A Simple Mapping from MPCs to 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 a durable stock. We compare the notional-consumption model to an isomorphic model with a durable stock, and map notional MPCs into MPXs. The mapping is especially simple for a one-period horizon: MPX $= \left(1 - s + \frac{s}{r+\delta}\right) \times$ MPC, with durable share s, real interest rate r, and durable depreciation rate δ.

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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 if it were a notional[1] flow of homogeneous consumption. This *notional-consumption model* does not specify the sources of this flow; in particular, the model does not distinguish between durable and nondurable consumption. This model is often used to analyze the response of notional consumption to liquidity injections, i.e., what we call the *notional* MPC.

In most practical macroeconomic policy analysis, notional consumption is not the key variable. Macroeconomic stimulus attempts to raise 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. Holding all else equal, the production/sale of this automobile raises GDP in Q1 by the market price p, but raises notional consumption in Q1 by an amount that is approximately two orders of magnitude smaller than p because notional consumption is the household's consumption flow from owning the new automobile, which accrues only slowly over time. For most policy applications, economists need to understand the dynamics of consumption *expenditure*. We refer to the response of expenditure to liquidity injections as the marginal propensity for expenditure (MPX).[2]

The relationship between notional consumption and consumption expenditure is complex. The two measures are identical for goods that have no durability (e.g., lettuce) and for

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

[2] Our MPX notation is similar to Auclert (2019) and Crawley and Kuchler (2020).

services.[3] The low rates of depreciation for durable goods[4] – such as home furnishings and automobiles – generate a large wedge between notional consumption of durables and expenditure on durables, even in data that is time-aggregated to annual periods.

The discrepancy between notional consumption and consumption expenditure has long been recognized and discussed in the household finance literature.[5] Especially in empirical work, economists frequently draw a distinction between the MPX on all expenditures (including both durables and nondurables) and the MPX on nondurables alone. Estimates of the quarterly MPX for all expenditure range from 50-90%, while estimates of the quarterly MPX for nondurable expenditure range from 15-25%.[6] In theory, the notional MPC lies below the total MPX and above the MPX on nondurables.

In this paper, we propose a portable and tractable modeling device that converts a notional MPC into an MPX. In particular, we show how to extend a notional-consumption model to generate predictions about consumption expenditures in an isomorphic model with durable stocks. We provide a parsimonious equation for calculating MPXs in the extended model with durables.

Our modeling device can be built in both continuous and discrete time. Though the continuous-time specification is generally more tractable, our discrete-time MPX formula is especially simple when used to calculate the MPX over one period:

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

where s is the durable share of notional consumption, r is the real interest rate, and δ is the depreciation rate for durables (so that $r + \delta$ is the user cost of durables). This total MPX

[3] "Services are commodities that cannot be stored or inventoried and that are usually consumed at the place and time of purchase." Bureau of Economic Analysis (2020)

[4] "Durable goods are goods that have an average useful life of at least 3 years." Ibid.

[5] See for example Mankiw (1982), Hayashi (1985), Lusardi (1996), Padula (2004), Parker et al. (2013), Jappelli and Pistaferri (2014), and Kueng (2018). Aguiar and Hurst (2005) emphasize a separate, but related, distinction of consumption versus expenditure, where consumption includes home production.

[6] Kaplan and Violante (2021) review nondurables, and Di Maggio et al. (2020b) review total spending. Kaplan and Violante (2021) review the determinants of notional MPCs in heterogeneous-agent models.

sums the MPX on nondurables, $(1-s)\times$MPC, and the MPX on durables, $\left(\frac{s}{r+\delta}\right)\times$MPC.

We use BEA data to calibrate $s = 0.125$ and a quarterly depreciation rate for consumer durables of $\delta = 0.054$.[7] Assuming a small quarterly real interest rate ($r \approx 0$), our model yields $1 - s + \frac{s}{r+\delta} = 3.2$ and hence a rule-of-thumb for calculating the quarterly MPX in a model of notional consumption: *multiply the MPC by 3.* For example, the seminal paper of Kaplan and Violante (2014) predicts a quarterly notional MPC of 15%, and our rule-of-thumb therefore implies a quarterly MPX of 45%.

Our framework can also be used to move back and forth between total MPXs and MPXs on nondurables. In our one-period discrete-time specification,

$$\text{Notional MPC} = \left(\frac{1}{1-s}\right) \times \text{Nondurable MPX}.$$

Accordingly,

$$\text{Total MPX} = \left(1 + \frac{s}{(r+\delta)(1-s)}\right) \times \text{Nondurable MPX},$$

or about 3.6 in our calibration.

Our simple MPX formula fits the available data well. For example, Parker et al. (2013) estimate quarterly MPXs on nondurables of 12-30% and quarterly total MPXs of 50-90%, while our framework comparably maps a 12%-30% MPX on nondurables into a total MPX of 43%-108%.[8]

Our mapping also highlights the importance of controlling for the time horizon over which MPCs and MPXs are compared. MPXs will initially be larger than MPCs, with the two measures steadily converging as the time horizon increases. This horizon effect arises

[7] Our calibration focuses on consumer durable goods, and Section 5.4 discusses how our framework extends to illiquid housing. Appendix C provides calibration details.

[8] $43\% = 3.6 \times 12\%$ and $108\% = 3.6 \times 30\%$. As we discuss in Section 4.1, MPXs are not bounded above by 100%. For example, a consumer who uses a \$1,000 liquidity injection to make a downpayment on a \$30,000 car has a 3,000% MPX.

because expenditure on durables is lumpy and front-loaded relative to the consumption flows that those durables subsequently provide. For example, we find that the quarterly MPX is roughly 3-times the quarterly MPC, the annual MPX is roughly 1.5-times the annual MPC, and the 5-year MPX is roughly 1.1-times the 5-year MPC.

To derive our MPX formula, our extended model with purchased durables makes a number of assumptions (see Assumptions 1 to 3 in Section 3.2). The strongest (and most indispensable) of these is that durables are liquid, i.e., households do not face adjustment frictions when buying and selling durables. Auclert et al. (2018) use the same assumption to map predictions of a notional-consumption model into predictions about expenditure in a model with durables, though they do not flesh out the MPC versus MPX distinction.[9] Similarly, Abel (1990) and Auclert (2019) use this assumption to discuss the relative size of different MPX measures but they do not provide a mapping from notional-consumption models to models with durables.[10]

Strong assumptions are needed in our framework in order to maintain an isomorphism between the extended model with durables and the benchmark notional-consumption model. Thus, our isomorphic extension with durables is partly an effort to spell out the assumptions that are already made implicitly in notional-consumption models, and to see how far we can push those assumptions in order to back out the expenditure dynamics that are implied by notional-consumption responses. Though our simple mapping tends to fit the available data, we do not claim that these strong assumptions are always valid. Rather, given the

[9] See Appendix E of Auclert et al. (2018). Our mapping is simpler than theirs because other assumptions differ. For example, we assume CES preferences over nondurables and durables whereas they assume that preferences are separable between the two goods. Another related mapping is by Fagereng et al. (2019b, Appendix B.1) who analyze a model with liquid housing and map it to a notional-consumption model with a time-varying consumption price index.

[10] See Section 3 of Abel (1990) and Appendix A.5 of Auclert (2019). The relation to Abel's work is especially simple: in the one-period discrete-time special case, our formula for the MPX on durables is $\left(\frac{s}{r+\delta}\right)\times$ MPC and the MPX on nondurables is $(1-s)\times$ 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) instead 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.

prevalence of notional-consumption models we view one of our contributions as identifying these assumptions explicitly in order to provide economists with a better understanding of the situations in which notional-consumption models can or cannot serve as a helpful guide. We therefore view our tractable extension with durables as complementary to consumption models that rigorously characterize durable frictions.[11] The benefit of the stylized approach taken here is that it is simple and easy to use, provides closed-form expressions that clarify key channels driving a wedge between consumption and expenditure, and triangulates notional-consumption models with the available empirical evidence on consumer spending.

Section 2 discusses the importance of having a modeling tool that maps between notional MPCs and MPXs. Section 3 lays out a notional-consumption model and our isomorphic model with durables, while Section 4 presents our main results about converting notional MPCs into MPXs. Section 5 discusses our approach for mapping notional consumption into expenditure, including its limitations and how they can be partially addressed. Section 6 concludes.

2 MPCs versus MPXs: An Important Distinction

2.1 Terminology

We begin with definitions. Whenever we use the term consumption we mean notional consumption, i.e., the utility-generating consumption flows that are studied in classical consumption models.[12] Accordingly, whenever we use the term MPC we mean a notional MPC.

In contrast to notional consumption, the alternative concept that we study is expenditure. We refer to the response of expenditure to liquidity injections as the MPX. The difference between consumption and expenditure derives from durability. The purchase of a

[11] For evaluations of the impact of durables on macroeconomic stabilization policy, see for example Berger and Vavra (2015), McKay and Wieland (2019), and Beraja and Wolf (2021). See also Yogo (2006) for an asset-pricing analysis.

[12] Seminal examples include Deaton (1991), Carroll (1997), and Gourinchas and Parker (2002).

durable good generates a one-time burst of expenditure but a long-lasting flow of notional consumption.[13] Unless specified otherwise, MPX refers to the *total* MPX, which includes spending on nondurables and consumer durables.

2.2 The Importance of Mapping MPCs Into MPXs

Given a model of notional consumption and notional MPCs, there are two broad reasons why it is important to develop a mapping from MPCs into MPXs. The first reason is measurement: developing a mapping from MPCs into MPXs expands the connections between model predictions and empirical moments. The second reason is policy: policy makers should possess models of the expenditure response to liquidity shocks, as consumer expenditure matters more than notional consumption for the response of GDP to stabilization policy. These reasons are detailed in turn below.

Starting with measurement considerations, it is important to differentiate MPXs from MPCs both in order to understand the underlying connection between spending and consumption flows, and to align notional-consumption models with a broader set of empirical moments. Total MPXs frequently differ from nondurable MPXs in the data because durable expenditures are an important part of the household spending response to liquidity injections. One early example is Souleles (1999), who estimates that households spent 9% of their income tax refunds on nondurables within a quarter, but spent 64% of their refunds overall within the quarter. Similarly, Parker et al. (2013) estimate that households spent 12-30% of the 2008 fiscal stimulus on nondurable goods within the first three months, but spent 50-90% of the stimulus in total over the same period.[14] Kueng (2018) estimates that

[13] In our terminology, the MPC on nondurables and services equals the MPX on nondurables and services. However, the total MPC (which includes both nondurable and durable consumption flows) will not equal the total MPX (which includes both nondurable and durable expenditures).

[14] A recent reexamination by Orchard et al. (2022) building on the econometric insights of Borusyak et al. (2022) suggests that these estimates should be revised downward to a nondurable MPX of 6% and a total MPX of roughly 30%. Despite this downward adjustment to spending *levels*, the conclusion of Orchard et al. (2022) echoes our own that durable spending can compose a large *share* of the total spending response to fiscal stimulus.

households spent 25% of payments from the Alaska Permanent Fund on nondurables over the first three months, but 73% of the payment was spent in total over those three months. While not all studies find such a wedge between nondurable and total spending responses (e.g., Johnson et al., 2006; Parker et al., 2022), the literature is reviewed in Di Maggio et al. (2020b) who suggest that nondurable MPXs are typically estimated to be around 20% while estimates of total MPXs range from 60-80%. We also identify a similar wedge using the estimates underlying the meta-analysis of Havranek and Sokolova (2020), where we calculate a mean nondurable MPX of 28% and a mean total MPX of 70% (details in Section 4.3 below).

This empirical evidence that durables often compose a large part of the expenditure response to wealth shocks has two immediate implications for how model-based notional MPCs should be understood in relation to both total and nondurable MPXs. For total MPXs, this evidence suggests that notional MPCs are not the correct tool for understanding the total expenditure response to liquidity injections in many scenarios, as large up-front expenditure on durables translates only slowly into MPCs. For nondurable MPXs, this evidence implies that nondurable MPXs alone do not fully capture the total notional-consumption response to wealth shocks, because households also derive consumption from durable goods. We formalize and quantify this discussion in Section 4.2.

Additionally, linking MPCs and MPXs enables models of notional consumption to make predictions about a wider variety of empirical moments. This is especially important given the rise of administrative data on household balance-sheets, which sometimes enables researchers to impute the total expenditure response to wealth shocks, but may not allow for a decomposition of total expenditure into its nondurable and durable components (see e.g. the discussions in Fagereng et al. (2019a) and Crawley and Kuchler (2020), both of whom impute MPXs from administrative balance-sheet data).[15] Alternatively, data on household

[15] See also Baker et al. (2022) for a recent overview of the household finance literature that imputes consumption expenditure from administrative data. Similar decomposition issues can also arise in survey data. For example, as discussed in Jappelli and Pistaferri (2014), the frequently used Italian Survey of

spending is often only partial. Automobile-purchase data is a leading example of this, with credit-bureau data being used to understand the effect of shocks on automobile purchases (e.g., Agarwal et al., 2015; Di Maggio et al., 2017, 2020a). Another example is account-level data, which provides an accurate and high-frequency measure of a subset of consumer spending (e.g., Ganong and Noel, 2019; Ganong et al., 2021; Baker and Kueng, 2021), but may miss large durable purchases such as automobiles. In both cases, our modeling device can be used to convert these partial MPXs into partial MPCs, thus providing a lower bound on the underlying notional-consumption response.

Turning to policy considerations, differentiating MPXs from MPCs matters for understanding the impact of policy on economic output. Personal consumption expenditures (PCE) – the "consumption" component of GDP – is composed of consumer expenditures on durables, nondurables, and services. That is, PCE is a measure of expenditure; it is not a measure of the utility-generating notional consumption that is often modeled. Policy makers should have models that identify both MPXs and MPCs, and our MPX tool provides a tractable technology for mapping predictions about notional consumption into predictions about expenditure.

Though our modeling framework studies MPCs and MPXs in partial equilibrium, such partial-equilibrium expenditure responses are important inputs to fuller general-equilibrium analyses. We highlight two specific ways in which the distinction between MPCs and MPXs may be important. First, as discussed above, durable purchases compose an appreciable part of the expenditure response to liquidity injections: quarterly total MPXs are three to four times larger than quarterly nondurable MPXs. For important policy questions such as evaluating the magnitude of fiscal stimulus relative to the output gap, policy makers need predictions about the response of consumer expenditures, not just notional consumption.

Second, the timing of MPXs may differ from MPCs. In particular, expenditures will

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Household Income and Wealth (SHIW) asks how much consumers would spend following a positive liquidity injection, but does not separate spending into nondurables versus durables.

be more front-loaded than consumption if expenditures are used to purchase durables that provide long-lasting consumption flows.[16] Section 4.4 makes this point analytically, while Appendix E applies our MPX technology to the model of Laibson et al. (2021) and finds significant front-loading of MPXs relative to MPCs. This is consistent with the results in Kueng (2018), who documents front-loading of durable relative to nondurable expenditure.

Despite these observations highlighting the importance of understanding MPXs, we do not want to imply that economists should therefore overlook MPCs. From a normative perspective, notional consumption is a key construct because utility derives from consumption flows. More generally, which concept is more relevant depends on the question being asked, highlighting the value of a simple and tractable mapping between MPCs and MPXs.

3 The Household Balance Sheet

Here we develop our modeling device for mapping notional consumption into expenditure. We present this framework in continuous time for tractability and expositional simplicity. However, because many consumption-saving models are written in discrete time we also provide a version in discrete time. Our main discrete-time MPX results are presented in Section 4.2, with details provided in Appendix B.

We begin by summarizing our approach for building the MPX modeling device. In Section 3.1 we present a standard consumption-saving model with 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 specifically to: (i) be isomorphic to the Bench-

[16] One offsetting effect is that durables are more import-intensive than nondurables and services (Hale et al., 2019). Nonetheless, modeling such considerations still requires a decomposition of consumption into durable and nondurable components, which is the goal of our MPC-MPX mapping.

mark, and (ii) deliver a tractable MPX formula. The isomorphism implies that a researcher can take an existing model of notional consumption that makes predictions about MPCs and use a simple formula to calculate MPXs.

3.1 Benchmark: Single Notional Consumption Good

Let b_t and y_t denote a household's liquid wealth and income at time t. Income y_t can follow an arbitrary Markov process. Let r denote the interest rate on liquid wealth. The household's notional consumption flow is denoted c_t. The budget constraint is:

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

Households also face a borrowing constraint: $b_t \geq \underline{b}$.

The state variables of the notional-consumption model are $x_t = (b_t, y_t)$. We denote the consumption policy function by $c_t = c(x_t)$. We also 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. This cumulative flow will play an important role because the numerator of an MPC is the integral of marginal consumption over a discrete time interval.

For simplicity we only model a liquid asset, since this is the asset that is used to fund consumption. However, our results do not rely on the single-asset framework described here. Our modeling tool is portable and it applies in richer environments, including those with both liquid assets and illiquid assets such as housing. Further discussion is provided in Section 5.4, and Appendix E demonstrates this portability by applying our MPX tool to the model of Laibson et al. (2021), which includes liquid wealth, illiquid home equity, and a wedge between the interest rates on bank deposits and credit card debt.

3.2 Extension: An Isomorphic Model with Durables

To bridge the gap between consumption and expenditure, we now introduce an extended model featuring the purchase of durable goods (the model can also allow for rentals, as discussed in Section 5.3). The key feature of this extension is that durables are modeled such that the extended model with durables is isomorphic to the notional-consumption model in Section 3.1. The goal of our approach is to provide a simple and tractable method for connecting MPCs to MPXs. Our methodology is general and can be applied in a wide range of economic models.

Setup with Durables. The household can now consume two different goods: durables and nondurables. Let n_t denote nondurable consumption, which the household purchases as a flow. To consume durables, the household must purchase a stock of durables $D_t \geq 0$. Durable stock D_t should be thought of as an aggregated composite of many durable goods, and we provide a CES-based microfoundation in Appendix D.1.

Durable stock D_t provides durable consumption as a flow, and depreciates at rate δ satisfying $r + \delta > 0$. In keeping with our partial equilibrium analysis, the price of durables is exogenous and we normalize it to one. The household continues to save in liquid bank holdings, which we now denote by ℓ_t. Total wealth is given by $b_t = \ell_t + D_t$.

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

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

for some $s \in [0,1]$. In words, notional flow consumption expenditure c_t is the sum of nondurable flow consumption expenditure n_t and the implied rental cost (user cost) of durables $(r+\delta)D_t$, with the latter equaling a constant share s of the notional consumption flow. This can be justified 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 most important and indispensable 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 this assumption, the household's 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 so that D_t can jump discontinuously, we introduce process ψ_t to record the household's *cumulative* spending on durables from time 0 to time t, and denote by $d\psi_t$ the household's purchases of durables at time t.

Importantly, note the absence of adjustment costs in equations (4) and (5). This is a direct consequence of Assumption 1. Similarly, because Assumption 1 establishes that the household can borrow against durables, the borrowing constraint now applies to the household's total liquid wealth holdings $b_t = \ell_t + D_t$:

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

Given Assumption 1 we can work with only one state variable for household wealth, namely total liquid wealth $b_t = \ell_t + D_t$.[17] To this end, sum (4) and (5) as $d\ell_t + dD_t = [y_t + r\ell_t - n_t - \delta D_t]\, dt$, or

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

[17]Without Assumption 1 we would need to keep track of ℓ_t and D_t as separate state variables.

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

We next make two additional assumptions to obtain (3).

Assumption 2 *The household values total notional flow consumption, which is 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 the durable stock D_t, $s \in [0,1]$ is the utility weight on durable consumption, and $\eta > 0$ is the elasticity of substitution between durables and nondurables.

Given the CES functional form in equation (8) we obtain the following result:

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

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

where

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

The cost of attaining notional consumption flow c is

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

Our third and final Assumption completes the derivation of (3).

Assumption 3 *The utility 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 therefore also that the CES price index $P = 1$. Using this in equations (9) and (11) we obtain

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

which is the key result (3) we wanted to derive. To interpret Assumption 3, recall first that the purpose of our paper is to study the MPC and MPX over relatively short time horizons, typically a quarter or a year. Over such horizons, it is generally reasonable to hold the interest rate r and hence the user cost of durables $r + \delta$ constant (as we did above). With a fixed interest rate, the ratio of nondurables and durables in equation (9) and hence the price index P in equation (10) are constant over time and across households. Assumption 3 then simply sets this constant price index equal to one and is therefore a very weak assumption.

Even though this is not the focus of our paper, an interesting question is whether our isomorphism can be extended to other applications in which time variation in interest rates is key, such as monetary policy analysis. The answer is yes, but only if one is willing to impose a time-varying analogue of Assumption 3, $f_t = r_t + \delta$ for all t, which then implies a constant ratio of nondurables and durables even though their relative prices move, and a constant price index $P = 1$.[18] This discussion of Assumption 3 highlights that strong assumptions are needed to maintain a *generic* isomorphism between a notional-consumption model and a model with durables. Thus for some applications like monetary policy analysis, notional-consumption models may miss economically relevant effects related to the impact of interest rate changes on the user cost of durables. In such cases we recommend resorting to richer models of durables.[19]

[18] With a time-varying interest rate and *without* Assumption 3, our extension with durables would still be isomorphic to a notional-consumption model but one with a time-varying price of notional consumption. In particular, equation (12) in Proposition 1 would be $\dot{b}_t = y_t + r_t b_t - P_t c_t$ with a time-varying P_t given by (10). This time-varying price P_t arises because of movements in the user cost of durables that are caused by corresponding movements in the interest rate r_t. Because the standard notional-consumption model in Section 3.1 does not feature a time-varying price P_t, Assumption 3 is needed to ensure that it remains constant at $P_t = 1$. Is it worth noting that while Assumption 3 therefore shuts down economically meaningful mechanisms in cases where time variation in interest rates is key, it only shuts them down because such mechanisms are missing from the standard notional-consumption model.

[19] These sorts of issues are discussed, for example, in Auclert (2019) and McKay and Wieland (2019).

Isomorphism to Notional-Consumption Model. With Assumptions 1 to 3 in hand we are now ready to prove the isomorphism between the extension with durables and our benchmark notional-consumption model.

Proposition 1 *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). ■

Note that the extended model has exactly the same state variables $x_t = (b_t, y_t)$ as the notional-consumption model. Given the assumption of no adjustment costs, the stock of durables D_t instead becomes a control variable.

Cumulative Expenditure Flows. Analogous to the cumulative notional consumption flow in equation (2), we here define X_τ to be the cumulative *expenditure* over a period τ, which is the sum of cumulative expenditure on nondurables X_τ^n and durables X_τ^D:

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

The cumulative expenditure flow X_τ will be used to define the MPX. Looking at nondurable expenditure X_τ^n, from equation (3) we have

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

meaning that nondurable spending composes share $1 - s$ of total cumulative notional consumption. Next consider durable expenditure X_τ^D. Budget constraint (5) implies that

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

Equation (15) shows that expenditure on durables has two components. First, $D_\tau - D_0$ captures the household's spending to increase their durable stock from D_0 to D_τ. But this is an incomplete measure of durable spending, because some durables have depreciated over period τ and need to be replaced. Spending to replace depreciated durables is given by $\int_0^\tau \delta D_t dt$.

4 Results: The MPC and the MPX

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

4.1 Mapping MPCs into MPXs

We first define MPCs in the notional-consumption model and MPXs in the extended model, and then provide a mapping from the former to the latter using the modeling isomorphism.

First consider the MPC in the notional-consumption model of Section 3.1. The MPC is the fraction of income consumed out of a liquid-wealth windfall *over a discrete time interval*. It is therefore closely related to the cumulative notional consumption flow in equation (2). More precisely, denote a point in the state space by $x = (b, y)$.[20] The notional marginal propensity to consume (MPC) over a period of length τ for households with initial state

[20] In the notional-consumption model of Section 3.1, the state variables are liquid wealth b and income y. However, this is WLOG (e.g., the model can be extended to allow for illiquid assets).

$x_0 = x$ is then

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

i.e., the expected change in cumulative consumption given a change in liquid wealth (Achdou et al., 2021).

Next consider the MPX in the extended model of Section 3.2. The MPX is the fraction of income *spent* out of a liquidity injection over a discrete time interval. The MPX is closely related to the cumulative expenditure flow defined in equation (13). Again denote a point in the state space by $x = (b, y)$. The marginal propensity for expenditure (MPX) over a period of length τ for households with initial state $x_0 = x$ is[21]

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

i.e., the expected change in cumulative expenditure given a change in liquid wealth.

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

Proposition 2 (The Marginal Propensity for Expenditure) *The nondurable, durable, and total expenditure over a period τ defined in equation (13) satisfy $X^n_\tau = (1-s)C_\tau$, $X^D_\tau = \frac{\delta s}{r+\delta}C_\tau + D_\tau - D_0$, and $X_\tau = \left(1 - s + \frac{\delta s}{r+\delta}\right)C_\tau + D_\tau - D_0$, 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 consumption at time τ.*

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

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

The MPX in equation (18) has three components: (i) nondurable spending of $(1-s)MPC_\tau(x)$,

[21] Our notation $\int_0^\tau d\psi(x_t)$ represents cumulative durables spending over τ years as the household's state evolves from x_0 to x_τ. More precisely, normalizing the household's initial cumulative durables spending to $\psi_0 = \psi(x_0) = 0$, the notation means $\int_0^\tau d\psi_t = \psi_\tau = \psi(x_\tau)$ for a household with initial state x_0.

(ii) spending to replace depreciated durables of $\left(\frac{\delta s}{r+\delta}\right) MPC_\tau(x)$*, and (iii) spending to increase the durable stock at time* τ *of* $\frac{s}{r+\delta} \times \frac{\partial}{\partial b}\mathbb{E}\left[c(x_\tau) \mid x_0 = x\right]$*. These components follow from the nondurable and durable expenditures given in equations (14) and (15), respectively.*

Additionally, the MPX in equation (18) can be broken down into a nondurable MPX and a durable MPX:

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

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

so that $MPX_\tau(x) = MPX^n_\tau(x) + MPX^D_\tau(x)$*.*

Proof. See Appendix A.2. ■

Proposition 2 provides a simple and tractable formula for converting MPCs into MPXs.[22] Only two additional ingredients are needed: the change in expected notional consumption at time τ, and the new parameters s and δ. The former can be calculated numerically from the solution of the notional-consumption model alone by using the Feynman–Kac formula. The latter can be calibrated. Here, we use BEA data to calibrate durable share $s = 0.125$ and depreciation rate $\delta = 0.22$ (see Appendix C).

To gain further intuition for the total MPX, the assumption that $r \approx 0$ allows us to approximate equation (18) as follows:

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

[22] We could have also defined cumulative durable expenditure in equation (13) to include the interest payments that are sacrificed by holding durables, i.e., $X^D_\tau = \int_0^\tau d\psi_t + \int_0^\tau rD_t dt$. In this case, the MPX simplifies even further:

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

Since r is typically small, this alternative definition of the MPX will be quantitively similar to equation (18).

This approximation highlights two important properties of the MPX in relation to the MPC. First, the MPX will typically be greater than the MPC. Second, the wedge between the MPX and the MPC at any future time τ depends on the expected change in consumption at that time, $\frac{\partial}{\partial b}\mathbb{E}\left[c(x_\tau) \mid x_0 = x\right]$, which generally decreases and converges toward zero as the time horizon increases. Hence, the MPC and the MPX will steadily converge over time. Both properties are intuitive, and follow from the fact that durable expenditure is front-loaded relative to durable consumption. The dynamic relationship between the MPC and the MPX is explored further in Section 4.4 below.

We emphasize that the MPX may take values far larger than one. In our extended model, the ability for consumers to borrow against durables allows for them to turn liquidity injections into larger durable purchases. Empirically, we also see evidence of expenditures exceeding liquidity 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 sharply following minimum wage hikes, and Fagereng et al. (2019a) estimate MPXs above 1 for small lottery winnings.

This section defines the MPC and the MPX out of an infinitesimal increase in liquid wealth. However, tax rebates and fiscal stimulus payments increase liquid wealth discretely. The definition of the MPC and the MPX are easily extended to discrete liquidity injections. See Appendix D.2 for details.

Finally, equations (19) and (20) show how to map the notional MPC into separate non-durable and durable MPXs. This can be useful because empirical studies often report decomposed MPX estimates. Section 4.3 discusses some examples.

4.2 Discrete-Time Specification

Our MPX result in equation (18) is derived in a continuous-time model. Since many consumption-saving models are written in discrete time, Proposition 7 in Appendix B provides a discrete-time version of our MPX result. Though the discrete-time version is less tractable, the discrete-time MPX takes on a particularly simple form when studied over the first period after a shock, which we present below.

Assume that we have a discrete-time notional-consumption model with a given period length, say one quarter or one year. Denote by r and δ the interest rate and durable depreciation rate over that discrete time period. This is a slight abuse of notation because these discrete-time rates differ slightly from the instantaneous continuous-time rates in the preceding sections. Similarly 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). With this notation we have:

Proposition 3 (The One-Period Marginal Propensity for Expenditure) *The discrete-time MPX over one period is simply:*

$$MPX_1(x) = \left(1 - s + \frac{s}{r+\delta}\right) MPC_1(x). \tag{21}$$

Analogously to Proposition 2, the one-period MPX in equation (21) can be broken down into one-period nondurable and durable MPXs:

$$MPX_1^n(x) = (1-s) MPC_1(x), \tag{22}$$

$$MPX_1^D(x) = \left(\frac{s}{r+\delta}\right) MPC_1(x), \tag{23}$$

so that $MPX_1(x) = MPX_1^n(x) + MPX_1^D(x)$.

Proof. See Appendix B. ■

Proposition 3 shows how to map notional MPCs into total, nondurable, and durable MPXs. Returning to the discussion in Section 2, we can use these mappings to clarify how empirical estimates of both nondurable and total spending should be interpreted in relation to models of notional consumption.

Starting with nondurable MPXs, a common approach for calibrating notional-consumption models is to set the notional MPC to match an empirical estimate of the nondurable MPX. While this is a reasonable approximation, equation (22) shows that nondurable MPXs are not quite the correct target. Instead, nondurable MPXs provide a lower bound on notional MPCs. Specifically, equation (22) implies that nondurable MPXs should be multiplied by $\frac{1}{1-s}$ to recover the appropriate MPC-target for calibrating notional-consumption models. Using our durable-share calibration of $s = 0.125$, notional MPCs exceed nondurable MPXs by roughly 15%.[23]

Turning to the total MPX implied by notional-consumption responses, equation (21) 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.[24] A key portability benefit of this mapping from MPCs to MPXs is that it involves no additional modeling, because the durable share s and the depreciation rate δ are empirical objects that can be calibrated, for example, by using BEA data (see Appendix C).

We highlight the power of this simple formula for the standard case of discrete-time models written at a quarterly frequency. In Appendix C we calibrate durable share $s = 0.125$ and quarterly durable depreciation rate $\delta = 0.054$. For small quarterly interest rates $r \approx 0$, this means $\left(1 - s + \frac{s}{r+\delta}\right) \approx 3$. Thus, equation (21) provides a very simple rule-of-thumb for converting quarterly MPCs into quarterly MPXs:

Remark 4 (The "MPC Times 3" Rule-of-Thumb) *The one-quarter MPX is roughly three times the one-quarter MPC.*

An important 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

[23] See Borusyak et al. (2022) for an illuminating application of this result.

[24] The one-period discrete-time MPX in equation (21) is comparable to the continuous-time MPX in equation (18), with the main difference being that the discrete-time MPX is "missing" the durable depreciation component in equation (18) of $\frac{\delta s}{r+\delta} MPC_\tau(x)$. This term reappears in discrete-time MPXs over longer horizons (see Proposition 7 in Appendix B), but it doesn't affect the one-period MPX since durable depreciation doesn't occur until the period after durables are purchased.

expenditure response to liquidity injections. For example, if a household has a quarterly MPC of 15%, this can easily be consistent with that household *spending* 45% of its liquidity injection within the quarter. This is not a critique of notional-consumption models. Rather, our rule-of-thumb simply quantifies the well-known fact that notional consumption is a different concept than expenditure, and researchers should keep this quantitative difference in mind when interpreting the predictions of notional-consumption models.

4.3 Taking the MPX Mapping to the Data

Our rule-of-thumb in Remark 4 is derived using only our extended model with durables and our calibration of the durable consumption share and depreciation rate. Hence, a good validation exercise is to study the extent to which our MPX mapping holds in the data.

Using equations (21) and (22) from our one-period MPX, we find that the total MPX is $\left(1 + \frac{s}{(r+\delta)(1-s)}\right)$ times the nondurable MPX, or 3.6 in our quarterly calibration. This mapping performs well empirically, as summarized in Table 1 below.

Panel A of Table 1 presents selected individual studies that estimate both the nondurable and the total quarterly MPX, as reviewed in Section 2 above. Panel B then looks across the literature estimating nondurable and total MPXs, using the estimates underlying the meta-analysis of Havranek and Sokolova (2020). Our calculations here follow a similar exercise by Ganong et al. (2020).[25] Specifically, the Havranek and Sokolova (2020) meta-analysis includes 178 estimates of the quarterly nondurable MPX and 71 estimates of the quarterly total MPX. Of these estimates, the mean nondurable MPX is 28% and the mean total MPX is 70%. Similarly, the median nondurable and total MPXs are 23% and 70%, respectively.[26]

[25] We thank the authors of Ganong et al. (2020) for sharing their analysis with us.

[26] Havranek and Sokolova (2020) also emphasize that published MPX estimates are likely to be biased upward due to negative MPX estimates being underreported. For example, Havranek and Sokolova (2020) report in their Table 3 that adjusting for publication bias results in a mean pooled MPX estimate of 11%. Decomposing this pooled estimate in Table 4, Havranek and Sokolova (2020) also report that MPXs are 18 percentage points larger for total consumption than for nondurables alone. So, similar to our discussion in footnote 14, while accounting for publication bias would likely lower the MPX *levels* that we report in Table 1, Havranek and Sokolova (2020) continue to find that durable spending composes a large *share* of the total

Overall, the evidence in both panels of Table 1 is broadly consistent with our calibrated mapping that the quarterly total MPX is 3.6-times the quarterly nondurable MPX.

Citation	Nondurable MPX	Total MPX
Panel A: Selected Studies		
Souleles (1999)	9%	64%
Parker et al. (2013)	12-30%	50-90%
Kueng (2018)	25%	73%
Parker et al. (2022)[27]	$\leq$ 16%	$\leq$ 23%
Orchard et al. (2022)	6%	30%
Panel B: Havranek and Sokolova (2020) Meta-Analysis		
Mean of Underlying Estimates	28%	70%
Median of Underlying Estimates	23%	70%

Table 1: Empirical Estimates of Quarterly Nondurable and Total MPXs

Notes: This table presents selected empirical estimates of quarterly nondurable MPXs and total MPXs. Panel A looks at specific studies that estimate both measures. Panel B uses the meta-analysis of Havranek and Sokolova (2020) to look across empirical estimates. See text for details.

4.4 The Timing of MPCs and MPXs

Having validated that our MPX modeling tool fits the available data relatively well at quarterly horizons, we now apply our mapping to examine the dynamic relationship between MPCs and MPXs over longer horizons.

To do so, we make the following two simplifying approximations. First, we set $r \approx 0$. Second, 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 the MPC in equation (16) can be approximated as $MPC_\tau(x) \approx \tau \times \frac{\partial}{\partial b}\mathbb{E}\left[c(x_\tau) \mid x_0 = x\right]$. To highlight how the MPC and the MPX dynamically relate to one another, we use these two approximations

spending response to wealth shocks.

[27] Parker et al. (2022) study the first round of Economic Impact Payments disbursed in the spring of 2020. They estimate a statistically insignificant total MPX of 8% (s.e. 7.5%), and argue that the estimate is "still informative as the upper bound of the 95% confidence interval for the MP[X] on total expenditures is 22.8%. (p. 21)" Parker et al. (2022) also estimate a nondurable MPX of 10% (s.e. 3.4%), and report an upper bound on the 95% confidence interval for the nondurable MPX of 16% (p. 1).

to rewrite equation (18) as follows:[28]

$$MPX_\tau(x) \approx \left(1 + \frac{s}{\delta} \times \frac{1}{\tau}\right) MPC_\tau(x). \tag{24}$$

In this approximation, the term $1 \times MPC_\tau(x)$ captures both nondurable spending and spending to replace depreciated durables, while $\frac{s}{\delta} \times \frac{MPC_\tau(x)}{\tau}$ captures spending to increase the durable stock over period τ (i.e., $D_\tau - D_0$). Over short horizons the $\frac{1}{\tau}$ will dominate and therefore MPX $\gg$ MPC, meaning that over short horizons the MPX is driven mainly by initial spending on durables. This property that MPXs are more front-loaded than MPCs is intuitive: durable expenditure is lumpy and happens quickly after a liquidity injection, whereas the consumption flows provided by these durables takes time to cumulate. Over longer horizons, as τ increases and consumption flows are steadily cumulated from the initial durable expenditure, the MPC and the MPX converge.

We can use approximation (24) to extend our quarterly "MPC times 3" rule-of-thumb in Remark 4 to longer horizons. To do so, we first rewrite approximation (24) in a different form to provide further intuition:

$$\frac{MPX_\tau(x) - MPC_\tau(x)}{MPC_\tau(x)} \approx \frac{s}{\delta} \times \frac{1}{\tau}.$$

The lefthand side of this approximation is the percent difference between the MPX and the MPC, and this gap is inversely related to the time-horizon τ over which the MPC and the MPX are being examined. In our continuous-time calibration we set $s = 0.125$ and depreciation rate $\delta = 0.22$. Our quarterly rule-of-thumb can then be extended to longer horizons, as presented in Table 2 below.

The results in Table 2 illustrate two important properties about MPCs and MPXs. First, the horizon over which these quantities are measured is important. This is perhaps an obvious point, though we mention it because we have observed this point being glossed over by other

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

Time Horizon	Extended Rule-of-Thumb
1 Quarter	$MPX_{\frac{1}{4}} \approx 3 \times MPC_{\frac{1}{4}}$
2 Quarters	$MPX_{\frac{1}{2}} \approx 2 \times MPC_{\frac{1}{2}}$
1 Year	$MPX_1 \approx 1.5 \times MPC_1$
2 Years	$MPX_2 \approx 1.25 \times MPC_2$
5 Years	$MPX_5 \approx 1.1 \times MPC_5$

Table 2: Dynamic Relationship Between MPCs and MPXs

Notes: This table calibrates $s = 0.125$ and $\delta = 0.22$, and uses approximation (24) to examine the horizon-dependent relationship between MPCs and MPXs.

papers in the literature. Our theoretical definitions of the notional MPC in equation (16) and the MPX in equation (17) highlight that these are cumulative measures of consumption and spending. As such, economic theory suggests that it is not generally admissible to compare MPCs or MPXs across differing horizons.[29]

Second, a key point of emphasis in this paper is that it is important to draw a distinction between MPCs and MPXs. The approximations in Table 2 refine this point by highlighting that the difference is likely to matter more over short horizons than over long horizons. Over long horizons, the MPC and the MPX converge as the household's stock of durables steadily translates into cumulated consumption flows. We return to this point, and discuss its implications for policy, in Section 5.2 below.

5 Discussion

5.1 Discussion of MPX Shortcomings

To generate a tractable model with durables that is isomorphic to the notional-consumption model, we needed to make three strong assumptions that explicitly relate notional consumption to expenditure. The resulting mapping from MPCs to MPXs is unlikely to provide an

[29] For example, if one study estimates a quarterly nondurable MPX of 25%, this estimate should not be viewed as comparable to another study that estimates an annual nondurable MPX of 25%.

accurate description of reality when the three assumptions in Section 3.2 fail to hold. When such failures occur, 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. A contribution of our isomorphism result 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.

We outline two sets of scenarios where our mapping likely fails: interest rate shocks or relative price shocks (where Assumption 3 is problematic), and negative liquidity injections (where Assumption 1 is problematic). We therefore recommend that our MPX formula be used to study the expenditure response to positive liquidity injections, holding constant interest rates and the relative prices of durables and nondurables. However, our MPX formula can be generalized so that it performs more accurately in cases of large adjustment frictions where Assumption 1 is problematic, which we discuss below in Section 5.2.

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.[30] 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

[30] Auclert (2019) and McKay and Wieland (2019, 2022) provide richer models detailing the channels through which durable spending is affected by interest rate changes.

MPCs and MPXs. On the one hand, an increase in the relative price of consumer durables following a positive wealth shock functions like an adjustment friction – the handling of which we discuss below in Section 5.2 – in the sense that it hinders households' ability to increase their consumption of durables. On the other hand, durable price movements may also lead to revaluation effects for the durables that households already own. These sorts of durable-driven wealth shocks are not captured by notional-consumption models, and are harder to fit within our framework to the extent that they are economically impactful.[31]

On negative liquidity injections, Berger and Vavra (2015) find that the durable response to liquidity injections is asymmetric. Households buy durables in response to positive liquidity injections, but wait for durables to depreciate in response to negative liquidity injections. In our MPX formula (equation (18)), the expenditure response to positive and negative liquidity injections is symmetric. However, we show in Section 5.2 that our MPX formula can be generalized so that it performs more accurately in these scenarios.

More broadly, the purchase and sale of durable goods is subject to various adjustment frictions, which we have heretofore omitted through Assumption 1. Potential durable adjustment frictions include financial adjustment costs (e.g., Bernanke, 1985; Caballero, 1993), procrastination (e.g., Laibson et al., 2021),[32] credit market search frictions (e.g., Agarwal et al., 2020; Argyle et al., 2020), and financial frictions that limit consumers' ability to finance durables (e.g., Benmelech et al., 2017; Green et al., 2020). We will show below that our MPX technology can be modified to account for adjustment frictions in reduced form.

[31] 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).

[32] Procrastination may also change the composition of purchased durables, since 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 new sports car.

5.2 Accounting for Adjustment Frictions in Reduced Form

The key idea in this subsection is to represent durable adjustment frictions as time variation in the durable share s. For example, Berger and Vavra (2015) argue that after a negative liquidity injection, adjustment frictions will result in households letting durables depreciate rather than immediately being sold. This results in a durable share that rises on impact and then slowly reverts back to its normal level as durables depreciate. We capture such behavior (in reduced form) by letting the preference parameter s in the CES aggregator (8) vary over time. Though our modeling device provides no guidance on how durable share s should vary over time, this added flexibility allows the researcher to feed in alternate time-paths for the durable share.[33]

Generalizing the MPX formula to allow for a time-varying durable share, we now have:

Corollary 5 (The MPX with a Time-Varying Durable Share) *Let s_t denote the time-t durable share. The Marginal Propensity for Expenditure over τ years is given by:*

$$MPX_\tau(x) = \frac{\partial}{\partial b}\mathbb{E}\left[\int_0^\tau \left(1 - s_t + \frac{\delta s_t}{r+\delta}\right) c(x_t)dt \;\middle|\; x_0 = x\right] + \frac{1}{r+\delta} \times \frac{\partial}{\partial b}\mathbb{E}\left[s_\tau c(x_\tau) \mid x_0 = x\right]. \tag{25}$$

When $r \approx 0$ the MPX in equation (25) is simply:

$$MPX_\tau(x) \approx MPC_\tau(x) + \frac{1}{\delta} \times \frac{\partial}{\partial b}\mathbb{E}\left[s_\tau c(x_\tau) \mid x_0 = x\right],$$

and this approximation is exact when $r = 0$.

Proof. See Appendix A.3. ■

The MPX with a time-varying durable share in equation (25) allows for an analysis of

[33] By representing adjustment frictions as time variation in durable share s, we are implicitly assuming that the overall basket of durable goods remains constant. If adjustment frictions only affect certain types of durables, then the aggregated durable depreciation rate δ may also need to be altered to account for changes to the basket of durables being purchased. See Appendix D.1 for details.

how household expenditures change due to durable adjustment frictions.[34] First, consider a negative liquidity injection, which households respond to by letting durables depreciate (Berger and Vavra, 2015). In this case, durable share s_t temporarily rises following the negative liquidity shock, which reduces the extent to which expenditure drops in the short-run. Alternatively, households might be slow to increase durable purchases following a positive liquidity injection, due possibly to adjustment costs or procrastination. In this case, durable share s_t temporarily falls before slowly returning to its typical level, causing the MPX to increase less quickly at first. Third, financing constraints may cause durable share s_t to depend on the size of a liquidity injection (see e.g. Parker et al. (2013), Zorzi (2020), and Fuster et al. (2021) for discussions related to such composition effects).

Durable Frictions Can Slow the Transmission of Fiscal Policy. We end by using our reduced-form mapping from MPCs to MPXs to identify an important policy implication of durable adjustment frictions — adjustment frictions can slow down the transmission speed of fiscal policy. To show this effect, we first generalize our approximation in equation (24) to allow for a time-varying durable share, as follows:[35]

$$MPX_\tau(x) \approx \left(1 + \frac{s_\tau}{\delta} \times \frac{1}{\tau}\right) MPC_\tau(x).$$

This generalized approximation illustrates that adjustment frictions that temporarily lower s_τ will have the effect of slowing down the speed at which notional consumption translates into expenditure, thereby limiting the short-run effectiveness of fiscal policy.[36]

To give an illustration that applies this reduced-form approach and shows the implications of durable frictions for policy, assume for example that at the time of receiving a

[34] Though the generalized MPX in equation (25) takes on a more complicated form than the baseline MPX in equation (18), the same numerical methods can be used to calculate either equation in a notional-consumption model.

[35] To further simplify this approximation we assume that the time-varying durable share s_τ is deterministic.

[36] We again emphasize that this discussion focuses on the partial-equilibrium response of households, and should be viewed as an input to fuller general-equilibrium analyses (e.g., Orchard et al., 2022).

positive wealth shock, households face some friction (such as a microchip shortage) that prevents them from purchasing automobiles over the following quarter. Since automobiles represent roughly one-third of consumer durable spending, substitution away from automobiles into nondurables would decrease the calibrated durable share from 12.5% to 8% while the depreciation rate would remain roughly unchanged. Plugging this updated calibration into equation (21) implies that the quarterly MPX decreases from 3.2-times the quarterly MPC to 2.5-times the quarterly MPC, thereby reducing the extent to which any path of notional consumption translates into quarterly expenditure.[37]

5.3 Rented Durables

To this point, we have assumed for simplicity that durables are owned by consumers, though 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.

5.4 Housing and Other Illiquid Assets

MPXs versus Housing Expenditures. Throughout this paper we define durables as consumer durable goods. Housing is not included in the basket of consumer durable goods. Accordingly, our calibration in Appendix C excludes housing expenditures, and our calibrated mapping from MPCs to MPXs is not intended to capture housing adjustments. As

[37] Calibration details are provided in Appendix C. By assigning all consumption that is substituted away from automobiles into nondurables, this example provides a lower bound on how automobile frictions affect the quarterly MPX in our reduced-form mapping.

we discuss here, we exclude housing expenditures for three reasons.

The first and most important reason that we exclude (major) housing adjustments is so that our mapping is consistent with the empirical literature estimating MPXs (see e.g. Table 1). For example, the Consumer Expenditure Survey does not measure home purchases.[38] Relatedly, construction of new housing and major improvements to existing housing are counted as residential investment by the BEA, not personal consumption expenditure. Similarly, imputed-consumption measures often exclude housing investments from consumption expenditures (e.g., Koijen et al., 2014).

The second reason for excluding housing adjustments relates to supply-side considerations. Major housing investments take time to plan, to navigate permitting processes, and finally to build. Hence, residential investment will be less likely to adjust over the shorter horizons at which we study MPCs and MPXs. Alternatively, consumer durables still account for other inputs to housing quality that are more easily adjusted, such as home furnishings and durable household equipment.[39]

Third, for researchers who are interested in studying housing-adjustment dynamics in specialized models of illiquid housing (e.g., Berger et al., 2018; Chen et al., 2020; Kaplan et al., 2020), a benefit of our portable MPC-MPX mapping is that it can be extended to these sorts of environments. For example, consider a model of illiquid housing in which utility is accrued from a combination of housing services and non-housing notional consumption. In this case, our mapping from MPCs to MPXs provides a mapping from non-housing notional consumption to expenditure on nondurables and consumer durables. We discuss this further below.

MPCs and MPXs out of Housing Wealth. Given that our benchmark notional-consumption model only has a single liquid asset, equations (16) and (17) define the MPC

[38]It may also miss some expenses associated with major home renovations.

[39]This discussion focuses on new residential investment because, from a general-equilibrium perspective, sales of existing housing is merely a shuffling of existing durables and not investment in new durables.

and the MPX as responses to liquid wealth injections. However, in a model with multiple types of assets, the MPC and the MPX can correspondingly be defined relative to changes in any of those assets.

As discussed above, our mapping from MPCs to MPXs readily extends to richer models with liquid and illiquid assets. In these models, our mapping from MPCs to MPXs can be applied not only to liquid wealth injections, but also to illiquid wealth injections such as housing wealth shocks. Indeed, one can use exactly the same calibration to map a model-implied MPC out of housing wealth into an MPX out of housing wealth. This relates our mapping to empirical analyses of the spending response to house price changes, estimated for example in Campbell and Cocco (2007), Carroll et al. (2011), and Mian et al. (2013), and reviewed in Cloyne et al. (2019).

6 Conclusion

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

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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

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

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

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

$$X_\tau = X^n_\tau + X^D_\tau = \int_0^\tau n_t dt + \int_0^\tau \delta D_t dt + D_\tau - D_0. \tag{26}$$

Next, from (3) we have

$$D_\tau = \frac{s}{r+\delta} c_\tau. \tag{27}$$

Intuitively, generating a notional consumption flow c_τ at time τ requires holding a durable stock D_τ defined by equation (27). 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 (27) and (2) in equation (15) yields the expressions 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

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

where the second equality uses equation (27). This is equation (18) in the Proposition.■

A.3 Proof of Corollary 5: The MPX with a Time-Varying Durable Share

To capture time variation in the durable share, we now allow the preference parameter s in the CES aggregator (8) to vary over time. We denote this time-varying durable share by s_t. With this time-varying durable share, equation (3) becomes

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

The rest of the proof follows similar steps as the proof of Proposition 2 simply replacing s by s_t. In particular, the MPX defined in equation (17) becomes:

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

where the second equality uses equation (3′) that $D_t = \frac{s_t}{r+\delta}c_t$. This is equation (25) in the Corollary.■

Internet Appendix

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. In particular it provides the derivations for Section 4.2 in the main text and proves Proposition 3. Our discrete-time construction is similar to the continuous-time construction presented in Section 3, and we leave many details to that section.

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:

$$b_t = (1+r)b_{t-1} + y_t - c_t, \tag{28}$$

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

$$C_\tau = \sum_{t=0}^{\tau-1} c_t \tag{29}$$

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 Section B.1. See Abel (1990) and Auclert et al. (2018) for related comparisons of discrete-time notional-consumption models to models with both nondurables and durables.

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 satisfying $r + \delta > 0$. The household continues to save in liquid bank holdings, which we denote 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 slightly 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

$$\ell_t = (1 + r)(\ell_{t-1} - \varphi_t) + y_t - n_t, \tag{30}$$

$$D_t = (1 - \delta)D_{t-1} + \varphi_t, \tag{31}$$

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 (30) and (31) 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 $\frac{r+\delta}{1+r}$.[40]

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

$$\ell_t + (1 - \delta)D_t \geq \underline{b}. \tag{32}$$

Given Assumption 1 we can work with only one state variable for household wealth, namely total liquid wealth $b_t = \ell_t + (1 - \delta)D_t$. To this end, use (30) and (31) to sum $\ell_t + (1 - \delta)D_t$, which gives

$$\begin{aligned} b_t &= (1 + r)(\ell_{t-1} - \varphi_t) + y_t - n_t + (1 - \delta)D_t \\ &= (1 + r)((b_{t-1} - (1 - \delta)D_{t-1}) - \varphi_t) + y_t - n_t + (1 - \delta)D_t \\ &= (1 + r)(b_{t-1} - D_t) + y_t - n_t + (1 - \delta)D_t \\ &= (1 + r)b_{t-1} + y_t - n_t - (r + \delta)D_t. \end{aligned} \tag{33}$$

A key implication of Assumption 1 is therefore that a relevant measure of the household's 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

$$n_t = (1 - s) \times c_t, \qquad (r + \delta)D_t = s \times c_t, \quad \text{and} \quad n_t + (r + \delta)D_t = c_t. \tag{34}$$

[40]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 are now ready to prove the isomorphism between the extension with durables and our benchmark notional-consumption model.

Proposition 6 *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*

$$b_t = (1+r)b_{t-1} + y_t - c_t, \tag{35}$$

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 (28).

Proof. Assumption 1 implies that equation (33) holds. Assumptions 2 and 3 imply that equation (34) holds. Substituting (34) into (33) yields equation (35). ■

Note that the extended model has exactly the same state variables $x_t = (b_{t-1}, y_t)$ as the notional-consumption model.

Cumulative Expenditure Flows. Analogous to the cumulative notional consumption flow in equation (29), we here define X_τ to be the cumulative *expenditure* over a period τ, which is the sum of cumulative expenditure on nondurables X_τ^n and durables X_τ^D:

$$X_\tau = X_\tau^n + X_\tau^D, \quad \text{where} \quad X_\tau^n = \sum_{t=0}^{\tau-1} n_t \quad \text{and} \quad X_\tau^D = \sum_{t=0}^{\tau-1} \varphi_t. \tag{36}$$

The cumulative expenditure flow X_τ will form the basis for defining the MPX below.

B.3 Results: The MPC and the 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 Section B.1. The MPC is closely related to the cumulative notional consumption flow in equation (29). More precisely, the notional marginal propensity to consume (MPC) over τ periods for households with initial state $x_0 = x$ is then

$$MPC_\tau(x) = \frac{\partial}{\partial b}\mathbb{E}\left[\sum_{t=0}^{\tau-1} c(x_t) \;\middle|\; x_0 = x\right]. \tag{37}$$

Next consider the discrete-time MPX in the extended model of Section B.2. The MPX is closely related to the cumulative expenditure flow defined in equation (36). The marginal propensity for expenditure (MPX) over τ periods for households with initial state $x_0 = x$ is

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

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

Proposition 7 (The Discrete-Time Marginal Propensity for Expenditure) *The discrete-time Marginal Propensity for Expenditure (MPX) over τ periods is given by:*

$$MPX_\tau(x) = (1-s)MPC_\tau(x) + \frac{\delta s}{r+\delta}MPC_{\tau-1}(x) + \frac{s}{r+\delta} \times \frac{\partial}{\partial b}\mathbb{E}\left[c(x_{\tau-1}) \mid x_0 = x\right]. \tag{39}$$

Similar to equation (18), the discrete-time MPX in equation (39) 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).

When $\tau = 1$, the equation simplifies to $MPX_1(x) = \left(1 - s + \frac{s}{r+\delta}\right) MPC_1(x)$, exactly as in equation (21). Additionally, the MPX in equation (39) can be broken down into a *nondurable MPX and a durable MPX:*

$$MPX^n_\tau(x) = (1-s)MPC_\tau(x), \tag{40}$$
$$MPX^D_\tau(x) = \frac{\delta s}{r+\delta} MPC_{\tau-1}(x) + \frac{s}{r+\delta} \times \frac{\partial}{\partial b} \mathbb{E}\left[c(x_{\tau-1}) \mid x_0 = x\right], \tag{41}$$

so that $MPX_\tau(x) = MPX^n_\tau(x) + MPX^D_\tau(x)$.

Proof. See Appendix B.4. ■

B.4 Proof of Proposition 7

First consider nondurable expenditure X^n_τ defined in equation (36). From equation (34) we have

$$X^n_\tau = (1-s)\sum_{t=0}^{\tau-1} c_t. \tag{42}$$

Next consider durable expenditure X^D_τ defined in equation (36). Using the property from budget constraint (31) that $\varphi_t = D_t - (1-\delta)D_{t-1}$, we have

$$\begin{aligned} X^D_\tau &= \sum_{t=0}^{\tau-1} \varphi_t \\ &= D_{\tau-1} - (1-\delta)D_{-1} + \sum_{t=0}^{\tau-2} \delta D_t. \end{aligned} \tag{43}$$

Therefore the total expenditure on both nondurables and durables defined in equation (36) is given by

$$X_\tau = X^n_\tau + X^D_\tau = (1-s)\sum_{t=0}^{\tau-1} c_t + \sum_{t=0}^{\tau-2} \delta D_t + D_{\tau-1} - (1-\delta)D_{-1}. \tag{44}$$

Finally, from (34) we have

$$D_t = \frac{s}{r+\delta} c_t. \tag{45}$$

Next consider the MPX defined in equation (38). Using equations (36) and (44) in the definition of the MPX in (38) we have

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

where equation (45) is used to go from the second to the third line. This is equation (39) in the Proposition. In the case of $\tau = 1$ (the one-period MPX), the second term drops out and the formula becomes simply $MPX_1(x) = \left(1 - s + \frac{s}{r+\delta}\right) MPC_1(x)$.

C Calibration: Durable Share and Depreciation Rate

We need to calibrate two parameters: durable depreciation rate δ and durable share s. As discussed in Section 5.4, our calibration excludes housing and focuses on consumer durables.

Baseline Calibration. We calibrate the durable depreciation rate from the 2016 BEA Fixed Assets Accounts Tables.[41] Table 1.1 reports a consumer durables stock of \$5,162.5 billion. Table 1.3 reports depreciation over the year of \$1,025.5 billion. This implies a discrete-time yearly depreciation rate of $\frac{1025.5}{5162.5} = 0.199$ and a continuous-time depreciation rate of $\delta = -\log\left(1 - \frac{1025.5}{5162.5}\right) = 0.22$. This calibration means that durables have a half-life of 3.15 years. For Section 4.2 we also calibrate a *quarterly* (rather than yearly) depreciation rate by mapping the yearly depreciation rate 0.199 into its quarterly counterpart

[41] 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 Laibson et al. (2021) who calibrate their model using 2016 data.

$1-(1-0.199)^{1/4}=0.054$.

To calibrate durable share s, we use the 2016 NIPA data. The 2016 NIPA Report (Table 2.4.5) documents that total household consumption expenditures (in billions) are \$12,693.3. This is composed of durable goods of \$1,345.2, nondurable goods of \$2,646.7, and services of \$8,701.4. From services we subtract the rent of tenant-occupied housing and the imputed rent of owner-occupied housing (\$1,964.8) in order to exclude marginal housing adjustments.

Assuming that households are in a static steady state, all durable expenditures are made to offset depreciation.[42] Thus, $\delta D = 1345.2$. Assuming $r = 0$ for simplicity, the restriction that $f \equiv \delta$ implies that a household's total durable expenditures of $\delta D_t = f D_t = s c_t$. We also have $n_t = (1-s)c_t$. Letting both nondurable goods and services compose "nondurables", we have $n_t = 2646.7+(8701.4-1964.8) = 9383.3$. Total consumption is given by $c_t = \delta D + n_t = 1345.2 + 9383.3 = 10728.5$. Now, the durable share can be imputed from $\frac{\delta D}{c_t}$:

$$s = \frac{1345.2}{10728.5} = 0.125.$$

Alternate Calibration Without Automobiles. As discussed in Section 5.2, for illustrative purposes we also briefly consider a calibration in which automobile expenditures are assumed to not adjust following a liquidity injection.

To calibrate the depreciation rate of consumer durables excluding automobiles, Table 8.1 of the 2016 BEA Fixed Assets Accounts Tables reports a consumer durables stock of \$5,162.5 billion, of which \$1,566.7 billion is attributed to motor vehicles and parts. Table 8.4 reports depreciation of \$1,025.5 billion, of which \$335.9 billion is attributed to motor vehicles and parts. This implies a discrete-time yearly depreciation rate of $\frac{1025.5-335.9}{5162.5-1566.7} = 0.192$ and a continuous-time depreciation rate of 0.21. The corresponding quarterly depreciation rate is 0.052. These depreciation rates are all comparable to the baseline calibration with automobiles detailed above.

[42] This assumption allows us to convert durable expenditures into durable consumption. It is also not too far off: total durable spending is 1,345.2, while depreciation is 1,025.5.

To calibrate the durable share excluding automobiles, the 2016 NIPA Report (Table 2.4.5) documents that total household consumption expenditures (in billions) on durable goods are \$1,345.2, with \$484.3 coming from motor vehicles and parts. Following a similar strategy as our baseline calibration except that automobile spending is now allocated to nondurables gives a non-automobile durable share of $s = \frac{1345.2-484.3}{10728.5} = 0.080$.

D Additional Generalizations and Extensions

D.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 is defined by the depreciation of each variety, $\delta D_t = \sum_{v\in V} \delta_v D_{v,t}$.

To build a simple microfoundation, we assume that the household values durable consumption flows using a CES aggregator:

$$fD_t = \left(\sum_{v\in V} s_v^{\frac{1}{\eta_D}} \left(f_v D_{v,t}\right)^{\frac{\eta_D - 1}{\eta_D}} \right)^{\frac{\eta_D}{\eta_D - 1}}, \tag{46}$$

where fD_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 this CES functional form we obtain the following result:

Lemma 2 *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 given by*

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

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 fD_t is

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

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 (46). Equivalently, defining $d_v := f_v D_v$ for each variety v, the household solves

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

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

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

■

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

Assumption 4 (Extending Assumption 3) *For each durable variety v, the utility flow per unit of durable f_v equals its user cost, $f_v = r + \delta_v$.*

With Assumption 4 we see from Lemma 2 that $R_v = 1$ for each variety v, and therefore also that the CES durable price index $P_D = 1$. Using this in Lemma 2, the cost of attaining aggregate durable consumption flow fD_t is:

$$\sum_{v \in V}(r + \delta_v)D_{v,t} = \sum_{v \in V} rD_{v,t} + \sum_{v \in V} \delta_v D_{v,t}$$
$$= (r + \delta)D_t,$$

where the last line uses the properties that $D_t = \sum_{v \in V} D_{v,t}$ and $\delta D_t = \sum_{v \in V} \delta_v D_{v,t}$. Thus, by imposing Assumption 4 at the level of individual durable varieties, we recover Assumption 3 at the level of aggregated durables. Additionally, Lemma 2 and Assumption 4 imply that for any aggregate durable cost of $(r + \delta)D_t$, the demand for each durable variety is $D_{v,t} = \frac{s_v}{r+\delta_v}(r + \delta)D_t$.

Finally, we use this microfoundation to understand the aggregate durable depreciation rate δ. Since $\delta D_t = \sum_{v \in V} \delta_v D_{v,t}$ and $D_t = \sum_{v \in V} D_{v,t}$, we have:

$$\delta = \frac{\sum_{v \in V} \delta_v D_{v,t}}{\sum_{v \in V} D_{v,t}}.$$

That is, the aggregate depreciation rate δ is the weighted average of the depreciation rate of each variety v, weighted by the share of variety v in the household's total holdings of durables. This is the approach that we follow in our calibration in Appendix C.

D.2 MPCs and MPXs out of Discrete Liquidity Shocks

Section 4 defines the MPC and the MPX over infinitesimal liquidity injections. Following Achdou et al. (2021), these definitions are easily extended to discrete liquidity injections.

We use $x+\chi$ as shorthand notation for point x in the state space, plus a liquidity injection of size χ. For a discrete liquidity 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 liquidity 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 2, this MPX out of a discrete liquidity injection can be rewritten as:

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

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. (2021) 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 Application: Laibson, Maxted and Moll (2021)

This appendix applies our MPX technology to the model of Laibson et al. (2021). This paper builds a heterogeneous-household model 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	13%	32%
1 Year	28%	37%
2 Years	41%	46%
3 Years	49%	53%

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 Laibson et al. (2021).

Table 3 reproduces the average MPC and MPX over various time horizons for the Laibson et al. (2021) model. 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 in Section 4.4 there is a sizable difference between the timing of MPCs and MPXs, with MPXs being much more front-loaded than MPCs. Put differently, (notional) consumption lags expenditure. 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. This implies that households purchase a stock of durables at the time of the fiscal transfer, which subsequently provides flow-consumption to households going forward.