* in each household's z. For the perturbed density $\tilde{g}(z;\Delta)$, the *aggregate* number of upward-adjustments that occur within period τ is:

$$\mathcal{U}_\tau(\Delta) = \int_{\text{supp}(\tilde{g})} \hat{u}_\tau(z)\tilde{g}(z;\Delta)dz.$$

Let $\mathcal{D}_\tau(\Delta)$ denote the corresponding measure for the aggregate number of downward-adjustments.

With this notation in hand, moment (iii) is then $\mathcal{U}_\tau'(0) \times \frac{\mu\epsilon}{o_t}$, which denotes the change in the aggregate number of upward-adjustments if all households experience a (leftward) change in their z_t of $-\frac{\mu\epsilon}{o_t}$. Similarly, moment (iv) is $\mathcal{D}'_\tau(0) \times \frac{\mu\epsilon}{o_t}$. Note that $\mathcal{U}'_\tau(0) > 0$ and $\mathcal{D}'_\tau(0) < 0$, since a negative z-shock moves households toward $\underline{z}$ and away from $\overline{z}$.

Putting this together, we approximate the aggregate durable MPX as:

$$MPX_\tau^D \approx \mathcal{U}'_\tau(0) \times \mu \times \left(\frac{s}{r+\delta}\left(z' - \underline{z}\right)\right) - \mathcal{D}'_\tau(0) \times \mu \times \left(\frac{s}{r+\delta}\left(\overline{z} - z'\right)\right).$$

Finally, denoting the MPC of the notional-consumption model by $MPC_\tau \approx \mu\tau$, our approximate mapping from the MPC of the notional-consumption model to the total MPX of the lumpy-adjustment model is:

$$\begin{aligned} MPX_\tau &= MPX_\tau^n + MPX_\tau^D \\ &\approx \left[1 + \mathcal{U}'_\tau(0) \times \frac{1}{\tau} \times \left(\frac{s}{r+\delta}\left(z' - \underline{z}\right)\right) - \mathcal{D}'_\tau(0) \times \frac{1}{\tau} \times \left(\frac{s}{r+\delta}\left(\overline{z} - z'\right)\right)\right] MPC_\tau. \quad (26) \end{aligned}$$

Equation (26) is straightforward to compute: $\mathcal{U}'_\tau(0)$, $\mathcal{D}'_\tau(0)$, $\underline{z}$, $\overline{z}$, and z' can be calculated numerically, while s, r, and δ can be calibrated.

Limit Case: Caplin and Spulber (1987). Building on the insights of Caplin and Spulber (1987), taking $\sigma \to 0$ delivers an intuitively useful limiting case. This $\sigma \to 0$ case is illustrated in the righthand panels of Figure 1: it features a uniform distribution of households between $\underline{z}$ and z'. Depreciation means households deterministically slide from right to left over time, and jump up to z' whenever they hit $\underline{z}$.

In this limiting case the uniform ergodic density is $g(z) = \frac{1}{z' - \underline{z}}$, implying that $\mathcal{U}'_\tau(0) = \frac{1}{z' - \underline{z}}$ and $\mathcal{D}'_\tau(0) = 0$. Equation (26) therefore becomes:

$$MPX_\tau \approx \left(1 + \frac{s}{r+\delta} \times \frac{1}{\tau}\right) MPC_\tau,$$

which is exactly equation (21) used to derive our frictionless rule-of-thumb in Remark 1.

In short, the *frictional* model with $\sigma \to 0$ produces the same mapping from notional

MPCs to MPXs as our *frictionless* model. Although adjustment frictions imply that fewer households adjust their durables at any time, those same frictions also imply that when households adjust, they adjust by more. When the distribution of households is uniform between the adjustment bands, these two effects cancel out. This is a key takeaway—adjustment frictions certainly matter at the household level, but such frictions do not necessarily affect the aggregate mapping from MPCs to MPXs.

Calibrated Solution. It turns out that this $\sigma \to 0$ case provides a reasonable qualitative approximation to our baseline consumer-durables calibration (in Panel (a) of Figure 1). Using equation (26) for our baseline calibration, we calculate that the quarterly MPX is 2.6-times the quarterly MPC. While this is not quite the same as our frictionless three-to-one rule, the effect of adjustment frictions only modestly changes the quantitative finding. For intuition, compare Panels (a) and (b) of Figure 1. Households around the dotted red line are the ones who are pushed into adjusting by the wealth shock. Since this mass is qualitatively similar for the $\sigma = 0.134$ and $\sigma \to 0$ cases (especially compared to the housing calibration discussed shortly), they generate similar mappings.

5.4 Housing Expenditures

We have thus far focused on (non-housing) consumer durables and excluded major housing adjustments (i.e., residential investment). There are three reasons for this choice.

First, we want our mapping to be consistent with the empirical literature estimating MPXs (see Table 1). This literature generally omits residential investment.

The second reason relates to supply-side considerations. Housing investments take time to plan, permit, and build, and hence are less likely to adjust over the quarterly horizon we focus on. Consumer durables still include other inputs to housing quality that are more easily adjusted, such as furniture and appliances.

The third reason is demand-side adjustment frictions. Although we just illustrated in

Section 5.3 that an (S, s)-type model produces a qualitatively similar mapping from MPCs to MPXs as its frictionless counterpart when calibrated to consumer durables, this result does not extend to housing.

When we include housing as a durable, the calibrated durable share increases to $s = 0.260$ and the depreciation rate decreases to $\delta = 0.061$ (details in Appendix C). In the frictionless mapping of equation (21), this calibration implies that the quarterly MPX is (unrealistically) 16-times the quarterly MPC.

The predictions of the lumpy-adjustment model are now sharply different, however. Housing's slower depreciation moves ergodic distribution $g(z)$ further from the near-uniform distribution that is needed for the lumpy-adjustment model to approximate its frictionless counterpart (compare Panels (c) and (d) of Figure 1). In the lumpy-adjustment model with housing, equation (26) now implies that the quarterly MPX is only 5.5-times the quarterly MPC, or roughly just one-third of its frictionless counterpart.[24]

Overall, our summary view is that our frictionless modeling device provides a reasonable approximation of expenditure on (non-housing) consumer durables, and researchers interested in housing expenditures likely require specialized models of housing.[25]

6 Conclusion

Policy and empirical analyses often focus on the response of consumer expenditures to wealth shocks. But economists' benchmark model studies notional consumption. To bridge the gap, this paper develops a simple, parsimonious, and portable modeling framework for converting MPCs into MPXs. Our calibrated formula is particularly simple in quarterly models: the MPX is approximately three-times the notional MPC. Our modeling device is easy to use and matches the available empirical evidence.

[24] As just discussed, supply-side frictions should lower this even further.

[25] See also Appendix D.5 for further discussion of various issues not covered in the main text, such as durable-financing constraints and time-dependent inaction.

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Internet Appendix

A Continuous-Time Proofs

A.1 Proof of Lemma 1

The household's intratemporal problem is as follows: minimize cost $n + (r+\delta)D$ subject to attaining a level of c given by equation (8). Equivalently, defining $d := fD$, the household solves

$$\text{Cost}(c) = \min_{n,d} \left\{ n + \frac{r+\delta}{f} d \quad \text{s.t.} \quad \left(s^{\frac{1}{\eta}} d^{\frac{\eta-1}{\eta}} + (1-s)^{\frac{1}{\eta}} n^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \geq c \right\}.$$

Defining $R := (r+\delta)/f$ and using the standard CES results, the demand for n and d and the cost function $\text{Cost}(c)$ are given by

$$\begin{aligned} n &= \frac{1-s}{sR^{1-\eta}+1-s} Pc \\ d &= \frac{sR^{-\eta}}{sR^{1-\eta}+1-s} Pc \\ \text{Cost}(c) &= Pc \\ P &= \left(sR^{1-\eta} + 1 - s \right)^{\frac{1}{1-\eta}} \end{aligned}$$

This recovers the equations in Lemma 1. ■

A.2 Proof of Proposition 3: Calculating the Marginal Propensity for Expenditure (MPX)

Following from equation (14) we have $X_\tau^n = (1-s)C_\tau$, as asserted in the Proposition. Following from equation (15) the total expenditure on both nondurables and durables defined in equation (13) is given by

$$X_\tau = X_\tau^n + X_\tau^D = \int_0^\tau n_t dt + \int_0^\tau \delta D_t dt + D_\tau - D_0. \tag{27}$$

Next, from (3) we have

$$D_\tau = \frac{s}{r+\delta} c_\tau. \tag{28}$$

Intuitively, generating a notional consumption flow c_τ at time τ requires holding a durable stock D_τ defined by equation (28). The reason is that, by Lemma 1, generating notional consumption flow c_τ requires generating *durable* consumption flow $fD_\tau = sc_\tau$. Since $f = r+\delta$ by Assumption 3, this requires holding a durable stock of $D_\tau = sc_\tau/(r+\delta)$. Using equations (28) and (2) in equation (15) yields the expression for X_τ^D in the Proposition.

Next consider the MPX defined in equation (17). Using equations (13), (14), and (15) in the definition of the MPX in (17) we have

$$\begin{aligned} MPX_\tau(x) &= \frac{\partial}{\partial b}\mathbb{E}\left[(1-s)\int_0^\tau c(x_t)dt + \int_0^\tau \delta D(x_t)dt + D(x_\tau) - D_0 \mid x_0 = x\right] \\ &= \frac{\partial}{\partial b}\mathbb{E}\left[\left(1 - s + \frac{s\delta}{r+\delta}\right)\int_0^\tau c(x_t)dt \mid x_0 = x\right] + \frac{s}{r+\delta}\frac{\partial}{\partial b}\mathbb{E}\left[c(x_\tau) \mid x_0 = x\right] \\ &= \left(1 - s + \frac{s\delta}{r+\delta}\right) MPC_\tau(x) + \frac{s}{r+\delta}\frac{\partial}{\partial b}\mathbb{E}\left[c(x_\tau) \mid x_0 = x\right] \end{aligned}$$

where the second equality uses equation (28). This is equation (18) in the Proposition. ■

B Discrete-Time Mapping from MPCs to MPXs

This Appendix presents a mapping from MPCs to MPXs that applies to discrete-time models of notional consumption. Our discrete-time construction is similar to the continuous-time construction presented in Section 3, and we leave many details to that section.

Period Length and Calibration. Before presenting the discrete-time model, we first highlight a slight abuse of notation relative to the continuous-time setup. In discrete time, assume that we have a model with a given period length, say one quarter or one year. In this discrete-time model, we will denote by r and δ the interest rate and durable depreciation rate over that discrete time period. Hence, these discrete-time rates can differ from the corresponding continuous-time rates (e.g., we calibrate a continuous-time depreciation rate of $\delta = 0.223$ but a quarterly depreciation rate of $\delta = 0.054$; see Appendix C). Similarly we will denote by $MPC_\tau(x)$ and $MPX_\tau(x)$ the notional MPC and MPX over τ discrete time periods (again these differ slightly from their continuous-time counterparts).

B.1 Benchmark: Single Notional Consumption Good

In discrete time, we again begin by presenting a standard consumption-saving model with a single notional consumption good, which we refer to as the *Benchmark*.

The Liquid Wealth Budget Constraint. The dynamic budget constraint for liquid wealth b_t is:

$$b_t = (1 + r)b_{t-1} + y_t - c_t, \tag{29}$$

subject to the borrowing constraint $b_t \geq \underline{b}$.

The state variables of the notional-consumption model are $x_t = (b_{t-1}, y_t)$. We denote by

$$C_\tau = \sum_{t=0}^{\tau-1} c_t \tag{30}$$

the cumulative notional consumption flow over τ periods.

B.2 Extension: An Isomorphic Model with Durables

We now introduce an extended model featuring the purchase of durable goods that is isomorphic to the notional-consumption model in Appendix B.1. See also Appendix B.5 for a discussion of other papers with related approaches.

Setup with Durables. Let n_t denote nondurable consumption, and let D_t denote the household's stock of durables. Durable stock D_t provides durable consumption as a flow and depreciates at rate δ, with $r + \delta > 0$. The household continues to save in a liquid bank account, denoted by ℓ_t. In our discrete-time model we continue to maintain Assumption 1 that the durables market is perfectly liquid. We let φ_t denote the household's purchases/sales of durables in period t.

Model Timing. We adopt one nonstandard timing convention to allow for closer comparability with the continuous-time specification presented in the main text. Specifically, we assume that durable purchases are made before interest is incurred. Given this timing convention, the household's budget constraint can be written as

$$\ell_t = (1 + r)(\ell_{t-1} - \varphi_t) + y_t - n_t, \tag{31}$$

$$D_t = (1 - \delta)D_{t-1} + \varphi_t, \tag{32}$$

where our timing convention implies that the household's returns are earned on liquid wealth net of durable purchases, $(1+r)(\ell_{t-1} - \varphi_t)$. The notation in equations (31) and (32) remains similar to equations (4) and (5) except that we now use variable φ_t to denote the household's spending on durables in period t. Given our timing convention, the household's total wealth at the end of period t is given by $b_t = \ell_t + (1 - \delta)D_t$.

Our timing convention is not necessary, but the benefit is that it shifts the cost of durable consumption forward in time and simplifies the user cost of durables. Specifically, the user cost of durables here will be $r + \delta$, just like in our continuous-time setup. Without our perturbed timing convention, the user cost would instead have been $\frac{r+\delta}{1+r}$.[26]

Because Assumption 1 imposes that the household can borrow against (the non-depreciated part of) durables, the borrowing constraint now applies to total liquid-wealth holdings $\ell_t + (1-\delta)D_t$:

$$\ell_t + (1-\delta)D_t \geq \underline{b}. \tag{33}$$

Given Assumption 1 we need only one state variable for household wealth, namely total liquid wealth $b_t = \ell_t + (1-\delta)D_t$. To this end, use (31) and (32) to sum $\ell_t + (1-\delta)D_t$, which gives

$$\begin{aligned} b_t &= (1+r)(\ell_{t-1} - \varphi_t) + y_t - n_t + (1-\delta)D_t \\ &= (1+r)((b_{t-1} - (1-\delta)D_{t-1}) - \varphi_t) + y_t - n_t + (1-\delta)D_t \\ &= (1+r)(b_{t-1} - D_t) + y_t - n_t + (1-\delta)D_t \\ &= (1+r)b_{t-1} + y_t - n_t - (r+\delta)D_t. \end{aligned} \tag{34}$$

An implication of Assumption 1 is therefore that a relevant measure of the cost of holding durables is the user cost $(r+\delta)D_t$.

As in the continuous-time model we continue to maintain Assumptions 2 and 3 here. Similar to key equation (3), these assumptions lead to the household choosing

$$n_t = (1-s) \times c_t, \qquad (r+\delta)D_t = s \times c_t, \quad \text{and} \quad n_t + (r+\delta)D_t = c_t. \tag{35}$$

[26] Without our timing convention, durables purchased in period t affect the household's wealth in period $t+1$, and hence the present-value user cost is $\frac{r+\delta}{1+r}$ (where the term $\frac{1}{1+r}$ reflects discounting from period $t+1$ to period t). Our alternate timing setup effectively moves durable purchases forward in time.

Isomorphism to Notional-Consumption Model. We now prove the isomorphism between the extension with durables and our benchmark notional-consumption model.

Proposition 4 *Under Assumptions 1 to 3, the extension with durables is isomorphic to the notional-consumption model. In particular, total liquid wealth* $b_t = \ell_t + (1-\delta)D_t$ *evolves as*

$$b_t = (1+r)b_{t-1} + y_t - c_t, \tag{36}$$

subject to the borrowing constraint $b_t \geq \underline{b}$*. This is identical to the law of motion and borrowing constraint for* b_t *in equation (29).*

Proof. Assumption 1 implies that equation (34) holds. Assumptions 2 and 3 imply that equation (35) holds. Substituting (35) into (34) yields equation (36). ■

Cumulative Expenditure Flows. Define X_τ as cumulative *expenditure* over τ periods, which is the sum of cumulative expenditure on nondurables X_τ^n and durables X_τ^D:

$$X_\tau = X_\tau^n + X_\tau^D, \quad \text{where} \quad X_\tau^n = \sum_{t=0}^{\tau-1} n_t \quad \text{and} \quad X_\tau^D = \sum_{t=0}^{\tau-1} \varphi_t. \tag{37}$$

Cumulative expenditure X_τ will be used to define the MPX below.

B.3 Results: The MPC and MPX

We now present our discrete-time construction for calculating MPXs from models featuring only a single notional consumption good.

First consider the discrete-time MPC in the notional-consumption model of Appendix B.1. The MPC is closely related to the cumulative notional consumption flow in equation (30). More precisely, the notional marginal propensity to consume (MPC) over τ periods for households with initial state $x_0 = x$ is

$$MPC_\tau(x) = \frac{\partial}{\partial b}\mathbb{E}\left[\sum_{t=0}^{\tau-1} c(x_t) \;\middle|\; x_0 = x\right]. \tag{38}$$

Next consider the discrete-time MPX in the extended model of Appendix B.2. The MPX is closely related to the cumulative expenditure flow defined in equation (37). The marginal propensity for expenditure (MPX) over τ periods for households with initial state $x_0 = x$ is

$$MPX_\tau(x) = \frac{\partial}{\partial b}\mathbb{E}\left[\sum_{t=0}^{\tau-1} n(x_t) + \sum_{t=0}^{\tau-1} \varphi(x_t) \;\middle|\; x_0 = x\right]. \tag{39}$$

In discrete time, we now have the following formula for the MPXs that are implied by a notional-consumption model:

Proposition 5 (The Discrete-Time Marginal Propensity for Expenditure) *The discrete-time Marginal Propensity for Expenditure (MPX) over τ periods is:*

$$MPX_\tau(x) = (1-s)MPC_\tau(x) + \frac{s\delta}{r+\delta}MPC_{\tau-1}(x) + \frac{s}{r+\delta} \times \frac{\partial}{\partial b}\mathbb{E}\left[c(x_{\tau-1}) \mid x_0 = x\right]. \tag{40}$$

Similar to equation (18), the discrete-time MPX in equation (40) has three components: (i) nondurable spending (first term), (ii) spending to replace depreciated durables (second term), and (iii) spending to increase the durable stock in period $\tau - 1$ (third term).

The MPX equation simplifies when $\tau = 1$, such that the discrete-time MPX over one period is simply:

$$MPX_1(x) = \left(1 - s + \frac{s}{r+\delta}\right) MPC_1(x), \tag{41}$$

which is the discrete-time analogue of equation (21) in the main text.

Additionally, the MPX in equation (40) can be broken down into a nondurable MPX and *a durable MPX:*

$$MPX_\tau^n(x) = (1-s)MPC_\tau(x), \tag{42}$$

$$MPX_\tau^D(x) = \frac{s\delta}{r+\delta} MPC_{\tau-1}(x) + \frac{s}{r+\delta} \times \frac{\partial}{\partial b} \mathbb{E}\left[c(x_{\tau-1}) \mid x_0 = x\right]. \tag{43}$$

Proof. See Appendix B.4. ■

The One-Period MPX: Additional Discussion. Although the discrete-time version of our mapping from MPCs to MPXs is generally less tractable, it takes on a particularly simple form when studied over the first period after a shock, as highlighted by equation (41) above.

The mapping from MPCs to MPXs in equation (41) is the discrete-time counterpart to equation (21) from the continuous-time model. Similar to the discussion there, equation (41) provides a useful method for converting one-period MPCs into total MPXs: take the MPC and multiply by $\left(1 - s + \frac{s}{r+\delta}\right)$ to recover the MPX.[27] We continue to calibrate durable share $s = 0.126$, and for quarterly period lengths, we calibrate a *quarterly* durable depreciation rate $\delta = 0.054$ (see Appendix C). For small quarterly interest rates $r \approx 0$, this means $\left(1 - s + \frac{s}{r+\delta}\right) \approx 3$. Thus, equation (41) in discrete time provides a comparable mapping from MPCs to MPXs as we characterized in continuous time in Remark 1.

[27] The one-period discrete-time MPX in equation (41) is comparable to the continuous-time MPX in equation (18) (and its approximation in equation (21)), with the main difference being that the discrete-time MPX is "missing" the durable depreciation component in equation (18) of $\frac{s\delta}{r+\delta} MPC_\tau(x)$. This term reappears in discrete-time MPXs over longer horizons (see Proposition 5), but it doesn't affect the one-period MPX since durable depreciation doesn't occur until the period after durables are purchased.

B.4 Proof of Proposition 5

First consider nondurable expenditure X_τ^n defined in equation (37). From equation (35) we have

$$X_\tau^n = (1-s)\sum_{t=0}^{\tau-1} c_t. \tag{44}$$

Next consider durable expenditure X_τ^D defined in equation (37). Using the property from budget constraint (32) that $\varphi_t = D_t - (1-\delta)D_{t-1}$, we have

$$\begin{aligned} X_\tau^D &= \sum_{t=0}^{\tau-1} \varphi_t \\ &= D_{\tau-1} - (1-\delta)D_{-1} + \sum_{t=0}^{\tau-2} \delta D_t. \end{aligned} \tag{45}$$

Therefore the total expenditure on both nondurables and durables defined in equation (37) is given by

$$X_\tau = X_\tau^n + X_\tau^D = (1-s)\sum_{t=0}^{\tau-1} c_t + \sum_{t=0}^{\tau-2} \delta D_t + D_{\tau-1} - (1-\delta)D_{-1}. \tag{46}$$

Finally, from (35) we have

$$D_t = \frac{s}{r+\delta} c_t. \tag{47}$$

Next consider the MPX defined in equation (39). Using equations (37) and (46) in the definition of the MPX in (39) we have

$$
\begin{aligned}
MPX_\tau(x) &= \frac{\partial}{\partial b}\mathbb{E}\left[(1-s)\sum_{t=0}^{\tau-1} c(x_t) + \sum_{t=0}^{\tau-2}\delta D(x_t) + D(x_{\tau-1}) - (1-\delta)D_{-1} \,\middle|\, x_0 = x\right] \\
&= \frac{\partial}{\partial b}\mathbb{E}\left[(1-s)\sum_{t=0}^{\tau-1} c(x_t) + \sum_{t=0}^{\tau-2}\delta D(x_t) \,\middle|\, x_0 = x\right] + \frac{\partial}{\partial b}\mathbb{E}\left[D(x_{\tau-1}) \mid x_0 = x\right] \\
&= \frac{\partial}{\partial b}\mathbb{E}\left[(1-s)\sum_{t=0}^{\tau-1} c(x_t) + \frac{s\delta}{r+\delta}\sum_{t=0}^{\tau-2} c(x_t) \,\middle|\, x_0 = x\right] + \frac{\partial}{\partial b}\mathbb{E}\left[\frac{s}{r+\delta}c(x_{\tau-1}) \,\middle|\, x_0 = x\right] \\
&= (1-s)MPC_\tau(x) + \frac{s\delta}{r+\delta}MPC_{\tau-1}(x) + \frac{s}{r+\delta}\frac{\partial}{\partial b}\mathbb{E}\left[c(x_{\tau-1}) \mid x_0 = x\right],
\end{aligned}
$$

where equation (47) is used to go from the second to the third line. This is equation (40) in the Proposition. In the case of $\tau = 1$ (the one-period MPX), the second term drops out and the formula becomes simply $MPX_1(x) = \left(1 - s + \frac{s}{r+\delta}\right) MPC_1(x)$.

B.5 Other Papers with Mappings Between Expenditure Measures

This appendix briefly discusses the relation between our approach and those in Abel (1990), Auclert (2019), and Auclert et al. (2024), which develop related discrete-time mappings between various measures of expenditure. Like our baseline formulation, all three papers make the assumption that durables are liquid, i.e., households do not face adjustment frictions when buying and selling durables.

Abel (1990, Section 3) uses this assumption to discuss the relative size of different MPX measures but he does not provide a mapping from notional-consumption models to models with durables. The relation between Abel's formula and ours is straightforward: in the one-period discrete-time special case, our formula for the MPX on durables is $MPX^D = \left(\frac{s}{r+\delta}\right) \times MPC$ and the MPX on nondurables is $MPX^n = (1-s) \times MPC$ so that the ratio of the two is $\frac{1}{r+\delta}\frac{s}{1-s}$. This is identical to Abel's equation (30b) (although he assumes Cobb-Douglas and we assume CES preferences).

Auclert (2019, Appendix A.5) conducts a similar exercise relating different MPX measures. He derives an expression for the total MPX as a multiple of the MPX on nondurables but this expression differs from the analogue in our framework $\left(1+\frac{s}{(r+\delta)(1-s)}\right)$ because of different assumptions on preferences.

Using essentially the same model as ours but with separable preferences instead of CES preferences (our Assumption 2), Auclert et al. (2024, Appendix B.5) recover our formula for converting MPCs to MPXs in the one-period discrete-time special case.

C Calibration: Durable Share and Depreciation Rate

This section discusses how we use BEA data to calibrate durable share s and durable depreciation rate δ. All data was accessed in August 2025.

Baseline Calibration. Our baseline calibration excludes housing and focuses on consumer durables. We calibrate the durable depreciation rate from the 2016 BEA Fixed Assets Accounts Tables.[28] Table 1.1 reports a consumer durables stock of \$5,136.7 billion. Table 1.3 reports depreciation over the year of \$1,028.1 billion. This implies a discrete-time yearly depreciation rate of $\frac{1028.1}{5136.7} = 0.200$ and a continuous-time depreciation rate of $\delta = -\ln\left(1-\frac{1028.1}{5136.7}\right) = 0.223$. This calibration means that durables have a half-life of slightly more than 3 years. For Appendix B.3 we also calibrate a *quarterly* (rather than yearly) depreciation rate of 0.054.

To calibrate durable share s, we use the 2016 National Income and Product Accounts. Table 2.4.5 reports that total household consumption expenditures (in billions) are \$12,726.8. This is composed of durable goods of \$1,356.5, nondurable goods of \$2,676.5, and services of \$8,693.8. From services we subtract housing services of \$1,953.2 (essentially the rent of tenant-occupied housing and the imputed rent of owner-occupied housing).

[28] We use 2016 data because it is a "typical" year in the sense that it is not a recession/pandemic year, and we apply our MPX tool to the model of Maxted et al. (2025) which is calibrated using 2016 data.

Assuming that households are in a static steady state, all durable expenditures are made to offset depreciation.[29] Thus, $\delta D = 1356.5$. Assuming $r = 0$ for simplicity, the restriction that $f = \delta$ implies that a household's total durable expenditures of $\delta D_t = f D_t = sc_t$. We also have $n_t = (1-s)c_t$. Letting both nondurable goods and services compose "nondurables," we have $n_t = 2676.5+(8693.8-1953.2) = 9417.1$. Total consumption is given by $c_t = \delta D + n_t = 1356.5 + 9417.1 = 10773.6$. Now, the durable share can be imputed from $\frac{\delta D}{c_t}$:

$$s = \frac{1356.5}{10773.6} = 0.126.$$

Alternate Calibration with Housing. We also provide an alternate calibration that includes housing as part of the durable stock, as discussed in Section 5.4.

Again using the 2016 BEA Fixed Assets Accounts Tables to calibrate the depreciation rate, Table 1.1 reports a consumer durables stock of \$5,136.7 billion plus private residential assets of \$20,233.0 billion. Table 1.3 reports depreciation of \$1,028.1 billion on consumer durables plus \$462.9 billion on private residential assets. This implies a discrete-time yearly depreciation rate of $\frac{1491}{25369.7} = 0.059$ and a continuous-time depreciation rate of $\delta^{incl-housing} = -\ln\left(1 - \frac{1491}{25369.7}\right) = 0.061$.

Our calibration of the durable share that includes housing is again very similar to above. The one difference is that we now assign housing services (\$1,953.2 billion) to durable consumption.[30] Again using the assumption that all durable expenditures are made to offset depreciation, total consumption is given by $c_t = \delta D + n_t = (1356.5+1953.2)+9417.1 = 12726.8$. Now, the durable share is $s^{incl-housing} = \frac{3309.7}{12726.8} = 0.260$.[31]

[29] This assumption allows us to convert durable expenditures into durable consumption. It is also not too far off: total durable spending is 1356.5, while depreciation is 1028.1.

[30] This approach differs from the NIPA, which counts housing in services.

[31] For further benchmarking, note that Kaplan and Violante (2014) point out that the ratio of expenditure on housing services to total consumption averaged roughly 15% from 1960–2009 (for more, see also Davis and Van Nieuwerburgh, 2015). Our calibration is proportionally larger to additionally account for (non-housing) consumer durables.

D Durable-Adjustment Frictions: Additional Details

D.1 Microfoundations for GBM Notional Consumption

As mentioned in Section 5.1, there are a variety of ways to microfound the GBM notional-consumption process in equation (22). A seminal example is the Merton (1969) infinite-horizon portfolio-choice model, where households with constant relative risk aversion (CRRA) utility derive income from capital gains on assets whose prices follow GBMs. Rather than asset price fluctuations, one can alternatively obtain GBM consumption dynamics from idiosyncratic shocks to labor income (i.e., human-capital shocks). We present these two models below.

Microfoundation #1: Merton (1969). Here we briefly present a version of the Merton (1969) model.

Households have access to two assets, a safe asset and a risky asset. The safe asset has a risk-free return of r. The risky asset has an expected return of $r + \pi$ and volatility of ς, with $\pi > 0$ and $\varsigma > 0$. Letting c_t denote consumption and θ_t denote the share of wealth $W_t > 0$ invested into the risky asset at time t, the budget constraint is

$$dW_t = ((r + \theta_t \pi)W_t - c_t)\, dt + \theta_t W_t \varsigma dB_t, \tag{48}$$

where B_t is a standard Brownian motion.

Each household has CRRA utility $u(c) = \frac{c^{1-\gamma}-1}{1-\gamma}$, and chooses its consumption c_t and asset allocation θ_t to maximize $\mathbb{E}_0 \int_0^\infty e^{-\rho t} u(c_t) dt$, subject to budget constraint (48).[32] Characterizing the solution to this model:

[32] We also assume that the model is calibrated such that $\frac{\rho}{\gamma} + \left(1 - \frac{1}{\gamma}\right)\left(r + \frac{\pi^2}{2\gamma\varsigma^2}\right) > 0$.

Lemma 6 (Merton, 1969) *The optimal asset allocation policy function θ is given by:*

$$\theta = \frac{\pi}{\gamma \varsigma^2}, \tag{49}$$

and the optimal consumption policy function is linear in wealth and given by:

$$c(W) = \left(\frac{\rho}{\gamma} + \left(1 - \frac{1}{\gamma}\right) \left(r + \frac{\pi^2}{2\gamma\varsigma^2} \right) \right) W. \tag{50}$$

Combining equations (48), (49), and (50), one can show that consumption evolves as a geometric Brownian motion:

$$\frac{dc_t}{c_t} = \frac{dW_t}{W_t} = \left((r + \theta\pi) - \kappa \right) dt + \theta \varsigma dB_t,$$

where $\kappa = \frac{\rho}{\gamma} + \left(1 - \frac{1}{\gamma}\right)\left(r + \frac{\pi^2}{2\gamma\varsigma^2}\right)$. This completes our first microfoundation of GBM notional consumption.

Proof. These results are relatively standard, so a proof is omitted. See Merton (1969) for the seminal formulation. ■

Microfoundation #2: Human-Capital Shocks. Our second microfoundation shows how GBM consumption dynamics can be obtained from idiosyncratic shocks to labor income (i.e., human-capital shocks).[33]

The starting point for this second microfoundation is a relabeling of the microfoundation just shown above, where we now treat the risky asset as the household's human capital.

In more detail, denote the household's current holdings of the risk-free asset by b_t and its risky human capital by H_t, with total wealth $W_t = b_t + H_t$. We set the household's income

[33] More broadly, see also Ding and Jiang (2025) for a recent paper that surveys various models with idiosyncratic risk that generate consumption-growth dynamics along these lines.

flow to $y_t = \alpha H_t$, with $\alpha > 0$. This essentially treats household income as a "dividend payment" from its human capital.

The budget constraints for b_t and H_t are then:

$$db_t = (y_t + rb_t - c_t)\, dt - d\psi_t^H,$$
$$dH_t = H_t\,(\xi dt + \varsigma dB_t) + d\psi_t^H,$$

where we use $d\psi_t^H$ to denote a household's investments into its human capital (e.g., education). Besides these potential investments, note that human capital simply follows a GBM, $\frac{dH_t}{H_t} = \xi dt + \varsigma dB_t$. We assume that $\alpha + \xi > r$ and $\varsigma > 0$.

The expected return from investing in human capital comes from the "dividend" α and the "capital gain" ξ, such that the "risk premium" that the household earns from investing in human capital is $\pi = \alpha + \xi - r > 0$. Letting $\theta_t = \frac{H_t}{W_t}$ denote the "portfolio share" of total wealth allocated to risky human capital, summing the budget constraints for b_t and H_t and using the property that $y_t = \alpha H_t$ implies that

$$dW_t = ((r + \theta_t \pi) W_t - c_t)\, dt + \theta_t W_t \varsigma dB_t,$$

which is equation (48) from above. In other words, and as already mentioned, this risky-human-capital model is effectively just a relabeling of the Merton model presented in Lemma 6. Thus, it will also generate the same GBM consumption dynamics.

However, although this reinterpretation of microfoundation #1 hypothetically provides an income-based microfoundation for GBM consumption, it has some economically strange properties. In particular, one likely wants to impose the restriction that $d\psi_t^H \geq 0$. This restriction allows households to invest into human capital (e.g., education), but it prevents households from selling their human capital (e.g., due to the limited pledgeability of labor income).

Fortunately, a meticulously chosen calibration can maintain the GBM consumption dynamics of the Merton model while respecting the restriction that $d\psi_t^H \geq 0$. In particular, we set $\alpha + \xi - r = \gamma\varsigma^2$ and $r = \rho + \gamma\xi - \frac{\gamma(\gamma+1)}{2}\varsigma^2$. Under this calibration, the household will maintain a "portfolio weight" of $\theta = 1$ and will adopt a consumption rate of $c_t = \alpha H_t = y_t$. In other words, the household will maintain $b_t = 0$ in perpetuity—never investing into human capital[34] nor disinvesting out of human capital—and will simply consume the labor-income flows provided by H_t. Under this calibration, the household's human capital thus follows the geometric Brownian motion $\frac{dH_t}{H_t} = \xi dt + \varsigma dB_t$. Then, since $y_t = \alpha H_t$ and the household sets $c_t = y_t$, the household's equilibrium consumption process adopts the same GBM properties; in particular, notional consumption follows $\frac{dc_t}{c_t} = \frac{dH_t}{H_t} = \xi dt + \varsigma dB_t$.

D.2 Lumpy-Adjustment Model: Setup and Characterization

Approximation 1 Details. Here we provide further details regarding Approximation 1. We also refer the reader to Bertola et al. (2005) for more, whose derivation we broadly follow.

Letting $h(D_t, n_t)$ denote CES aggregator (8), we have $h(D_t, n_t) = \left(s^{\frac{1}{\eta}}(fD_t)^{\frac{\eta-1}{\eta}} + (1-s)^{\frac{1}{\eta}} n_t^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}$. Assuming log utility, the household's utility flow at time t is $\ln\big(h(D_t, n_t)\big)$. Letting $d_t = \ln(D_t)$ and using that $o_t = n_t + (r+\delta)D_t$, we can rewrite $h(D_t, n_t)$ as $h(e^{d_t}, o_t - (r+\delta)e^{d_t})$.

Recall that for any given o_t, the optimal durable stock is $D_t^* = \frac{s}{r+\delta}o_t$. The utility loss at time t from holding a suboptimal level of durables is then given by:

$$\ln\big(h(e^{d_t},\ o_t - (r+\delta)e^{d_t})\big) - \ln\big(h(e^{d_t^*},\ o_t - (r+\delta)e^{d_t^*})\big). \tag{51}$$

A second-order approximation of the first term of equation (51) with respect to d_t (around

[34] To be fully precise, the household will invest in human capital if: (i) it starts with some initial liquid wealth $b_0 > 0$, or (ii) it is given an unanticipated liquid-wealth injection of $\epsilon > 0$ at time t (i.e., our MPX experiment—see Section 5.3). In both cases, the household immediately invests that excess liquid wealth into human capital in order to restore $b = 0$. In case (ii) where the household receives an unanticipated liquid-wealth injection at time t, consumption jumps up by $\alpha\epsilon$ on impact (since the household's wealth jumps by ϵ and our calibration implies $c_t = \alpha W_t$), and then continues to follow a GBM thereafter.

d_t^*) recovers Approximation 1. Note that the first derivative vanishes at the optimum.

Lumpy-Adjustment Model: Characterization Details. For full characterization details we refer readers to Bertola and Caballero (1990), Eberly (1994), and Bertola et al. (2005). Here we provide some additional discussion.

To begin, we can rewrite the (S, s)-type model characterized by optimization problem (23) and law-of-motion (25) as an HJB Quasi-Variational Inequality (HJBQVI):[35]

$$\rho v(z) = \max\left\{\frac{\lambda}{2}z^2 - v'(z)\left(\nu + \delta - \frac{\sigma^2}{2}\right) + v''(z)\frac{\sigma^2}{2},\quad \rho(v^* - A)\right\}, \tag{52}$$

where $v^* = \max_z v(z)$. As discussed in the main text, the household's optimal strategy will consist of a lower adjustment threshold $\underline{z}$ (where the durable stock is too low and the household adjusts its durables upward), an upper adjustment threshold $\overline{z}$ (where the durable stock is too high and the household adjusts its durables downward), and an adjustment target (return point) of z'. When z is in the inaction region (i.e., z is between $\underline{z}$ and $\overline{z}$), z evolves stochastically following equation (25).

Under this optimal strategy, the ergodic density for state variable z is given by the piecewise function (Bertola et al., 2005):

$$g(z) = \begin{cases} K_1 z + K_2 & \text{if } \nu + \delta - \frac{\sigma^2}{2} = 0 \\ K_1 \exp\left(\frac{-2\left(\nu+\delta-\frac{\sigma^2}{2}\right)}{\sigma^2} z\right) + K_2 & \text{otherwise} \end{cases}, \tag{53}$$

where K_1 and K_2 are constants that can differ to the left and right of return point z'. For our calibrations (bottom row), this implies that $g(z)$ is piecewise exponential, with the shape of $g(z)$ depending on the ratio $\frac{\nu+\delta}{\sigma^2}$. As discussed in the main text, $g(z)$ tends toward a uniform distribution as this ratio gets larger.

[35] See the notes provided under the heading "Stopping Time Problem" at https://benjaminmoll.com/codes/ for additional details and references.

D.3 Lumpy-Adjustment Model: Calibration and Robustness

We solve the HJBQVI in equation (52) using finite-difference methods.[36] Here we discuss calibration details and parameter robustness.

Baseline Calibration. For our baseline calibration with consumer durables (excluding housing), we set $s = 0.126$ and $\delta = 0.223$ (details in Appendix C). We also set adjustment cost $A = 0.039$ to generate an annual adjustment probability of 0.24 (Beraja and Zorzi, 2024).

Another important parameter is σ, which governs the volatility of consumption growth in equation (22). Our baseline calibration sets $\sigma = 0.134$. To obtain this calibration, we start from the commonly used Floden and Lindé (2001) estimate of log-wages, who find that log-wages follow a highly persistent AR(1) process with an annual persistence parameter of 0.91 and an annual standard deviation of 0.21. Next, it is often shown empirically that there is only a partial pass-through of such income shocks to consumption. For example, Blundell et al. (2008) estimate that 64% of permanent income shocks pass through to consumption, while Heathcote et al. (2014) estimate that 39% of permanent wage shocks pass through to consumption. Taking the higher estimate to be conservative,[37] we set $\sigma = 0.21 \times 0.64 = 0.134$. Robustness to alternative parameter choices is presented below.

The remaining parameters that we need to calibrate are η, ν, and ρ. We set $\eta = 1$, meaning that the CES aggregator in equation (8) is Cobb-Douglas and hence that welfare-loss parameter $\lambda = \frac{-s}{1-s}$ (see Approximation 1). We set $\nu = 0$ for simplicity.[38] Finally, we set $\rho = r - \gamma\nu + \frac{\gamma(\gamma+1)}{2}\sigma^2$ for consistency with the human-capital based microfoundation in Appendix D.1. Specifically, we use $r = 1\%$ following Maxted et al. (2025) (to which we apply our frictionless mapping in Appendix F) and $\gamma = 1$ for consistency with Approximation 1,

[36] See the codes provided under the heading "Stopping Time Problem" at https://benjaminmoll.com/codes/ for numerical details.

[37] As shown in Section 5, lower values of σ bring our (S, s)-type model closer to the Caplin and Spulber (1987) limit case and hence raise the model's mapping from MPCs to MPXs.

[38] Recall that as ν increases, the ergodic density $g(z)$ tends toward uniformity.

which then implies that $\rho = 0.028$.

Housing Calibration. For our alternate calibration that includes housing as part of the durable stock, the calibration is the same as the baseline except for three parameter changes. First, the calibrated durable share increases to $s = 0.260$. Second, the depreciation rate decreases to $\delta = 0.061$ (details in Appendix C). Third, we set adjustment cost $A = 0.089$ to target a 10% annual adjustment probability. The numbers in Appendix C imply that consumer durables make up 20% of the total durable stock (including housing), while housing composes the rest. Using an annual adjustment probability for housing of $\frac{1}{15}$ (Maxted et al., 2025) and continuing to use an annual adjustment probability for consumer durables of 0.24, the weighted-average adjustment probability is 10%.

Robustness. Figure 2 plots robustness to various parameter calibrations. Specifically, we start from the baseline calibration for consumer durables, and then perturb the parameters σ, δ, s, and A up/down by 25%. For each perturbation, Table 2 provides the ratio of the quarterly MPC-to-MPX scaling factor of the lumpy-adjustment model (from equation (26)) relative to the quarterly MPC-to-MPX scaling factor of the frictionless model (from equation (21)).

Key parameters that affect the extent to which the scaling factor of the lumpy-adjustment model approximates the scaling factor of the frictionless model are σ and δ. This is because the ratio of these two parameters alters the shape of the ergodic density $g(z)$ (see equation (53)); in particular, as σ decreases or δ increases, $g(z)$ converges to a uniform density. As discussed in Section 5, a near-uniform distribution is needed for the lumpy-adjustment model to approximate its frictionless counterpart.[39] Thus, a lower σ or a higher δ brings the scaling factor of the lumpy-adjustment model closer to that of the frictionless model (and vice versa). Alternatively, the ratio of the scaling factor of the lumpy-adjustment model relative to the

[39]In particular, it is intuitively helpful to focus on the mass of households around the dotted red lines in Figure 2, as these are generally the households that are pushed into adjusting by the wealth shock.

frictionless model is essentially unaffected by our perturbations to s and A.

Lumpy-Adjustment MPX / Frictionless MPX (Quarterly)		
Parameter	+25% Perturbation	−25% Perturbation
σ	0.77	0.91
δ	0.90	0.73
s	0.82	0.85
A	0.83	0.83

Table 2: Lumpy-Adjustment Model: Robustness

Notes: For each parameter perturbation, this table provides the ratio of the quarterly MPC-to-MPX scaling factor of the lumpy-adjustment model (from equation (26)) relative to the quarterly MPC-to-MPX scaling factor of the frictionless model (from equation (21)).

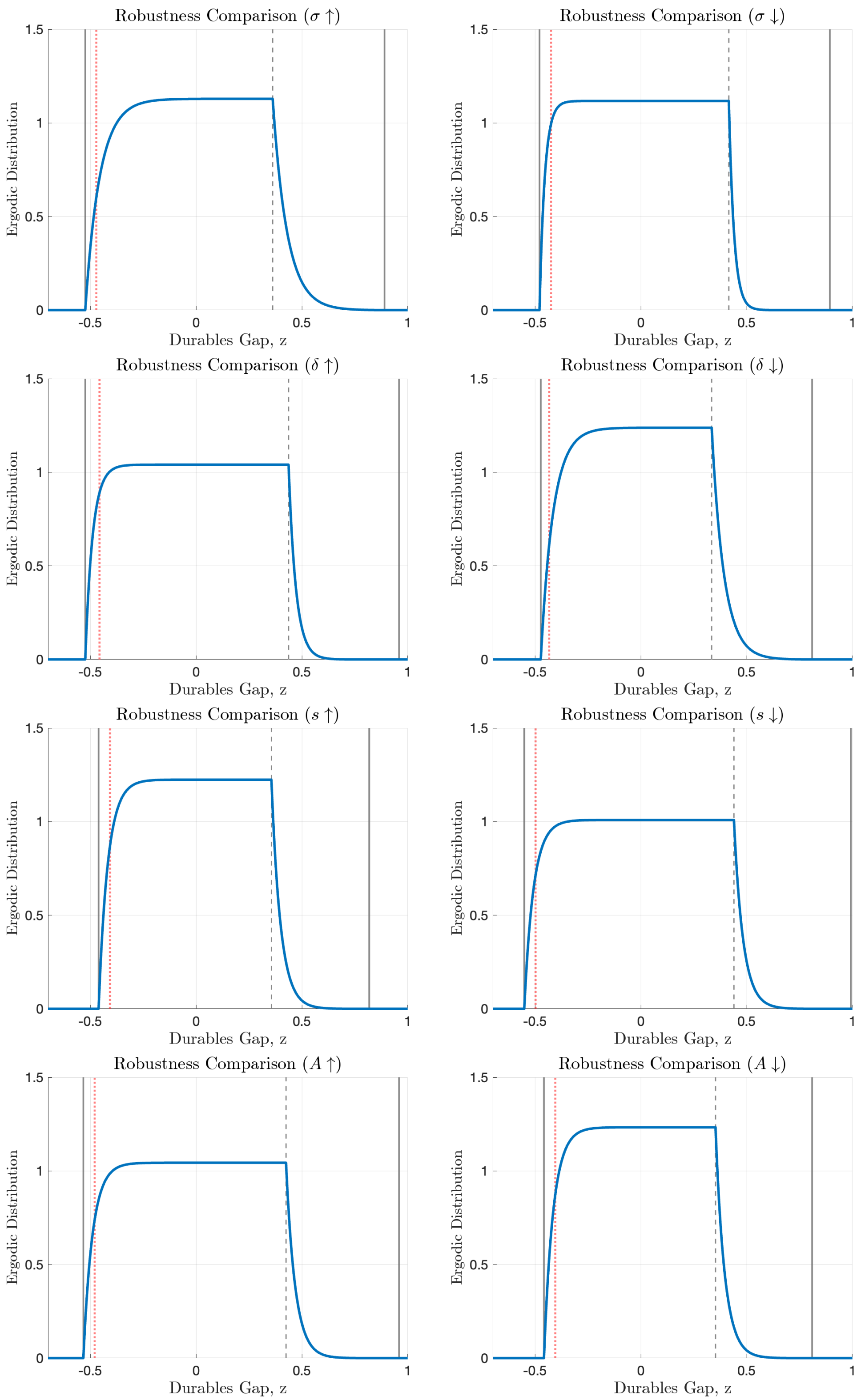

Figure 2: Lumpy-Adjustment Model: Robustness

D.4 The MPX with Lumpy Adjustment: Additional Details

This section provides further details on the heuristic MPX approximation described in Section 5.3. Recall that τ is the period length over which the MPX is defined. Certain steps of our approximation will be more accurate when τ is relatively short (e.g., one quarter).

Three Household Types. There are three household types that are important to consider separately: (i) households that do not adjust their durable stock over the period τ, (ii) households that do adjust their durables over the period τ, but would have done so even without the ϵ-shock, and (iii) households that only adjust their durable stock over the period τ as a result of the ϵ-shock. In short, type-i and type-ii households have their intensive-margin spending decisions affected by the shock, while type-iii households have their extensive-margin adjustment decision affected by the shock.

Note that our approximation in Section 5.3 only discusses type-i households and type-iii households (and treats all type-ii households as if they were type-i households). Although this is only an approximation—one that we further justify below—note already that the quarterly adjustment probability is only 6% in our baseline calibration (it is even lower for the housing calibration). Thus, for our main application with $\tau = \frac{1}{4}$, we have that 94% of households are type-i while only 6% of households are type-ii (and assuming a small ϵ-shock, only a vanishingly small set of households are type-iii).

Intensive Margin: Type-i and Type-ii Households. Since type-i households do not adjust, all additional spending over the period τ must be on nondurables. Taking o_t from the notional-consumption model (Approximation 2) with instantaneous MPC μ, cumulating over τ gives:

$$\text{Type-i: } MPX_\tau^n \approx \mu \times \tau$$
$$\text{Type-i: } MPX_\tau^D = 0.$$

Turning next to type-ii households, we start by considering durable adjustment. When a household adjusts its durables, it adjusts to a new durable level D_t' defined implicitly by $z' = \ln\left(\frac{D_t'}{D_t^*}\right) = \ln\left(\frac{D_t'}{\frac{so_t}{r+\delta}}\right)$. Rearranging gives: $D_t' = \left(\frac{so_t}{r+\delta}\right) e^{z'}$. This household adjusts from an old durable level $\underline{D}_t$ defined implicitly by $\underline{z} = \ln\left(\frac{\underline{D}_t}{D_t^*}\right)$, and rearranging similarly gives: $\underline{D}_t = \left(\frac{so_t}{r+\delta}\right) e^{\underline{z}}$. Thus, the household's total durable purchases upon adjustment are:

$$\begin{aligned} D_t' - \underline{D}_t &= \frac{so_t}{r+\delta}\left(e^{z'} - e^{\underline{z}}\right) \\ &\approx \frac{so_t}{r+\delta}\left(z' - \underline{z}\right), \end{aligned}$$

where the approximation becomes exact as $A \to 0$.

Next, recall that an ϵ-shock increases o_t by $\mu\epsilon$ on impact. Thus, the effect of the ϵ-shock on durable purchases $D_t' - \underline{D}_t$ is roughly $\frac{s}{r+\delta}\left(z' - \underline{z}\right)\mu\epsilon$. So, the durable MPX for type-ii households is approximately:

$$\text{Type-ii: } MPX_\tau^D \approx \frac{s}{r+\delta}\left(z' - \underline{z}\right)\mu.$$

For our baseline calibration, $\frac{s}{r+\delta}\left(z' - \underline{z}\right) = 0.48$.

For the nondurable MPX of type-ii households, recall first that we take $o_t = n_t + (r+\delta)D_t$ from the underlying notional-consumption model (Approximation 2). If o_t increases by $\mu\epsilon$, this will pass through entirely to n_t until the household adjusts its durables, after which the pass-through to n_t will be lower because type-ii households' durable purchases impose a drag on subsequent nondurable spending. Thus, it should generally be the case that the nondurable MPX of type-ii households is less than the nondurable MPX of type-i households.

As already mentioned, to get to our approximation in Section 5.3 we make the simplifying assumption of treating type-ii households as if they were type-i households. This is not exactly correct, since it ignores type-ii households' durable MPX while overstating their nondurable MPX. However, it is a reasonable simplification when the share of type-ii households is small, as is true for our calibrations when τ is relatively short. With this simplification, we get back to the claim in Section 5.3 that for all non-type-iii households, additional spending in response to the ϵ-shock "is essentially all on nondurables," and hence overall we conclude:

$$MPX_\tau^n \approx \mu \times \tau.$$

Extensive Margin: Type-iii Households. To approximate the spending of type-iii households, we focus entirely on their extensive-margin durable purchases. Although an increase in durable purchases will decrease households' nondurable flow spending for any given o_t path, we ignore the effect of durable purchases on type-iii households' nondurable spending since the effect cumulates over only short horizons if τ is small.[40]

Calculation details for the extensive margin of durable purchases caused by the ϵ-shock are provided in Section 5.3; see in particular the equation for the aggregate durable MPX of:

$$MPX_\tau^D \approx \mathcal{U}_\tau'(0) \times \mu \times \left(\frac{s}{r+\delta} \left(z' - \underline{z}\right) \right) - \mathcal{D}_\tau'(0) \times \mu \times \left(\frac{s}{r+\delta} \left(\overline{z} - z'\right) \right).$$

For the first term of this equation, recall that $\mathcal{U}_\tau'(0) \times \mu$ captures how the ϵ-shock affects the number of households that jump upward, and $\frac{s}{r+\delta}\left(z' - \underline{z}\right)$ captures how far households jump if adjusting. The explanation for the second term is similar, but for downward adjustments.

Although intuitive, this equation for MPX_τ^D is again only an approximation. First, recall from the derivation in Section 5.3 that moments (i) and (ii) of the calculation, which capture the dollar purchases/sales of durables upon adjustment, are only approximations. For durable purchases we used: $D_t^* \left(e^{z'} - e^{\underline{z}}\right) \approx \frac{s o_t}{r+\delta}\left(z' - \underline{z}\right)$, and for durable sales we used $D_t^* \left(e^{\overline{z}} - e^{z'}\right) \approx \frac{s o_t}{r+\delta}\left(\overline{z} - z'\right)$.[41] Second, note that our derivation of the equation for MPX_τ^D

[40] The relevant horizon is typically less than τ, since the extensive-margin adjustment caused by the ϵ-shock is often not made right away.

[41] For further details, the formula for durable purchases was derived above when discussing type-ii households. The formula for durable sales can be derived similarly.

calculates households' durable purchases/sales assuming that those purchases/sales are made immediately (which is why o_t shows up). In reality, households could make those adjustments at any time over the period τ, in which case o_t will have evolved to some extent. However, we conjecture that this is a reasonable approximation for the calibrations we consider.

Aggregation. Putting together all of the above approximations, type-i and type-ii households generate the nondurable MPX of

$$MPX_\tau^n \approx \mu \times \tau,$$

while type-iii households generate the durable MPX of

$$MPX_\tau^D \approx \mathcal{U}_\tau'(0) \times \mu \times \left(\frac{s}{r+\delta}\left(z' - \underline{z}\right)\right) - \mathcal{D}_\tau'(0) \times \mu \times \left(\frac{s}{r+\delta}\left(\overline{z} - z'\right)\right).$$

Summing these up and denoting the MPC of the underlying notional-consumption model by $MPC_\tau \approx \mu \times \tau$ recovers equation (26).

D.5 Additional Discussion

To generate a tractable model with durables that is isomorphic to the notional-consumption model, we needed to make three strong assumptions in Section 3.2 in order to explicitly relate notional consumption to expenditure. Despite these strong (and unrealistic) assumptions, our frictionless mapping nonetheless fits the available data well—see Table 1. Although it may be puzzling at first glance that our frictionless mapping fits the data, we illustrated in Section 5 that a calibrated (S, s)-type model with durable-adjustment frictions can produce a similar mapping from MPCs to MPXs as its frictionless counterpart. Collectively, this evidence underpins our summary view that—as discussed in Section 5.4—our frictionless modeling device provides a reasonable approximation of expenditure on (non-housing) consumer durables.

However, our (S, s)-type model is itself quite stylized. As such, there still exist a variety of scenarios where our framework may fail, which we now discuss. Specifically, in this section we outline four sets of scenarios where our frictionless mapping likely has shortcomings (in addition to housing as discussed in Section 5.4): durable-financing constraints, time-dependent inaction, interest rate or relative price shocks, and time periods where the cross-sectional distribution of households is particularly near/far from adjustment thresholds. When such issues arise, they point to mechanisms that are potentially missing from notional-consumption models and suggest the need for additional analysis using specialized models that account for the relevant durable frictions.[42]

Durable-Financing Constraints. One implication of Assumption 1 is that households do not face financing constraints when purchasing durables. While some consumer durables are (partially) collateralizable, this strong assumption may fail in many settings.

An interesting question is how durable-financing constraints affect the mapping from MPCs to MPXs. There are likely to be effects pushing in both directions. On one hand, if financing constraints prevent households from purchasing their desired level of durables upon receiving a positive wealth shock, then this will lower the mapping from MPCs to MPXs. On the other hand, financing constraints are likely to generate "pent-up demand" for durables by creating a set of households that want to increase their durable stock, but cannot finance it. If a positive wealth shock suddenly provides these households with the down-payment needed to finance their durable purchases, then we would expect a larger mapping from MPCs to MPXs. The strength of these effects may also depend on the size of the wealth shock—see e.g. Parker et al. (2013), Christelis et al. (2019), Zorzi (2020), Fuster et al. (2021), and Beraja and Zorzi (2024) for discussions related to such composition effects.

[42] A contribution of our paper is that it explicitly spotlights the assumptions that are implicit in models of notional consumption, thereby providing guidance on the situations for which notional-consumption models will or will not provide a sufficiently rigorous framework for evaluation.

Time-Dependent Inaction. Our (S, s)-type model in Section 5 features what is sometimes referred to as "state-dependent" inaction, but it does not feature "time-dependent" inaction.[43] Beraja and Zorzi (2024) point out that the addition of time-dependent inaction can have the effect of lowering the durable MPX (and hence the total MPX) relative to the nondurable MPX. Beraja and Zorzi (2024) microfound this sort of time-dependent inaction with durable adjustment taste shocks. Relatedly, households might also be slow to adjust their durable stock due to inattention (e.g., McKay and Wieland, 2021; de Silva and Mei, 2025) or even procrastination (e.g., Maxted et al., 2025).[44]

Shocks to Interest Rates and Relative Prices. On interest rate shocks, Assumption 3 assumes that durables generate consumption flow $f = r + \delta$. This means that the durable stock needed to attain a given consumption flow varies with r. As discussed when this assumption was first presented, it is reverse-engineered to maintain an isomorphism with the notional-consumption model. To the extent that the assumption is unrealistic, it suggests that notional-consumption models are missing channels through which monetary policy can influence the demand for durable goods.[45] However, we view this issue as less critical for our aim of understanding the consumption and expenditure response to wealth injections, particularly over the relatively short horizons that we focus on.

A related scenario where Assumption 3 may fail is when there are sizable movements in the relative prices of durables and nondurables over the horizons at which we study MPCs and MPXs (e.g., Orchard et al., 2025). For example, if a positive wealth shock leads to an increase in the relative price of consumer durables, this will lessen households' willingness to purchase new durables. On the other hand, durable price increases can also lead to positive

[43] For readers not familiar with this terminology, see e.g. Andersen et al. (2020) for a clarifying discussion.

[44] Procrastination may also change the composition of purchased durables. Following a positive wealth shock, we conjecture that households will be more likely to procrastinate on purchasing durables that do not bring excitement, such as replacing an aging hot water storage tank, than on durables that are exciting to purchase, such as a sports car.

[45] See for example Auclert (2019), McKay and Wieland (2021, 2022), and de Silva and Mei (2025) for richer models detailing channels through which durable spending is affected by interest rate changes.

revaluation effects for the durables that households already own.[46]

The Cross-Sectional Distribution of Households. Our (approximate) mapping in equation (26) integrates over the ergodic distribution, and hence is best interpreted as a time-series average (as mentioned in footnote 22). However, the cross-sectional distribution of households at any specific point in time may differ from the ergodic distribution (e.g., during booms or recessions). In such cases, time variation in the cross-sectional distribution of households will also affect the lumpy-adjustment model's predicted mapping from MPCs to MPXs. In general, we expect the short-run expenditure response following a positive wealth shock to be larger when relatively more households are near $\underline{z}$, and vice versa. These sorts of issues are also discussed more fully in Bertola and Caballero (1990), Eberly (1994), Berger and Vavra (2015), and Beraja and Zorzi (2024).

E Additional Generalizations and Extensions

E.1 Microfounding the Aggregate Durable Stock

This section provides a microfoundation for the aggregate durable stock D that is analyzed in our extended model presented in Section 3.2. We assume that there are V varieties of durable goods, such as cars, furniture, televisions, etc., each of which is perfectly liquid (Assumption 1). Each variety v provides a consumption flow of f_v and depreciates at rate δ_v. At any time t, the household's total durable stock D_t equals the sum of its holdings of each of these varieties, $D_t = \sum_{v \in V} D_{v,t}$. This also implies that the aggregate durable depreciation rate δ_t is defined by the depreciation of each variety, $\delta_t D_t = \sum_{v \in V} \delta_v D_{v,t}$.

To build a simple microfoundation, we assume that the household values durable con-

[46]We conjecture that the revaluation of consumer durables is likely to have a larger effect on the consumption decisions of lower-wealth households, for whom automobiles often compose a sizable share of their overall portfolio (Campbell, 2006).

sumption flows using a CES aggregator:

$$f_t D_t = \left(\sum_{v \in V} s_v^{\frac{1}{\eta_D}} \left(f_v D_{v,t} \right)^{\frac{\eta_D - 1}{\eta_D}} \right)^{\frac{\eta_D}{\eta_D - 1}}, \tag{54}$$

where $f_t D_t$ is the total durable consumption flow generated by aggregate durable stock D_t, $f_v D_{v,t}$ is the durable consumption flow generated by the household's holdings of durable variety v, s_v is the utility weight on variety v, and $\eta_D > 0$ is the elasticity of substitution between each durable variety. We assume that utility weights sum to 1: $\sum_{v \in V} s_v = 1$.

Given the CES functional form we obtain:

Lemma 7 *Let $R_v := (r + \delta_v)/f_v$ denote the price of a unit of durable flow consumption from variety v. The optimal intratemporal choice of each variety is:*

$$f_v D_{v,t} = \frac{s_v R_v^{-\eta_D}}{\sum_{v \in V} s_v R_v^{1-\eta_D}} P_D (f_t D_t),$$

where

$$P_D = \left(\sum_{v \in V} s_v R_v^{1-\eta_D} \right)^{\frac{1}{1-\eta_D}}.$$

The cost of attaining aggregate durable consumption flow $f_t D_t$ is

$$\sum_{v \in V} (r + \delta_v) D_{v,t} = P_D (f_t D_t).$$

Proof. Similar to the proof of Lemma 1, the household's intratemporal problem for durables is as follows: minimize cost $\sum_{v \in V} (r + \delta_v) D_{v,t}$ subject to attaining a level of durable consumption flow d given by equation (54). Equivalently, defining $d_v := f_v D_v$ for each variety v, the household solves

$$\text{Cost}(d) = \min_{d_v} \left\{ \sum_{v \in V} \frac{r + \delta_v}{f_v} d_v \quad \text{s.t.} \quad \left(\sum_{v \in V} s_v^{\frac{1}{\eta_D}} d_v^{\frac{\eta_D - 1}{\eta_D}} \right)^{\frac{\eta_D}{\eta_D - 1}} \geq d \right\}.$$

Defining $R_v := (r+\delta_v)/f_v$ and using the standard CES results, the demand for each variety d_v and the cost function $\text{Cost}(d)$ are given by

$$\begin{aligned} d_v &= \frac{s_v R_v^{-\eta_D}}{\sum_{v\in V} s_v R_v^{1-\eta_D}} P_D d \\ \text{Cost}(d) &= P_D d \\ P_D &= \left(\sum_{v\in V} s_v R_v^{1-\eta_D}\right)^{\frac{1}{1-\eta_D}} \end{aligned}$$

■

To complete the microfoundation, we now extend Assumption 3 as follows:

Assumption 3′ *For each durable variety v, the consumption flow per unit of durable f_v equals its user cost, $f_v = r + \delta_v$.*

With Assumption 3′ we see from Lemma 7 that $R_v = 1$ for each variety v, and therefore also that the CES durable price index $P_D = 1$. Using this in Lemma 7:

$$\begin{aligned} f_t D_t &= \sum_{v\in V} (r+\delta_v) D_{v,t} \\ &= \sum_{v\in V} r D_{v,t} + \sum_{v\in V} \delta_v D_{v,t} \\ &= (r+\delta_t) D_t, \end{aligned}$$

where the last line uses the properties that $D_t = \sum_{v\in V} D_{v,t}$ and $\delta_t D_t = \sum_{v\in V} \delta_v D_{v,t}$. This result alongside Assumption 3′ in Lemma 7 then implies that the demand for each durable variety is $D_{v,t} = \frac{s_v}{r+\delta_v}(r+\delta_t)D_t$. Finally, the aggregate durable depreciation rate δ_t can now be expressed as:

$$\delta_t = \frac{\sum_{v\in V} \delta_v D_{v,t}}{\sum_{v\in V} D_{v,t}} = \frac{\sum_{v\in V} \frac{s_v \delta_v}{r+\delta_v}}{\sum_{v\in V} \frac{s_v}{r+\delta_v}},$$

which is a constant (i.e., we can drop the t-subscript from the aggregate depreciation rate δ_t). We showed above that $f_t D_t = (r+\delta_t)D_t$, and since δ_t is constant we now have $f = r+\delta$. Thus, by imposing Assumption 3′ at the level of individual durable varieties, we recover Assumption 3 at the level of aggregated durables.

E.2 MPCs and MPXs out of Discrete Liquid-Wealth Shocks

Section 4 defines the MPC and the MPX over infinitesimal liquid-wealth injections. Following Achdou et al. (2022), these definitions are easily extended to discrete wealth injections.

We use $x + \chi$ as shorthand notation for point x in the state space, plus a liquid-wealth injection of size χ. For a discrete liquid-wealth injection of size χ the MPC is defined as:

$$MPC_\tau^\chi(x) = \frac{\mathbb{E}\left[\int_0^\tau c(x_t)dt \;\middle|\; x_0 = x+\chi\right] - \mathbb{E}\left[\int_0^\tau c(x_t)dt \;\middle|\; x_0 = x\right]}{\chi}.$$

The MPX out of a discrete liquid-wealth injection is defined as:

$$MPX_\tau^\chi(x) = \frac{\mathbb{E}\left[\int_0^\tau n(x_t)dt + \int_0^\tau d\psi(x_t) \;\middle|\; x_0 = x+\chi\right] - \mathbb{E}\left[\int_0^\tau n(x_t)dt + \int_0^\tau d\psi(x_t) \;\middle|\; x_0 = x\right]}{\chi}.$$

Following similar steps as the proof of Proposition 3, this MPX out of a discrete liquid-wealth injection can be rewritten as:

$$MPX_\tau^\chi(x) = \left(1 - s + \frac{s\delta}{r+\delta}\right) MPC_\tau^\chi(x) + \frac{s}{r+\delta}\left(\frac{\mathbb{E}\left[c(x_\tau) \mid x_0 = x+\chi\right] - \mathbb{E}\left[c(x_\tau) \mid x_0 = x\right]}{\chi}\right),$$

which can again be calculated from a notional-consumption model given a calibration of parameters s and δ. Specifically, the MPC can be calculated numerically using the Feynman-Kac formula (see Lemma 2 of Achdou et al. (2022) for details). Expected future consumption $\mathbb{E}[c(x_\tau)|x_0 = x]$, which is used in the MPX calculation, can also be calculated numerically using the Feynman-Kac formula.

E.3 Rented Durables

For simplicity, we have assumed throughout that durables are owned by consumers. In reality, some durables are owned and some are rented. For partial-equilibrium analyses, durable share s can be calibrated as the share of notional consumption coming from *purchased* durables, rather than the total durable share. However, for general-equilibrium analyses what matters is the total durable share. It is immaterial whether a household purchases a durable directly or whether a firm purchases the durable and then rents it to the household. In either case, the durable still needs to be produced and this will typically be what matters for macroeconomic dynamics.

F Application: Maxted et al. (2025)

This appendix applies our MPX technology to the model of Maxted et al. (2025), which is a heterogeneous-household model built to understand how present-biased time preferences affect household budgeting decisions. The model features a liquid savings account and an illiquid home on the asset side of the balance sheet, and credit cards and mortgages on the liabilities side of the balance sheet. There is a single notional consumption good. The model is calibrated to match two empirical moments: the average quantity of credit card debt and the average mortgage loan-to-value ratio.

Time Horizon	MPC	MPX
1 Quarter	14%	30%
1 Year	28%	36%
2 Years	40%	45%
3 Years	48%	51%

Table 3: \$1,000 MPCs and MPXs

Notes: This table presents the average MPC and MPX out of a \$1,000 fiscal transfer in the Present-Bias Benchmark calibration of Maxted et al. (2025).

Table 3 reproduces the average MPC and MPX over various time horizons for the Maxted et al. (2025) model.[47] There are two key takeaways from Table 3. First, MPXs are larger than MPCs. This is intuitive, as MPXs capture total expenditures rather than just notional consumption flows. Second, as highlighted by equation (21) there is a sizable difference between the timing of MPCs and MPXs, with MPXs being more front-loaded than MPCs. The one-quarter MPX is more than twice as large as the one-quarter MPC, but the cumulative three-year MPX is almost identical to the three-year MPC.[48]

Numerical Applications: Additional Discussion. For researchers applying our MPX mapping, we briefly mention two additional considerations. First, the MPX can be larger than one. In our extended model, households' ability to borrow against durables allows them to convert wealth injections into larger durable purchases.[49] Second, MPXs may be non-monotonic in τ. As equation (18) shows, this is particularly likely if $\frac{\partial}{\partial b}\mathbb{E}\left[c(x_\tau) \mid x_0 = x\right]$ is declining quickly in τ. Although this non-monotonicity is partially due to our strong assumption that durables are liquid, it is not completely unrealistic. For example, a household that buys a used car and sells it three years later would have a non-monotonic MPX.

[47] The two- and three-year MPCs reported here are marginally higher than those reported in Figure 4 of Maxted et al. (2025). The exercises are slightly different, however, as that paper's fiscal policy experiment combines a one-time stimulus payment with future (offsetting) income taxes.

[48] In this specific application, the one-quarter MPX is somewhat lower than the "quarterly MPC times 3" rule-of-thumb in Remark 1. The reason for this is that the Maxted et al. (2025) model predicts that the consumption rate declines *very quickly* following a liquid-wealth transfer, even over a short one-quarter horizon (see Figure 4 of Maxted et al., 2025). This deviates from the simplifying assumption we made when deriving equation (21) that $\frac{\partial}{\partial b}\mathbb{E}\left[c(x_\tau) \mid x_0 = x\right]$ is roughly constant in τ, and, as a result, that simplification is less accurate in this particular setting.

[49] Empirically, expenditures often exceed wealth injections. For example, Parker et al. (2013) document a large response of automobile purchases to the 2008 fiscal stimulus, Aaronson et al. (2012) find that debt-financed durable spending increases following minimum-wage hikes, and Fagereng et al. (2021) estimate MPXs above one for small lottery winnings.

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