Demand Composition and the Strength of Recoveries*

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Abstract
We argue that the composition of household consumption declines in recessions matters for the strength of the subsequent recovery. In particular, everything else equal, the recovery from a more durables-led recession — a recession in which durables decline more than services, as in most U.S. recessions — is stronger than the recovery from a more services-led recession — like COVID-19. Our argument relies on basic consumption theory together with output being demand-determined. Following a more durables-led recession, households need to replenish their durable stocks. This pent-up demand boosts aggregate spending, generating an internal tendency towards recovery that is much weaker after more services-led recessions. We formalize this argument in a simple general equilibrium model and provide supporting evidence in U.S. time series data. Finally, we quantify the causal effect of consumption demand composition on the strength of recovery using: (i) a simple sufficient statistic, (ii) a semi-structural shift-share design, and (iii) a quantitative structural model. Everything else equal, a recession as services-led as COVID-19 is between 60 and 100 per cent costlier – in terms of the present discounted value of lost output – than an ordinary, durables-led recession.

Keywords: recoveries, durables, services, business cycles, demand recessions, pent-up demand, shift-share design, COVID-19. JEL codes: E32, E52

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1 Introduction

In ordinary recessions, households largely cut back on durable consumption, while expenditures on non-durables and in particular services remain much more stable. Figure 1 reveals, however, that this pattern is more pronounced in some recessions than others, and sometimes may even be reversed. For example, the decline in durable consumption (like cars) was particularly salient during the 1973 recession, whereas the decline in services (like food at restaurants) has been the largest contributor to consumption expenditure declines in the COVID-19 pandemic.

In this paper, we argue that the composition of household consumption declines in recessions plays an important role in determining the strength of the subsequent recovery in aggregate output. In particular we claim that, everything else equal, recoveries are stronger whenever consumption declines during the recession are more biased towards durables — as in ordinary U.S. recessions or, more extremely, in the 1973 recession — but weaker when they are more biased towards services (or nondurables) — as during the COVID-19 recession. Our argument hinges on basic consumer theory, and only requires that aggregate output is (at least partially) demand-determined. When households cut durable expenditures during a recession, they are left with a depreciated stock of durables, thus seeking to replenish it in the future. This “pent-up demand” leads to a Z-shaped cycle in durable expenditures, with part of the consumption lost in the recession made up later on. As a result, more durables-led recessions invariably sow the seeds for their own recovery. This internal tendency towards recovery due to pent-up demand is, in contrast, weaker after a more services-led recession. Here, the lost consumption is simply foregone and the overall cycle of services expenditures is V-shaped.

To make our case, we proceed in three steps. First, we formalize the core argument in a simple general equilibrium model of demand-driven output fluctuations. Second, we provide empirical evidence for the main mechanism: In response to shocks to aggregate household consumption demand, durables expenditure shows strong pent-up demand effects, while non-durables and services do not. Third, we quantify the causal effect of demand composition on recovery strength. We do so using (i) a simple sufficient statistic, (ii) a semi-structural shift-share design, and (iii) a fully parameterized, extended version of our baseline structural model. All approaches suggest that, everything else equal, a recession which is as services-led as the COVID-19 U.S. recession is between 60 and 100 per cent costlier — in the sense of the present value of lost output over the cycle — than an equally deep, ordinary durables-led recession.

Our analysis begins with a model of a simple Keynesian rationing economy (similar to Eggertsson & Krugman, 2012; Werning, 2015) in which: (i) output is demand-determined because prices and wages are fixed in the short run, and (ii) a representative household derives utility from both her stock of durable goods and from the flow of services consumption. For simplicity, we also assume that the elasticity of substitution between the two goods is constant and identical to the intertemporal elasticity of substitution. We then study the responses of consumption
Figure 1: Decomposition of consumption declines in past U.S. recessions from 1960 to 2019 (peak-to-trough), for the 1973 recession (peak-to-trough), and for the COVID-19 recession (February - May 2020), by Durable Goods and Services plus Non-Durable Goods.

expenditures and output to different types of demand shocks, with a particular focus on the discounted cumulative impulse response of output (DCIR) as our main measure of the strength of recoveries. We present two main results.

First, we characterize the dynamic behavior of our economy following a discount rate shock. This shock, which affects households’ valuation of durable goods and services alike, can be interpreted as a reduced-form stand-in for many more plausibly structural shocks to consumption demand, in particular increases in household earnings risk and tightened borrowing constraints (Mian et al., 2013; Werning, 2015). The induced general equilibrium dynamics of durables and services spending are markedly different. Since durables spending is more elastic, durable expenditures decline more than services on impact, resulting in a durables-led contraction that resembles ordinary U.S. recessions of the past. During the recovery, durable expenditures temporarily overshoot due to pent-up demand effects — resulting in Z-shaped cycle — whereas services expenditures always recover from below — resulting in a V-shaped cycle. With both recession and recovery durables-led, the dynamics of aggregate output more closely resemble the durable expenditure path; in fact, in the limit of a perfectly durable good, the elasticity of durables demand is infinite (Barsky et al., 2007), so output dynamics are completely dominated by durable expenditures (a perfect Z-shaped cycle) and the DCIR of output is exactly zero.

Second, we study the dynamic behavior of our economy following a combination of two shocks: a common discount rate shock (as before) and a preference shock that decreases the relative demand of services vis-à-vis durables. To ease comparison with our first experiment, we
pick the magnitude of the two shocks to normalize the trough of the induced demand recession. The two cases thus differ in the composition of demand during the recession, but not in their overall magnitude. In particular, when the preference shock for services is relatively large, the contraction in aggregate activity can be as services-led as the COVID-19 recession. We then show that, the larger the services component in the recession, the weaker the recovery and the costlier it is in DCIR terms: pent-up demand effects are muted, so the economy shows little internal tendency to recover lost recession output.

We conclude our theoretical analysis with several extensions of the baseline model. These include: adjustment costs on durables, incomplete markets, partially flexible prices (or wages), an arbitrary number of goods varying in their durability, and substitutability or complementarity between durable and services consumption. Our qualitative results change relatively little: As long as output is at least somewhat demand-determined, pent-up demand effects shape aggregate output in general equilibrium, and so durables-led recessions are associated with stronger recoveries than services-led ones.

To test for pent-up demand effects in aggregate time-series data, we estimate the response of household consumption (by category) to a wide range of aggregate shocks to household demand. Most of our analysis looks at relatively broad categories of expenditures: durables, non-durables and services. As our main empirical test, we study monetary policy shocks, which are equivalent to discount rate shocks in our baseline model, adopting a simple recursive identification scheme similar in spirit to Christiano et al. (1999). We find that the evidence is in line with the predictions of our model: Durables exhibit a pronounced Z-shaped cycle in response to a sudden monetary contraction, declining first and then overshooting, while services and non-durables display the expected V-shaped cycle. We document similar patterns using other sources of time-series variation: (i) uncertainty shocks à la Basu & Bundick (2017), (ii) oil shocks as in Hamilton (2003), and (iii) unconditional sectoral expenditure dynamics. Taken together, our time-series evidence paints a consistent picture of strong pent-up demand effects for durables, and much less so for non-durables and in particular for services.

We then leverage our theoretical and empirical results to provide an estimate of the causal effect of demand composition in a recession on the strength of the subsequent recovery. In particular, we ask: how much stronger is the recovery when the composition of household spending resembles that of an ordinary durables-led recession compared to when it resembles that of the COVID-19 recession? We first show that, in a multi-sector variant of our simplest baseline structural model, the harmonic mean of depreciation rates in the affected sectors is a sufficient statistic for the strength of recovery. Taken at face value, this simple sufficient statistic suggests that a services-led recession (similar to COVID-19) will be almost twice as costly as a similarly deep durables-led contraction. We complement this transparent sufficient statistics characterization with two more quantitative measurement exercises.
The first approach is a simple shift-share design. We prove that, in a variant of our baseline model with arbitrarily many goods, incomplete markets, arbitrary adjustment costs on durables, and fixed prices, the behavior of aggregate consumption in a recession of arbitrary spending composition can be estimated semi-structurally, simply by suitably re-weighting and then summing the category-specific consumption responses to monetary policy shocks. Using the estimates from our empirical analysis of monetary policy transmission, this semi-structural shift-share predicts that a recession as services-led as COVID-19 is almost 70 per cent costlier than an ordinary durables-led recession, with the difference strongly statistically significant.

The second approach is fully structural. We augment the baseline model to feature partially sticky prices, a conventional monetary policy rule, and durable adjustment costs, all calibrated to be consistent with (i) the relative volatilities of durables and non-durables consumption expenditures in U.S. time series data and (ii) extant evidence on the slope of the Phillips curve. We then subject this model to different sectoral demand shocks, and compare the induced business-cycle dynamics. The results from this fully structural exercise align qualitatively and quantitatively with those of the semi-structural shift-share: Regardless of the persistence of the underlying disturbance, services-led recessions are invariably followed by weaker recoveries and thus are much costlier in present-value terms of output than ordinary durables-led fluctuations. Relative to our simple sufficient statistics characterization (which implied a twice as large DCIR), the somewhat lower estimated difference of around 60 to 70 per cent chiefly reflects the durable adjustment costs and partial price stickiness.

Overall, we believe that these findings shed light on important forces driving past U.S. recoveries as well as the one expected to follow the COVID-19 recession. However, we would like to emphasize that we do not view them as a forecast of how the unique COVID-19 recovery will actually unfold – in particular, the everything else equal assumption may not hold regarding, for example, the policy response and persistence of the pandemic shock.

LITERATURE. This paper relates and contributes to several strands of literature. First, in studying the aggregate effects of shocks to consumption demand, we build on a long literature emphasizing the importance of nominal rigidities for short-run macroeconomic fluctuations. Most recent work (e.g. Eggertsson & Krugman, 2012; Werning, 2015; Auclert et al., 2018; Bilbiie, 2008, 2018, 2019a) studies the dynamics of non-durable consumption over the business cycle. We show theoretically and empirically that, because of pent-up demand effects, recovery dynamics may look very different when consumption goods are durable.

Second, many papers have sought to understand the determinants of the strength and, more recently, the shape of recoveries. Motivated by the Covid-19 recession, Gregory et al. (2020) ask whether the recovery will be V- or L-shaped, whereas Ricardo Reis has argued for an ABC-shaped...
recovery.\textsuperscript{1} An older and much larger literature has emphasized a variety of mechanisms affecting persistence and the strength of recoveries. These include the nature of business cycle shocks (Galí et al., 2012; Christiano et al., 2015; Beraja et al., 2019), structural forces (Fukui et al., 2018; Fernald et al., 2017), secular stagnation (Hall, 2016; Benigno & Fornaro, 2018), social norms (Coibion et al., 2013), beliefs changes (Kozlowski et al., 2020), and labor market frictions (Schmitt-Grohé & Uribe, 2017; Hall & Kudlyak, 2020). We contribute to this literature by emphasizing a previously unappreciated mechanism: the composition of household spending declines in recessions matters for the strength of pent-up demand effects, and so plays an important role in determining both the strength and shape of the subsequent recovery.

Third, a large literature considers the implications of sectoral heterogeneity for business-cycle dynamics, with most emphasis so far on the production side. For example, one branch highlights heterogeneity in nominal rigidities across sectors (Mankiw & Reis, 2003; Carvalho, 2006; Barsky et al., 2007; Nakamura & Steinsson, 2010); another one incorporates rich network structures (Carvalho & Grassi, 2019; Bigio & La’o, 2020), sometimes combining them with nominal rigidities as well (Pasten et al., 2017, 2019; Farhi & Baqae, 2020). We complement this literature by highlighting the importance of heterogeneity on the demand side, sorting goods and sectors by their durability.

Fourth, we are of course not the first ones to emphasize the importance of durable consumption for business-cycle dynamics. In particular, Barsky et al. (2007) show that the dynamics of durable goods spending dominate total consumption dynamics in response to a change in monetary policy, and Berger & Vavra (2015) document that the elasticity of durable spending varies over the business cycle. McKay & Wieland (2020) argue that this time-varying elasticity can result in the monetary authority facing an intertemporal trade-off in aggregate demand, similar to the Z-shapes of durables expenditure highlighted here. A natural antecedent for our emphasis on pent-up demand dynamics is Mankiw (1982), who studies durable spending in a partial equilibrium consumption-savings problem. We embed this consumption-savings problem in a general equilibrium model with demand-determined output, study the effects of shocks to consumption demand, and draw implications for the causal effect of demand composition on recovery strength. In particular, our novel closed-form solutions reveal transparently why this causal effect is likely to be quantitatively meaningful.

Finally, our results relate to the exploding literature on the COVID-19 recession. Theoretical work has studied how the pandemic supply shock may result in demand shortages (Guerrieri et al., 2020) and considered the effects of mitigation policies (Alvarez et al., 2020; Atkeson et al., 2020; Eichenbaum et al., 2020). Empirically, it has been established that the recession, at least in its early stages, is largely a services recession (Chetty et al., 2020; Cox et al., 2020). We add to this literature by connecting the unique demand composition to widely discussed shapes for

\textsuperscript{1}See https://threadreaderapp.com/thread/1253988696749150208.html. Last accessed on September 11th, 2020.
the recession and subsequent recovery: temporary contractions in durables spending induce Z-shaped dynamics, while temporary contractions in services spending are never reversed, giving a V-shape. Moreover, our interpretation of spending declines as induced by temporary preference shocks to services demand are in line with the results of Goolsbee & Syverson (2020), who show that fears of infection — not lockdowns — explain household consumption behavior.

Outline. Section 2 provides analytical characterizations of recession dynamics in a simple Keynesian rationing economy with durable and non-durable consumption. In Section 3 we test the core predictions of our theory using aggregate U.S. time series data. Section 4 then blends theory and empirics to estimate the causal effect of demand composition on recovery strength. Finally Section 5 concludes, with supplementary details and proofs relegated to several appendices.

2 Pent-up Demand and the Strength of Recoveries

In this section, we study business cycles in an economy with durable goods and (purely non-durable) services. Section 2.1 outlines the model, Section 2.2 presents our main results, and Section 2.3 discusses various model extensions.

2.1 Model

We consider a discrete-time, infinite-horizon economy populated by a representative household, monopolistically competitive retailers, and a government. Households consume services and durables, and the only source of aggregate risk are shocks to household preferences over consumption bundles — a simple reduced-form stand-in for more plausibly exogenous shocks to household demand (e.g. increased precautionary savings due to greater income risk).²

Notation. Throughout we will use bars to refer to steady-state values and hats to indicate log deviations from steady state. We study log-linearized aggregate impulse response dynamics to three shocks, \( b^c_t, b^s_t \) and \( b^d_t \) — shocks to the valuation of the household consumption bundle as a whole, to services consumption and to durables consumption, respectively. Impulse response functions to a shock \( \{c,s,d\} \) will be indicated using superscripts. Finally, we will use boldface notation to denote cumulative discounted impulse response functions (DCIR). For a generic variable \( x_t \) in response to a generic shock \( b \):

\[
x^b_t \equiv \sum_{t=0}^{\infty} \beta^t \times \hat{x}^b_t
\]

²Our results apply with little change to sectoral supply shocks: In our framework, both kinds of shocks would simply show up as wedges in goods-specific Euler equations.
where $\beta$ denotes the household discount factor. We will pay particular attention to the DCIR for aggregate output $y^b$.

**HOUSEHOLDS.** Household preferences over services $s_t$, durables $d_t$ and hours worked $\ell_t$ are represented by the utility function

$$E_0 \left[ \sum_{t=0}^{\infty} \beta^t \{ u(s_t, d_t; b_t) - v(\ell_t) \} \right]$$

(2)

where

$$u(s, d; b) = e^{b \phi \rho s^{1-\rho} + e^{b (1-\phi)} d^{1-\rho}} \left[ \frac{1}{1-\gamma} \right] - 1, \quad v(\ell) = \chi \frac{\ell^{1+\frac{1}{\gamma}}}{1 + \frac{1}{\phi}}$$

(3)

For convenience we normalize total consumption expenditure to one. We let $\phi$ denote the expenditure share of services consumption, so $\bar{s} = \phi$ and $\delta \bar{d} = 1 - \phi$. The preference parameter $\bar{\phi}$ is then pinned down to make these expenditure shares consistent with optimal household behavior (see Appendix A.1 for details). From now on, and until Section 2.3, we will furthermore impose that $\rho = \gamma$ — durables and services are neither complements nor substitutes.

Households borrow and save in a single nominally risk-free asset $a_t$ at nominal rate $r^n_t$, supply labor at wage rate $w_t$, and receive dividend payouts $q_t$. Letting $p^s_t$ and $p^d_t$ denote the real relative prices of services and durables, and with $\pi_t$ denoting inflation, we can write the household budget constraint as

$$p^s_t s_t + p^d_t \left[ d_t - (1-\delta) d_{t-1} \right] + a_t = w_t \ell_t + \frac{1 + r^n_{t-1}}{1 + \pi_t} a_{t-1} + q_t$$

(4)

In much of the subsequent analysis, we will pay particular attention to the case of an “idealized durable” (Barsky et al., 2007): with $\delta = 0$ and $\beta = 1$, a durable purchase today has undiscounted utility benefits from now until the infinite future, while a services purchase today only affects household utility today.

**REST OF THE ECONOMY.** Both services and durable goods are produced by aggregating varieties sold by monopolistically competitive retailers. Production of both goods only uses labor, and price-setting is subject to standard nominal rigidities. Since the problems of retailers are entirely standard we relegate details to Appendix A.1. The economy is closed with a monetary authority setting nominal rates in line with a conventional Taylor rule. There is no government consumption, and the risk-free bond is in zero net supply. To simplify the analysis we will, from now on and until Section 2.3, assume that all prices in the economy are fully rigid, and that the monetary authority fixes the nominal rate of interest. With output thus completely demand-determined, our specification of the labor disutility function $v(\bullet)$ is irrelevant for all equilibrium quantities.
The disturbances $b^c_t$, $b^s_t$ and $b^d_t$ follow exogenous AR(1) processes with persistence $\rho_b$ and innovation volatilities $\sigma^c$, $\sigma^s$ and $\sigma^d$, respectively.

**EQUILIBRIUM.** Steady-state output in our economy is $\bar{y} \equiv \bar{s} + \delta \bar{d} = 1$. To first order, equilibrium output $y_t$ then satisfies

$$\hat{y}_t = \phi \hat{s}_t + (1 - \phi) \hat{e}_t$$

(5)

To ensure equilibrium uniqueness given perfectly rigid prices, we assume that output impulse responses to any shock $b$ satisfy

$$\lim_{t \to \infty} \hat{y}_t^b = 0$$

(6)

It is straightforward to see that this equilibrium selection device coincides with the limiting behavior of an economy with arbitrarily — but not perfectly — sticky prices.

### 2.2 Demand Shocks and Business Cycle Dynamics

We now study the response of the economy to the consumption demand shocks $\{b^c_t, b^s_t, b^d_t\}$. Throughout we will mostly contrast the common shock $b^c_t$ — a plausible description of shocks to consumption demand in ordinary recessions — with a combination of shocks $b^c_t + b^s_t$ resulting in a services-led recession — as observed in the COVID-19 crisis. For all experiments in this section we scale the shock volatilities $\{\sigma^c, \sigma^d, \sigma^s\}$ to normalize the impact impulse response of output to each shock to -1 per cent.

**Transitory shocks.** First, and in keeping with the analysis in Eggertsson & Krugman (2012), we consider perfectly transitory shocks.

**Proposition 1.** The impulse responses of aggregate output to one-off shocks to services and durables demand, $b^s_t$ and $b^d_t$, satisfy

$$\hat{y}_0^s = -1, \quad \hat{y}_t^s = 0 \quad \forall t \geq 1$$

(7)

and

$$\hat{y}_0^d = -1, \quad \hat{y}_t^d = (1 - \delta), \quad \hat{y}_t^d = 0 \quad \forall t \geq 2$$

(8)

The impulse response to the common shock $b^c_t$ is

$$\hat{y}_t^c = \omega_d \hat{y}_t^d + (1 - \omega_d) \hat{y}_t^s$$

(9)

where the durables weight $\omega_d$ is given as

$$\omega_d = \frac{1 - \phi}{(1 - \phi) + \phi \delta [1 - \beta (1 - \delta)]} > 1 - \phi$$

(10)

Proposition 1 reveals that the general equilibrium dynamics of aggregate output induced by shocks to consumption demand very much depend on the sectoral incidence of the shock. Figure 2 provides a graphical illustration.
Figure 2: Recession dynamics in the baseline model with purely transitory shocks. Responses correspond to: a common demand shock (solid blue), a pure durables shock (dashed light blue), a pure services shock (dashed light orange), and a combined common and services demand shock reproducing a COVID-19-style recession (solid orange). For details on model calibration see Appendix A.1.

We consider first the pure sectoral demand shock for durables, $b_d^t$, with impulse response functions depicted by light blue dashed lines. Consumption demand and so equilibrium output decline on impact. Following the contraction in durables spending, the household durable stock at the beginning of the recovery is below target, so there is pent-up demand for durables. As a result, durable expenditures overshoot their steady-state at $t = 1$, and so does aggregate consumption demand. But since output is demand-determined, output also overshoots at $t = 1$ – a Z-shaped cycle. The corresponding output DCIR shows that the lost output over the cycle (in present value terms) is decreasing in the durability of the durable good ($\delta$).

$$y^d = 1 - \beta(1 - \delta)$$ \hspace{1cm} (11)

Matters are different for a pure services demand shock $b_s^t$, depicted by the light orange dashed lines. Here services consumption falls, but durable consumption does not. As a result, there is no pent-up demand, equilibrium consumption and output return to steady state at $t = 1$, and the cycle is V-shaped. Moreover, since the lost output is never made up, the DCIR of output satisfies

$$y^s = 1$$ \hspace{1cm} (12)

Taken together, these results imply that, in a DCIR sense, the recovery from a services-led recession is always strictly weaker than the recovery from an equally deep durables-led recession — in one case the recovery is buffeted by pent-up demand, while in the other it is not.

We now turn to studying more realistic business cycle fluctuations with mixed spending compositions. The solid blue lines depict the impulse responses following a common demand
shock $b^c_t$. Here the dynamics closely resemble those of the durables-only shock $b^d_t$. Intuitively, ordinary demand-driven demand recessions are mostly durables-led because durable spending is much more intertemporally elastic than spending on services (and non-durable goods). Formally, in Proposition 1, the durables weight $\omega_d$ always strictly exceeds the share of durable production in total output. For example, even if the share of durable consumption in total consumption is only 10 per cent, the weight $\omega_d$ on durable dynamics in total consumption is, for a quarterly depreciation rate of $\delta = 0.1$, above 90 per cent. The limit case of an ideal durable — no depreciation ($\delta = 0$) and no discounting ($\beta = 1$) — is of particular interest: In that limit, the dynamics of aggregate output are completely governed by durables demand, and the DCIR associated with a durables-led recession is zero, as the contraction in output at $t = 0$ is perfectly offset by an equally large boom at $t = 1$.

**Corollary 1.** In the limit of an ideal durable good, the common demand shock $b^c_t$ only affects the consumption of durables, i.e.,

\[ \omega_d = 1 \]  

and the DCIRs of output to durable and common demand shocks are zero.

The importance of durables for macro aggregates in the ideal-durable limit are discussed at length in Barsky et al. (2007). For our purposes, the key takeaway is that, precisely because ordinary demand recessions tend to be dominated by durables expenditures, they invariably sow the seeds for their own recovery — a feature of recession dynamics that is noticeably absent in most standard models of consumption demand recessions (e.g. Eggertsson & Krugman, 2012; Werning, 2015; Auclert et al., 2018).

Finally, the solid orange lines in Figure 2 are the responses to a mixed demand shock $b^c_t + b^s_t$, with the relative shock volatilities chosen so that the composition of expenditures during the recession is as the one observed during the COVID-19 recession (see Figure 1). With durables spending accounting for little of the initial decline in output, there is a very small spending boost from durables pent-up demand at $t = 1$. Thus, the dynamics of total consumption and output closely resemble the V-shaped cycle associated with a pure services-led recession.

**Persistent shocks.** Our results extend with relatively little change to the case of persistent shocks. Proposition 2 presents the formal result.

**Proposition 2.** The DCIRs of aggregate output to persistent shocks to services and durables demand, $b^s_t$ and $b^d_t$, satisfy

\[ y^s = \frac{1}{1 - \rho_b \beta}, \quad and \quad y^d = \frac{1 - \beta (1 - \delta)}{1 - \rho_b \beta} \]  

The DCIR of output to the common shock $b^c_t$ is

\[ y^c = \omega_d y^d + (1 - \omega_d) y^s \]
where the durables weight $\omega_d$ is given as

$$
\omega_d = \frac{1 - \phi}{(1 - \phi) + \phi\delta \frac{1 - \beta(1 - \delta)}{1 - \beta(1 - \delta)\rho_s}} > 1 - \phi
$$

(16)

As before, durables-led recessions are less severe than services-led recessions in a DCIR sense, and shocks to consumption demand as a whole invariably induce durables-led dynamics. In particular, the expressions in (14) reveal that, with persistent shocks, only the levels of the two DCIRs are affected, but not their ratios. Also as before, in the limit of an idealized durable good, recession dynamics are completely dominated by durable goods, and so the associated DCIR again converges to zero.

2.3 Extensions

The environment of Section 2.1 is purposefully simple, allowing us to characterize the differences of services-led and durables-led recessions in the starkest possible way. In this section we argue that our results extend with little to no change to models with adjustment costs in durables consumption, richer preference specifications over a larger menu of goods, household market incompleteness, and models with partially demand-determined output.

Adjustment costs. So far we have made the stark assumption that consumption of durable goods is not subject to any kind of adjustment costs. We here argue that adjustment costs smooth out durable consumption dynamics, but leave unchanged the basic intuition at the heart of our results — contractions in durables demand sow the seeds of a subsequent recovery, while contractions in services demand do not.

We generalize the household budget constraint to allow for durables adjustment costs:

$$
p^s_t s_t + p^d_t \underbrace{[d_t - (1 - \delta)d_{t-1}]}_{\ell_t} + a_t = \omega_t \ell_t + \frac{1 + \rho^n_{t-1}}{1 + \pi_t} a_{t-1} + q_t + \psi(d_{t-1}, d_t)
$$

(17)

where

$$
\psi(d_{t-1}, d_t) = \frac{\kappa}{2} \left( \frac{d}{d_{t-1}} - 1 \right)^2 d
$$

(18)

Proposition 3 characterizes the DCIR of output in response to a transitory durables demand shock in this extended model.

**Proposition 3.** In the model with durables adjustment costs, the DCIR of output to a transitory shock to

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3For simplicity, we throughout assume that durables adjustment costs are returned to households as part of the lump-sum dividend payments $q_t$. Adjustment costs thus do not drain any resources from the economy.
durables demand, $b_t^d$, satisfies

$$y^d = \frac{1 - \beta (1 - \delta)}{1 - \theta_d \beta}$$

where

$$\theta_d = 1 - \delta \gamma - \frac{\sqrt{1 + \frac{4\kappa}{\delta \gamma}} - 1}{2\kappa}$$

For $\kappa = 0$, the adjustment coefficient $\theta_d$ is equal to zero and we recover the baseline result. For positive $\kappa$, adjustment in durables is slowed down. Since the fast future recovery is driven by households replacing undepreciated past shortfalls in durable purchases, slower adjustment invariably increases DCIRs: A larger fraction of lost consumption was “replaced” through depreciation, so no future excess demand is needed. For an ideal long-lived durable, however, this effect is of course irrelevant: We get

$$\lim_{\delta \to 0} y^d = 0,$$

exactly as in our baseline model. Thus, as long as durable goods are sufficiently long-lived, our results are barely affected by the presence of adjustment costs to durables purchases.

**Richer preferences.** Our baseline specification assumed that households could only consume two goods — durables and services — and that the marginal utility of one was independent of the other. We here relax both assumptions.

First we consider the case of a unit continuum of goods $i \in [0, 1]$, each with its own depreciation rate $\delta_i$ and all produced by a continuum of fixed-price, monopolistically competitive retailers, as before. For simplicity, we assume that the consumption shares of all goods are identical, and we consider the limit $\beta \to 1$. We then study impulse response paths of aggregate output in response to a demand shock $b_t^c$ for all goods.

**Proposition 4.** Let $\beta = 1$. In the model with a continuum of consumption goods, the DCIR of output to a shock to overall consumption demand, $b_t^c$, satisfies

$$y^c = \frac{1 - \rho_b [1 - \mathbb{E}_i(\delta_i)]}{1 - \rho_b} \mathbb{E}_i[(1 - \rho_b)\delta_i^{-1} + \rho_b]^{-1}$$

In particular, for a transitory shock, the DCIR of output is

$$y^c = \mathbb{E}_i(\delta_i^{-1})^{-1}$$

The strength of the recovery is now governed by the harmonic mean of depreciation (and so durability) rates. This result formalizes how, in a rich multi-good environment, the most durable goods exert a disproportionate influence on overall equilibrium output dynamics, invariably making ordinary recessions durables-led. In **Section 4** we will use (22) to derive a simple sufficient statistics formula for the causal effect of spending composition on recovery strength.
Second, we return to our most general preference specification (3), with $\rho$ not necessarily equal to $\gamma$. In that case, shocks to services demand also affect durables consumption, and vice-versa. Most empirical estimates suggest that $\rho < \gamma$, so durables and services are net substitutes. In that case our results become even stronger: services recoveries are even weaker, and the DCIR for a recession in durables demand can actually be negative. We provide details in Appendix A.2.

**Incomplete markets.** In our baseline model, we summarized the household block through a simple representative household, implicitly assuming perfect insurance (market completeness). An argument similar to that in Werning (2015) reveals that our insights generalize without change to generic models with market incompleteness on the household side. To see this most transparently, we extend the baseline model to feature a margin $\mu \in (0, 1)$ of hand-to-mouth households. These constrained households always consume their entire income each period (so their asset holdings $a_t$ are always equal 0), but are otherwise free to rebalance their consumption between durables and services, exactly like unconstrained households. Furthermore, we assume that the elasticity of hand-to-mouth income with respect to aggregate income is $\eta$, thus allowing for cyclicality in income risk. A detailed model outline is presented in Appendix A.2.

We arrive at the following equilibrium characterization.

**Proposition 5.** Let $\eta = 1$. Then all aggregate impulse responses are exactly as in the baseline model (with $\mu = 0$). For arbitrary $\eta$, all normalized impulse responses are exactly as in the baseline model.

The main takeaway from Proposition 5 is that market incompleteness potentially affects the scale of impulse response functions, but not the shape — as before, services recessions follow a V-shape, and durables recessions follow a Z-shape. The income incidence channel discussed in Werning (2015) and Bilbiie (2008) thus does not interact with the characterization of recession dynamics emphasized here.

**Richer supply-side models.** In our baseline model, output is fully demand-determined — prices do not adjust, and all changes in desired household spending translate one-to-one into actual equilibrium output paths. While this assumption is central to the simplicity of our expressions in Section 2.2, it is not at all crucial to our general insights on recession and recovery shapes. In Appendix A.2 we consider a model variant with partially fixed prices and so partially demand-determined output, and show that, with standard degrees of price stickiness, the V- and Z-shapes remain almost as pronounced as in Figure 2. The exact same conclusions also extend to models in which output is demand-determined via nominal rigidities in wage-setting.
3 Pent-Up Demand Effects in Time Series Data

Having characterized our basic theoretical prediction and documented its robustness to various plausible model perturbations, we now turn to a test of the theory in aggregate time series data. Section 3.1 begins with our main experiment: surprise changes in the aggregate monetary policy stance as an example of a common shock to all categories of consumption demand. In Section 3.2 we confirm the conclusions from our monetary experiment using various other sources of variation: uncertainty shocks, oil shocks, as well as simple innovations to the unconditional dynamics of aggregate consumer expenditure.

3.1 Monetary Policy

As the main empirical test of our theory, we study the response of different consumption categories to identified monetary policy shocks. We do so for two reasons. First, among all of the macroeconomic shocks studied in applied work, monetary shocks are arguably the most prominent, and much previous work is in agreement on their effects on the macro-economy (Ramey, 2016; Wolf, 2020). Our contribution thus need not lie in shock identification; instead, we can focus on the impulse responses themselves and their connections to our theory. Second, monetary shocks are well-suited to test the basic predictions of the theory. To establish this claim, consider an extended version of our baseline with partially fixed prices, as discussed in Section 2.3. We now generalize the rule of the monetary authority to allow for stochastic disturbances $m_t$:

$$\hat{r}_t^n = \phi_r \hat{r}_{t-1}^n + (1 - \phi_r) \left( \phi_n \hat{\pi}_t + \phi_y \hat{y}_t + m_t \right)$$

We assume that the monetary shocks $m_t$ are i.i.d. and as volatile as the common demand shock $b_c^t$. We then get the following equivalence result.

**Proposition 6.** In the model with partially fixed prices and innovations to the central bank’s Taylor rule, the impulse responses of all real quantities $x \in \{s, e, d, y\}$ to a common demand shock $b_c^t$ with persistence $\rho_b = \phi_r$ and to a monetary shock $m_t$ are identical:

$$\hat{x}_i^c = \hat{x}_i^m$$

In our model, monetary policy shocks transmit to consumption spending exactly like the pure demand shocks $b_c^t$ studied in Section 2.2. All conclusions from our previous analysis thus apply without change; in particular, the recovery of durables spending after a contractionary monetary policy shock should be faster than the recovery of services and non-durables consumption, in a DCIR sense. It is this core prediction that we take to the data.

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4It is well-known that granular spending data confirm the intertemporal shifting of durable expenditure that lies at the heart of our theory (e.g. Mian & Sufi, 2012). Time series data allow us to test whether those effects are also important in the aggregate, in general equilibrium.
Empirical Framework. Our analysis of monetary policy transmission closely follows the seminal contribution of Christiano et al. (1999): We estimate a reduced-form Vector Autoregression (VAR) in measures of consumption, output, prices and the federal funds rate, and identify monetary policy shocks as the innovation to the federal funds rate under a recursive ordering, with the policy rate ordered last.

We estimate our VARs on quarterly data, with the sample period ranging from 1960:Q1 to 2007:Q4. To keep the dimensionality of the system manageable, we fix aggregate consumption, output, prices and the policy rate as a common set of observables, and then estimate three separate VARs for each category of spending — durables, non-durables, and services. We include four lags throughout, and estimate the models using standard Bayesian techniques. Details are provided in Appendix B.1.

Results. Consistent with previous work, we find that a contractionary monetary policy shock lowers aggregate output and consumption. Figure 3 decomposes the response of aggregate consumption into its three components — durables, non-durables, and services. To facilitate the comparison of empirical estimates with the theoretical predictions of Section 2.2, we scale the impulse response of each component to drop by -1 per cent at the trough.

![Figure 3: Quarterly impulse responses to a recursively identified monetary policy shock by consumption spending category, all normalized to drop by -1% at the trough. The solid blue line is the posterior mean, while the shaded areas indicate 16th and 84th percentiles of the posterior distribution, respectively.](image)

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5 As shown in Plagborg-Møller & Wolf (2020), the econometric estimands of all three specifications would be identical if the different measures of sectoral consumption did not affect the forecast errors in the non-consumption equations. Since the additional explanatory power (in a Granger-causal sense) of sectoral consumption measures for other macroeconomic aggregates is relatively small in our set-up, all three specifications are effectively projecting on similar shocks.

6 In our baseline specification, prices increase — the well-known price puzzle. Augmenting our model to include a measure of commodity prices ameliorates the price puzzle, without materially affecting any other impulse responses. These results are available upon request.

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The empirical results confirm the basic predictions of our theory: Following the negative monetary policy shock, all components of consumption initially decline. Durables, however, recover quickly and in fact overshooot, while expenditure on non-durables and in particular services simply returns to baseline. Overall, our estimated empirical impulse responses are the expected smoothed version of the sharp Z- and V-shapes discussed in Section 2.2.

Our results of heterogeneous spending dynamics by consumption category are also consistent with previous work. First, Erceg & Levin (2006) consider a similar recursive monetary policy VAR, and find that consumer durables and residential investment recover more quickly than other components of GDP. Second, McKay & Wieland (2020) show that the impulse response of total GDP to a narratively identified monetary policy shock reverses over time. Our results are complementary in that they show, at the level of household spending by category, consistency between empirics and the basic predictions of pent-up demand theory.

3.2 Other Tests

While impulse responses to monetary policy innovations are, for the reasons discussed in Section 3.1, a close-to-ideal experiment to test our theory, they are of course not the only possible one. In this section we collect the results of several other empirical exercises, with details for all relegated to Appendices B.2 to B.4.

Uncertainty. Uncertainty shocks are a natural structural candidate for the reduced-form demand shocks studied in Section 2, and as such a promising alternative to the baseline monetary policy experiment. Following Basu & Bundick (2017), we identify uncertainty shocks as an innovation in the VXO, a well-known measure of aggregate uncertainty. Consistent with Plagborg-Møller & Wolf (2020), our VAR-based implementation controls for a large number of shock lags, ensuring consistent projections even at medium horizons.

Our results are very similar to the monetary policy experiment: All components of consumption drop on impact, but durables expenditure recovers quickly and then overshoots, while the recoveries in non-durable and service expenditure are more sluggish. However, given the relatively short sample, our estimates are less precise than for monetary policy shock transmission.

Oil. As a third test we study oil price shocks, identified as in Hamilton (2003) and embedded in a recursive VAR. While such shocks can generate broad-based recessions, they are special in that they directly affect the relative prices of consumption goods, exactly equivalent (from the perspective of an individual household) to the reduced-form sector-specific demand shocks studied in Section 2. In particular, a sudden increase in oil prices will increase the effective relative price of all transport-related consumption, allowing us to test the basic predictions of our theory at a finer sectoral level.
Again, our results are in line with the predictions of the theory. Since transport-related expenditures are an important component of durables expenditure (e.g., motor parts and vehicles), total durable consumption is strongly affected by the shock and follows the predicted Z-shaped recovery pattern. Food, clothes and finance expenditures instead all dip in the initial recession, but then simply return to baseline, without any further overshoot. We discuss further sectoral impulse responses in Appendix B.3.

**Unconditional spending dynamics.** So far our analysis has been purely conditional: We have studied the dynamic behavior of different components of consumption expenditure conditional on different aggregate shocks. As a final check, we show that the predictions of our theory also hold unconditionally. To do so, we estimate a simple high-order autoregressive representation for each category of consumer expenditure, and then trace out category-specific impulse responses to an innovation in that univariate (invertible) representation, all normalized to give the same initial shock size. It then simply remains to compare across specifications by estimating DCIRs for each separate category of consumer spending.

Consistent with both theory and our previous empirical results, we find that innovations to durables spending decay much faster, and so give much smaller DCIRs than equally large innovations to non-durables and services spending. In particular, we find that the DCIR for non-durables is around 80 per cent larger than the durables DCIR, with the corresponding number for services an even larger 120 per cent.

### 4 The Effect of Demand Composition on the Strength of Recovery

We now quantify the causal effect of the composition of consumption declines during a recession on the strength of the subsequent recovery. The simple model analyzed in Section 2 suggests that this causal effect is potentially large: In the extended model with a unit continuum of consumption goods, the DCIR of output in response to a transitory demand shock for a subset $S \in [0, 1]$ of goods is the harmonic mean of depreciation rates in the affected sectors:

$$y = \mathbb{E}_{i \in S} (\delta_i^{-1})^{-1}$$  \hspace{1cm} (25)

A simple back-of-the-envelope calculation based on (25) suggests that a recession as services-led as COVID-19 may be up to 100 per cent costlier in present-value output terms than a similarly deep durables-led contraction.\(^7\)

This number, however, is likely to be an upper bound for the actual causal effect — as discussed in Section 2.3, adjustment costs, shock persistence and partially flexible prices are all likely

\(^7\)This simple calculation uses the shares of Figure 1 and assumes a quarterly durables depreciation rate of around 7 per cent.
to dampen the strength of pent-up demand effects. We thus in this section go beyond the simple sufficient statistic of (25), and instead estimate the causal effect under weaker structural assumptions. We do so in two ways. First, in Section 4.1, we give a set of sufficient conditions under which the causal effect can be estimated directly via aggregate impulse responses to monetary shocks, through a simple shift-share design. As such, this approach is entirely semi-structural, and only relies on our impulse response estimates from Section 3. Second, in Section 4.2, we calibrate a generalized version of our baseline model to be consistent with the relative roles of durables and non-durables in past U.S. recessions, and use the model to construct fully structural recession composition counterfactuals. Encouragingly, these two very different approaches paint a consistent picture: In present-value terms, a services-led recession (like COVID-19) is around 70 per cent costlier than a similarly deep durables-led contraction.

4.1 Shift-Share Design

In Section 3.1, we estimate the responses of all components of household spending to a change in the aggregate monetary stance and so, under the conditions of Proposition 6, to a common demand shock \( b^d_t \). To quantify the causal effect of demand composition on the strength of the recovery, however, we need the responses of aggregate consumption to sectoral demand shocks. Proposition 7 gives sufficient conditions under which the response of total consumption to an arbitrary combination of sectoral demand shocks can be recovered through a simple shift-share based on the sectoral responses to a common demand shock.

**Proposition 7.** Consider a variant of the baseline model with durables adjustment costs, incomplete markets, fixed prices and innovations to the monetary authority’s Taylor rule, and let \( \hat{s}_m^s \) and \( \hat{e}_m^d \) denote the impulse responses of services and durables spending, respectively, to a monetary policy shock. Then

\[
\hat{y}_t = \xi^s \hat{s}_m^s + \xi^d \hat{e}_m^d
\]

is the impulse response of aggregate output to a pair of sectoral demand shocks \((b^s_t, b^d_t)\) with persistence \( \rho_b = \phi_r \) and volatilities \( \sigma^s = \sigma^n \xi^s \frac{\zeta}{\phi} \), \( \sigma^d = \sigma^n \xi^d \frac{\zeta}{\phi} \).

Under the conditions of Proposition 7, arbitrary linear combinations of the sectoral spending responses in Figure 3 give valid general equilibrium impulse responses to sectoral demand shocks. Thus, we can consistently estimate the causal effect of spending composition on the dynamics of recovery by tracing out different weighted averages of sectoral spending impulse responses. Figure 4 shows the results of this exercise, with all impulse responses evaluated at the posterior mode of the estimated VAR.

The shaded grey area shows the range of possible outcomes, varying the weights on each spending component — durables, non-durables and services — between 0 and 1, and normalizing the total trough impulse response to -1 per cent of total steady-state consumption. It follows immediately from Figure 3 that the lower bound corresponds to a pure services-led recession,
Figure 4: Shift-share point estimates of the impulse response of aggregate consumption to sectoral demand shocks, quarterly horizon, evaluated at the posterior mode of the VAR of Section 3.1. The grey shaded area shows the range of possible impulse responses with positive weights on all spending components and normalized to lower consumption by 1 per cent at the trough. The blue and orange lines, respectively, correspond to the weights given in Figure 1.

while the upper bound is a fully durables-led recession. Within the grey band we highlight two particular weighted averages: (i) a recession with spending composition equal to the average past U.S. recession (blue), and (ii) a recession with spending declines mirroring those of the COVID-19 pandemic (orange), as displayed in Figure 1. Since ordinary recessions are durables-led, the blue line is close to the upper bound of our feasible range.\(^8\) Recovery from a recession as tilted towards services as the COVID-19 pandemic is, in contrast, predicted to be much slower.\(^9\)

The corresponding causal effect of spending composition on recovery strength is large. At the posterior mode reported in Figure 4, the DCIR of output in a recession as services-led as COVID-19 is 67.8 per cent larger than that in an ordinary durables-led recession. This difference is economically and statistically significant, with the 68 per cent posterior credible set ranging from 20 per cent to 170 per cent.\(^10\) Overall, and as expected, our estimates of the effect of recession

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\(^8\)In fact, since services contribute negatively to ordinary recessions (see Figure 1), the blue line can in principle lie outside the grey area.

\(^9\)In Appendix B.2, we derive the exact same conclusions using a shift-share based on estimated impulse responses to uncertainty shocks à la Basu & Bundick (2017).

\(^10\)To construct the posterior credible set, we estimate a single VAR containing all consumption measures, compute the DCIR ratio for each draw from the posterior, and then report percentiles.
spending composition are somewhat smaller than suggested by the simple sufficient statistic in (25), but still quantitatively meaningful.

4.2 Structural Counterfactuals

The results in Section 4.1, while appealingly semi-structural, only apply to demand shocks that are exactly as persistent and occur in exactly the same macroeconomic environment as the monetary policy shocks of historical time series data, and furthermore assume fixed prices. We here complement these results by showing that, in a calibrated version of the structural model of Section 2, the same conclusions apply: For shocks of varying persistence, and with an empirically plausible degree of nominal rigidity, we robustly conclude that recoveries from services-led recessions are weaker (and thus much costlier in terms of lost output) than otherwise identical durables-led ones.

Calibration. We study shocks to household spending in a quantitative version of the baseline model of Section 2.2, augmented to feature partially sticky prices, a standard monetary policy rule, and adjustment costs to durable holdings. Table 1 presents all parameter values.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Source/Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>Discount Rate</td>
<td>0.99</td>
<td>Annual Real FFR</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Inverse EIS</td>
<td>1</td>
<td>Literature</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Elasticity of Substitution</td>
<td>1</td>
<td>$= EIS$</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Depreciation Rate</td>
<td>0.068</td>
<td>BEA Fixed Asset</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Durables Consumption Share</td>
<td>0.1</td>
<td>Literature</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>NKPC Slope</td>
<td>0.02</td>
<td>Ajello et al. (2020)</td>
</tr>
<tr>
<td>$\phi_\pi$</td>
<td>Inflation Response</td>
<td>1.5</td>
<td>Literature</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>Adjustment Cost</td>
<td>0.06</td>
<td>Recession Share (Figure 1)</td>
</tr>
</tbody>
</table>

Table 1: Calibration of the quantitative Durable/Non-Durable Model.

The three preference parameters ($\beta, \rho, \gamma$) are standard; in particular, we set $\rho = \gamma$, so durables and non-durables are neither net complements nor net substitutes. We consider a broad notion of durables, so the depreciation rate $\delta$ is set as annual durable depreciation divided by the total durable stock in the BEA Fixed Asset tables, exactly as in McKay & Wieland (2020). Given $\delta$, we set the preference share $\phi$ to fix durables expenditure as 10 per cent of total steady-state consumption expenditure. Next, we take the slope of the New Keynesian Phillips Curve from Ajello et al. (2020), and consider a simple monetary policy rule with a strong inflation response. Finally, given all other parameters, we set the quadratic adjustment cost parameter $\kappa$ so that,
after a persistent demand shock $b^*_t$ (with $\rho_b = 0.9$), fluctuations in durable expenditure account for around 65 per cent of total consumption fluctuations, consistent with Figure 1.

We now use the model to trace out aggregate output impulse responses to weighted averages of goods-specific demand shocks $b^*_t$ and $b^d_t$. We consider shocks with persistence $\rho_b = 0$ (transitory) and $\rho_b = 0.9$ (persistent).

**Results.** Figure 5 shows that structural model-based counterfactuals closely agree with the predictions of the semi-structural shift-share design of Section 4.1.

![Figure 5: Structural model counterfactuals for sectoral demand shocks of different persistence, quarterly horizon, evaluated at the parameterization of Table 1. The grey shaded area shows the range of possible impulse responses with positive weights on durable and non-durable demand shocks, and normalized to lower consumption by 1 per cent at the trough. The blue and orange lines, respectively, correspond to the weights given in Figure 1.](image_url)

As before, the shaded grey area indicates the range of possible recession consumption paths, with the lower bound corresponding to a pure services-led recession, while the upper bound is a pure durables-led recession. For the transitory shock, we see the overshoot predicted by the stylized model of Section 2.2, while for persistent shocks we simply see a faster recovery for durables than for non-durables. The blue and orange lines, respectively, show the predicted dynamics for recessions as tilted towards durables as the average post-war U.S. recession and the early stages of the COVID-19 pandemic recession, respectively.

For both transitory and persistent shocks, the structural model predicts that a COVID-19-style services-led recession is around 60 to 70 per cent costlier (in the usual output DCIR sense) than an ordinary (durables-led) recession. Thus, even though the two approaches are conceptually very different, the semi-structural shift-share and the structural model paint a consistent picture
of large causal effects of recession composition on recovery strength, as also predicted by our much simpler sufficient statistic in (25).

5 Conclusions

Standard consumer theory predicts that the recovery from a more services-led recession should be weaker — in the sense that the lost output over the cycle is larger — than from a similarly deep, more durables-led one. This is because service expenditures declines during a recession do not lead to pent-up demand for this type of consumption in the future, whereas durable expenditures declines do. We have formalized this argument in a simple general equilibrium model of demand-determined output, documented support for the key model predictions in aggregate U.S. time series data, and used structural and semi-structural approaches to quantify the causal effect of recession demand composition on the strength of the subsequent recovery. Our results suggest that, in present-value output terms, a recession as services-led as that induced by the COVID-19 pandemic in the US will be be around 60 to 100 per cent costlier than a similarly deep, ordinary durables-led US recession.

We plan to extend the analysis in this paper in two directions. First, as the economy recovers from the COVID-19 recession, we will be able to use granular household spending data (as in Cox et al., 2020) to test our predictions for spending recoveries by consumption category. Second, we will verify the robustness of our conclusions to even richer models of durable consumption in general equilibrium, similar to Berger & Vavra (2015) and McKay & Wieland (2020).
References


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A Model appendix

In this appendix we provide further details on the structural models of Section 2 and Section 4.2. First, in Appendix A.1, we elaborate on our baseline model and present the full set of equilibrium conditions. Then, in Appendix A.2, we offer analogous equilibrium characterizations and other supplementary results for the various model extensions discussed in Section 2.3.

A.1 The Baseline Model

We first complete the description of the model environment in Section 2.1, and then derive the key equations needed to characterize the equilibrium in Section 2.2.

Production. We assume that both durables and services are produced by aggregating a common set of varieties sold by monopolistically competitive retailers, exactly as in Galí (2015, Chapter 3). We can thus summarize the production side of the economy with a single aggregate New Keynesian Phillips curve, relating inflation \( \hat{\pi}_t \) and aggregate output \( \hat{y}_t \):

\[
\hat{\pi}_t = \zeta \hat{y}_t + \beta E_t [\hat{\pi}_{t+1}]
\]

where \( \zeta \) is a function of the labor disutility \( v(\bullet) \), the production function of retailers, the discount factor \( \beta \) and the degree of price stickiness. For much of our analysis we consider the limit of perfectly sticky prices and so a flat Phillips curve (\( \zeta \to 0 \)).

Firms discount at the stochastic discount factor of their owners (the representative household), and pay out dividends \( q_t \). The dynamics of dividends are irrelevant for our purposes, so we do not discuss them further.

Policy. The monetary authority issues a nominal bond at nominal interest rate \( r^n_t \), set in accordance with a generic Taylor rule:

\[
\hat{r}^n_t = \phi r^n_{t-1} + (1 - \phi) (\phi_s \hat{r}_t + \phi_y \hat{y}_t)
\]

The bond is in zero net supply overall.

Equilibrium characterization. We begin with optimal household consumption behavior. With \( c_t \equiv \left[ \phi^s s_t^{1-\rho} + (1 - \phi^d) d_t^{1-\rho} \right]^{\frac{1}{1-\rho}} \) denoting the total household consumption bundle, we to first order have

\[
\tilde{c}_t = \frac{\phi}{\phi + [1 - \beta(1 - \delta)] \frac{1}{\delta} (1 - \phi) \tilde{s}_t + [1 - \beta(1 - \delta)] \frac{1}{\delta} (1 - \phi) \tilde{d}_t}
\]

(A.3)
where \( \phi \) and \( 1 - \phi \) are the expenditure shares, respectively, and \( \tilde{\phi} \) satisfies
\[
\left( \frac{\phi}{1 - \phi} \right)^\rho = \frac{1}{1 - \beta(1 - \delta)} \left( \frac{\phi}{\frac{1}{2}(1 - \phi)} \right)^\rho \tag{A.4}
\]

The marginal utility of wealth \( \lambda_t \) satisfies
\[
\hat{\lambda}_t = \hat{r}_t - \mathbb{E}_t [\hat{\pi}_{t+1}] + \mathbb{E}_t [\hat{\lambda}_{t+1}] \tag{A.5}
\]

Optimal consumption of services and durables is then characterized by the following two Euler equations:
\[
\begin{align*}
(\rho - \gamma)\hat{c}_t - \rho\hat{s}_t &= \hat{\lambda}_t + b^c_t + b^s_t \\
(\rho - \gamma)\hat{c}_t - \rho\hat{d}_t &= \frac{1}{1 - \beta(1 - \delta)} \left( \hat{\lambda}_t + b^c_t + b^d_t \right) \\
&\quad - \frac{\beta(1 - \delta)}{1 - \beta(1 - \delta)} \mathbb{E}_t \left[ \hat{\lambda}_{t+1} + b^c_{t+1} + b^d_{t+1} \right] \tag{A.7}
\end{align*}
\]

The analysis in Section 2.2 assumes fixed prices and imposes the boundary condition (6). It thus follows that \( \hat{\lambda}_t = 0 \) for all \( t \), and so we can solve for the impulse responses of services and durables consumption by solving the system (A.3), (A.6) and (A.7).

Example parameterization. For our quantitative illustration in Figure 2, we set \( \gamma = \rho = 1 \), \( \beta = 0.99 \), \( \delta = 0.068 \), and \( \phi = 0.9 \), with \( \tilde{\phi} \) set as in (A.4). All numbers are chosen in line with the quantitative model of Section 4.2.

A.2 Details on Model Extensions

This section provides supplementary details on all model extensions discussed in Section 2.3.

Adjustment costs. In the model with durable adjustment costs, the household FOC for durable consumption demand becomes
\[
(\rho - \gamma)\hat{c}_t - \rho\hat{d}_t = \frac{1}{1 - \beta(1 - \delta)} \left[ \hat{\lambda}_t + b^c_t + b^d_t + \kappa(\hat{d}_t - \hat{d}_{t-1}) \right] \\
- \frac{\beta(1 - \delta)}{1 - \beta(1 - \delta)} \mathbb{E}_t \left[ \hat{\lambda}_{t+1} + b^c_{t+1} + b^d_{t+1} + \kappa(\hat{d}_{t+1} - \hat{d}_t) \right] \tag{A.8}
\]

All other model equations are unaffected.
Richer preferences. For our first extension, we consider household felicity functions of the form

\[ u(d) = \frac{d^{1-\gamma} - 1}{1-\gamma} \]

where

\[ d = \left( \int_0^1 \tilde{\phi}_i d_i^{1-\rho} d_i \right)^{\frac{1}{1-\rho}} \]

The depreciation rate of good \( i \) is \( \delta_i \), and we set \( \tilde{\phi}_i \) to ensure that all goods have identical consumption shares, i.e. \( \delta_i d_i \) is the same for all \( i \). As in the baseline model, all varieties \( i \) are produced out of a common final consumption good. To simplify the algebra we assume that \( d_i = 1 \) for all varieties \( i \), giving \( \bar{y} = E_i(\delta_i) \equiv \delta \). We also impose throughout that \( \gamma = \rho \). With \( \beta = 1 \), the path of durable holdings in response to a transitory common demand shock \( b_c + b_s \) satisfies

\[ \hat{d}_{it} = -\frac{1}{\gamma} \frac{1 - \rho b_i (1 - \delta_i)}{\delta_i \rho t} b_c \]

Second, we allow for \( \rho \neq \gamma \) — that is, durables and non-durables demand can be either substitutes or complements. For transitory preference shocks, optimal household consumption behavior is now fully characterized by the following system of equations:

\[ \hat{c}_t = \frac{\phi}{\phi + [1 - \beta(1 - \delta)] \frac{1}{\delta} (1 - \phi)} \hat{s}_t + \frac{[1 - \beta(1 - \delta)] \frac{1}{\delta} (1 - \phi)}{\phi + [1 - \beta(1 - \delta)] \frac{1}{\delta} (1 - \phi)} \hat{d}_t \]  

\[ (\rho - \gamma)\hat{c}_t - \rho \hat{s}_t = b_c^t + b_s^t \]  

\[ (\rho - \gamma)\hat{c}_t - \rho \hat{d}_t = \frac{1}{1 - \beta(1 - \delta)} \left( b_c^t + b_d^t \right) \]

For simplicity we assume that \( \beta = 1 \), giving weights of \( \phi \) and \( 1 - \phi \) in (A.11). Straightforward algebra then gives the good-specific shock DCIRs

\[ y^s = 1 + (1 - \delta) \frac{\left( \frac{\gamma}{\rho} - 1 \right) (1 - \phi)}{1 + \left( \frac{\gamma}{\rho} - 1 \right) \phi - \frac{\gamma}{\rho} (1 - \delta)} \]

and

\[ y^d = 1 - (1 - \delta) \frac{1 + \left( \frac{\gamma}{\rho} - 1 \right)}{1 + \left( \frac{\gamma}{\rho} - 1 \right) \phi (1 - \delta)} \]

We consider the arguably empirically relevant case of \( \rho < \gamma \) — services and durables are net substitutes. Now consider first a pure services demand shock. As demand for services decreases, spending on durables increases. This spending is reversed at \( t = 1 \), so in present-value terms the recession becomes even costlier. The opposite is true for a demand shock to durables and, since durables as usual dominate aggregate consumption dynamics, for a common demand shock.

Incomplete markets. We consider an extension of the baseline model with a fringe \( \mu \in (0, 1) \) of hand-to-mouth households, and let \( \eta \) denote the elasticity of their income to market income.
Total consumption expenditure of every hand-to-mouth household $H$ satisfies

$$\phi \hat{s}_t^H + (1 - \phi) \hat{c}_t^H = \eta \hat{y}_t$$  \hspace{1em} (A.13)

Finally, the optimal split between services and durable consumption is governed by the following relation:

$$(\rho - \gamma) \hat{c}_t^H - \rho \hat{d}_t^H = \frac{1}{1 - \beta(1 - \delta)} \left[ (\rho - \gamma) \hat{c}_t^H - \rho \hat{s}_t^H - b_s^t + b_d^t \right]$$

\[ - \frac{\beta(1 - \delta)}{1 - \beta(1 - \delta)} \mathbb{E}_t \left[ (\rho - \gamma) \hat{s}_{t+1}^H - \rho \hat{s}_{t+1}^H - b_s^{t+1} + b_d^{t+1} \right] \]  \hspace{1em} (A.14)

Optimal consumption behavior of non-hand-to-mouth households (indexed by an $R$ superscript) is governed by the same equations as before, and total services and durables consumption are then given as

$$\hat{s}_t = (1 - \mu) \hat{s}_t^R + \mu \hat{s}_t^H$$  \hspace{1em} (A.15)

$$\hat{d}_t = (1 - \mu) \hat{d}_t^R + \mu \hat{d}_t^H$$  \hspace{1em} (A.16)

This expanded set of equations completes the equilibrium characterization.

**Richer supply-side models.** Finally we consider models with imperfectly sticky prices; that is, we now close the production side of our economy with a general New Keynesian Phillips curve \( (A.1) \), with the slope $\zeta$ given as

$$\zeta = \frac{(1 - \theta_p)(1 - \beta \theta_p)}{\theta_p} (\gamma + \varphi)$$

where $1 - \theta_p$ is the probability of a price re-set and $\varphi$ is the Frisch elasticity of labor supply (Galí, 2015). For our quantitative illustration in Figure A.1 we choose the same baseline parameterization as for Figure 2 and additionally set $\theta_p = 0.9$ and $\varphi = 1$, as in Section 4.2.
Figure A.1: Recession dynamics in a model with partially demand-determined output and purely transitory shocks. Responses correspond to: a common demand shock (solid blue), a pure durables shock (dashed light blue), a pure services shock (dashed light orange), and a combined common and services demand shock reproducing a COVID-19-style recession (solid orange).
B Empirical appendix

This appendix provides further details for the empirical exercises in Section 3.

B.1 Monetary Policy

We estimate a recursive VAR in a sectoral measure of consumption, aggregate consumption, aggregate GDP (all real), the GDP deflator, and the federal funds rate, in this order. We consider three specifications, changing the sectoral measure of consumption from durables to non-durables to services. All series are taken from the St. Louis Fed’s FRED database.

Our three VARs are estimated on a quarterly sample from 1960:Q1 — 2007:Q4, with four lags, a constant and a linear time trend, and with a uniform-normal-inverse-Wishart prior over the orthogonal reduced-form parameterization (Arias et al., 2018). Throughout, we display confidence bands constructed through 10,000 draws from the model’s posterior. Finally, to construct a posterior credible set for the DCIR difference of durables- and services-led recession, we estimate a single VAR containing all consumption series.

B.2 Uncertainty

Our analysis of uncertainty shocks closely follows Basu & Bundick (2017). We estimate recursive VARs in the VIX as a measure of uncertainty shocks, real GDP, the GDP deflator, and real measures of sectoral consumption (durables, non-durables, services). By the results in Plagborg-Møller & Wolf (2020), this specification is asymptotically equivalent to direct projection on innovations in the VIX. All series are taken from the replication files for Basu & Bundick (2017). We estimate the recursive VAR on a quarterly sample from 1986:Q1 — 2014:Q4, and include four lags.11 As before we include a constant and a linear time trend, impose a uniform-normal-inverse-Wishart prior over the orthogonal reduced-form parameterization of the VAR, and draw 10,000 times from the model’s posterior.

Figure B.1 shows the sectoral consumption impulse responses, all scaled to show a peak drop in consumption of -1 per cent. As predicted by theory and as in our application to monetary policy transmission, we find that durables expenditures overshoot and then return to baseline, while non-durables and services expenditure return to baseline from below.

Figure B.2 uses these impulse response estimates to construct a shift-share evaluation of the causal effects of recession composition on recovery speed, analogous to the analysis in Section 4.1. As in our baseline monetary policy exercise, we find that recovery from a recession as tilted towards services as the COVID-19 pandemic is predicted to be substantially slower than recovery.

\[ \text{11 The results are unaffected with longer lag lengths, which reduce precision but ensure accurate projection at longer horizons.} \]
Figure B.1: Quarterly impulse responses to an uncertainty shock (à la Basu & Bundick (2017)) by consumption spending category, all normalized to drop by -1% at the trough. The solid blue line is the posterior mean, while the shaded areas indicate 16th and 84th percentiles of the posterior distribution, respectively.

from an otherwise identical durables-led recession; here, the estimated DCIR difference is 47.9 per cent, and again the 68 per cent posterior credible set does not contain 0.

Figure B.2: Shift-share point estimates of the impulse response of aggregate consumption to sectoral demand shocks, quarterly horizon, evaluated at the posterior mode of the VAR of Appendix B.2. The grey shaded area shows the range of possible impulse responses with positive weights on all spending components and normalized to lower consumption by 1 per cent at the trough. The blue and orange lines, respectively, correspond to the weights given in Figure 1.
B.3 Oil

For our analysis of oil price shocks we take the shock series from Hamilton (2003), and order it first in a recursive VAR containing the shock measure, real GDP, the GDP deflator, aggregate consumption, and sectoral measures of consumption. The model specification is largely as before: We estimate the VAR on a sample from 1970:Q1 — 2006:Q4 (dictated by data constraints), include 8 lags to ensure for accurate projection at long horizons, all for a constant and a linear time trend, and use Bayesian estimation methods.

Since the oil price shock directly reflects relative sectoral prices at a level finer than the durable/non-durable distinction considered in most the paper, we include several granular measures of sectoral consumption. The results from a subset of our experiments are reported in Figure B.3.

![Figure B.3: Quarterly impulse responses to an oil shock (à la Hamilton (2003)) by consumption spending category, all normalized to drop by -1% at the trough. The solid blue line is the posterior mean, while the shaded areas indicate 16th and 84th percentiles of the posterior distribution, respectively.](image)

Durables show the expected overshoot. At a finer sectoral level, we show that expenditures on gas and transport show a similar overshoot. Intuitively, transport — in particular holiday travel — is arguably a memory good and so behaves like a durable good, explaining the overshoot in transport itself as well as the complementary gas expenditure (Hai et al., 2013). In contrast, expenditure on food, clothes and financial services all decline in the initial recession, but then only recover gradually and without much of an overshoot.
B.4 Unconditional Dynamics

We estimate univariate autoregressive representations for our three main sectoral consumption series (durables, non-durables, services) on the largest possible sample, from 1960:Q1 — 2019:Q4. To flexibly capture general Wold dynamics in each individual series we include six lags, with results largely unchanged for even more flexible lag specifications. We then compute DCIRs for Wold impulse response functions, discounting using an annual real interest rate of 4 per cent.

Our main conclusion is that innovations in non-durables and services spending are much more persistent than innovations in durables spending, giving large differences in the implied DCIRs. While not tied to any particular structural shock interpretation, this reduced-form unconditional evidence is also in line with the predictions of our basic theory.
C Proofs

C.1 Proof of Proposition 1

We guess and verify that the aggregate effects of the shocks are entirely static: $\hat{s}_t$ and $\hat{d}_t$ only respond at $t = 0$, so output only responds at $t = 0$ and $t = 1$. Under this conjecture, and since $\hat{\lambda}_t = 0$, the equilibrium system is

\[
\begin{align*}
-\gamma \hat{s}_t &= b^c_t + b^s_t \\
-\gamma \hat{d}_t &= \frac{1}{1 - \beta(1 - \delta)} \left( b^c_t + b^d_t \right)
\end{align*}
\]

Consider first the two pure sectoral shocks. With $\sigma^d = \gamma \frac{\delta}{1 - \phi} \left[ 1 - \beta(1 - \delta) \right]$ and $\sigma^s = \gamma \frac{1}{\phi}$ we get that $\hat{y}_0 = -1$, as desired; given this impact contraction, and by the definition of $\hat{e}_t$, we find $\hat{y}^d_1 = (1 - \delta)$. Since the common shock is just a sum of two equal-volatility sectoral shocks, the desired unit contraction in aggregate output for that common demand shock requires

\[
\sigma^c = \gamma \times \left\{ \phi + \frac{1 - \phi}{\phi} \frac{1}{1 - \beta(1 - \delta)} \right\}^{-1}
\]

The weights in (10) then follow from straightforward algebra.

C.2 Proof of Corollary 1

Consider (10) and let $\beta \to 1$, $\delta \to 0$. The conclusion is then immediate from (8) and (9).

C.3 Proof of Proposition 2

Simplifying the FOCs (A.6) - (A.7) and using the properties of the stochastic shocks, we get the simplified system

\[
\begin{align*}
-\gamma \hat{s}_t &= b^c_t + b^s_t \\
-\gamma \hat{d}_t &= \frac{1 - \rho \beta(1 - \delta)}{1 - \beta(1 - \delta)} \left( b^c_t + b^d_t \right)
\end{align*}
\]

Again consider first the two pure sectoral shocks. We can now engineer the desired unit impact contraction of output by setting $\sigma^d = \gamma \frac{\delta}{1 - \phi} \frac{1 - \beta(1 - \delta)}{1 - \rho \beta(1 - \delta)}$ and $\sigma^s = \gamma \frac{1}{\phi}$; the implied dynamics of $\hat{s}_t$ and $\hat{e}_t$ then immediately give DCIRs in (14). As before, since the common shock is just a sum of two equal-volatility sectoral shocks, the desired unit contraction in aggregate output for that common demand shock now requires

\[
\sigma^c = \gamma \times \left\{ \phi + \frac{1 - \phi}{\delta} \frac{1 - \rho \beta(1 - \delta)}{1 - \beta(1 - \delta)} \right\}^{-1}
\]
The weights in (16) then follow from straightforward algebra.

C.4 Proof of Proposition 3

The non-durable consumption block of the model is unaffected. We will guess and verify that the solution for durables takes the form

\[ \hat{d}_t = \theta_d \hat{d}_{t-1} + \theta_b \left( b_t^c + b_t^d \right) \]

Under the stated restrictions, the optimality condition for durable consumption demand becomes

\[ -\gamma \hat{d}_t = \frac{1}{1 - \beta(1 - \delta)} \left[ b_t^c + b_t^d + \kappa(\hat{d}_t - \hat{d}_{t-1}) \right] - \frac{\beta(1 - \delta)}{1 - \beta(1 - \delta)} \mathbb{E}_t \left[ \kappa(\hat{d}_{t+1} - \hat{d}_t) \right] \]

Plugging in the guess and matching coefficients, we get

\[ \theta_d = 1 - \delta \gamma \frac{\sqrt{1 + \frac{4\kappa}{\delta \gamma} - 1}}{2\kappa} \]
\[ \theta_b = -\frac{1}{\kappa} \theta_d \]

The expression for the DCIR in (19) then follows from straightforward algebra. Finally, using L'Hôpital's rule, we can establish that \( \lim_{\delta \to 0} y^d = 0 \). \qed

C.5 Proof of Proposition 4

The impulse response for total output is given as

\[ \hat{y}_t = \int_0^1 \left[ \frac{1}{\delta} \hat{d}_{it} - (1 - \delta) \frac{1}{\delta} \hat{d}_{it-1} \right] di \]

We are interested in the DCIR of output, given as

\[ \hat{y} = \sum_{t=0}^{\infty} \hat{y}_t = \int_0^1 \frac{1}{\delta} \sum_{t=0}^{\infty} \left[ \hat{d}_{it} - (1 - \delta) \hat{d}_{it-1} \right] di \]

Using (A.9), we can recover the DCIR of expenditure on good i as

\[ \hat{e}_t = \frac{1 - \rho_b(1 - \delta_i)}{\delta_i} \frac{\delta_i}{1 - \rho_b \gamma} b_0^c \]

We normalize the impact output response to \(-1\), i.e.

\[ \hat{y}_0 = \int_0^1 \frac{11 - \rho_b(1 - \delta_i)}{\delta_i} \frac{1}{\gamma} b_0^c di = -1 \]
The output DCIR is then
\[ \dd y = -\frac{1}{1-\rho_b} \int_0^1 \frac{1}{\rho_b} \left[ 1 - \rho_b (1 - \delta_i) \right] b_0 d_i \]

Simplifying, using the fact that \( \dd y_0 = -1 \):
\[ \dd y = \frac{1 - \rho_b (1 - \delta)}{1 - \rho_b \left( 1 - \dd \delta_i \right)} \int_0^1 \left( \frac{1 - \rho_b}{\delta_i} + \frac{\rho_b}{1} \right) d_i \]
as claimed. The special case of a transitory shock (\( \rho_b = 0 \)) is then immediate. \( \square \)

C.6 Proof of Proposition 5

First set \( \eta = 1 \). It is then straightforward to verify that all equilibrium relations are satisfied for \( \dd x_t^R = \dd x_t^H \) for \( x \in \{s, d, e, c\} \). Now consider arbitrary \( \eta \). Then, following the same steps as in Bilbiie (2019b), we can easily verify that the total response of output is scaled by a factor of \( \frac{1 - \mu}{1 - \mu \eta} \), with unchanged shape. This completes the argument.

C.7 Proof of Proposition 6

Let \( \dd \tilde{\lambda}_t \equiv \lambda_t - \phi_t^i m_0 \). We can then write the consumption FOCs as
\[
\begin{align*}
(\rho - \gamma) \dd \tilde{c}_t - \rho \dd \tilde{d}_t &= \dd \tilde{\lambda}_t + \phi_t^i m_0 \\
(\rho - \gamma) \dd \tilde{c}_t - \rho \dd \tilde{a}_t &= \frac{1}{1 - \beta (1 - \delta)} \left( \dd \tilde{\lambda}_t + \phi_t^i m_0 \right) - \frac{\beta (1 - \delta)}{1 - \beta (1 - \delta)} \mathbb{E}_t \left( \dd \tilde{\lambda}_{t+1} + \phi_{t+1}^i m_0 \right)
\end{align*}
\]
Next, plugging the Taylor rule into the bond FOC, we have
\[
\dd \tilde{\lambda}_t = \phi_t \dd \tilde{r}_{t-1} + (1 - \phi_t) (\phi_{t+1} \dd \tilde{\pi}_t + \phi_{t+1} \dd \tilde{y}_t + m_t) - \mathbb{E}_t \left( \dd \tilde{r}_{t+1} + \dd \tilde{\lambda}_{t+1} \right)
\]
Using the definition of \( \dd \tilde{\lambda}_t \) and defining \( \dd \tilde{r}_t^m \equiv \dd r_t^m - \phi_t^i (1 - \phi_t) m_0 \), we can re-write this equation as
\[
\dd \tilde{\lambda}_t = \phi_t \dd \tilde{r}_{t-1}^m + (1 - \phi_t) (\phi_{t+1} \dd \tilde{\pi}_t + \phi_{t+1} \dd \tilde{y}_t) - \mathbb{E}_t \left( \dd \tilde{r}_{t+1}^m + \dd \tilde{\lambda}_{t+1} \right)
\]
We have thus recast the system with monetary shocks in \( (\dd \tilde{\lambda}_t, \dd \tilde{r}_t^m) \) as a system with consumption demand shocks in the shifted variables \( (\dd \tilde{\lambda}_t, \dd \tilde{r}_t^m) \). It follows that all variables except for \( (\dd \tilde{\lambda}_t, \dd \tilde{r}_t^m) \) respond to a monetary shock exactly as they do to a consumption demand shock, as claimed. \( \square \)

C.8 Proof of Proposition 7.

The conditions of the proposition are consistent with the requirements of Proposition 3 and Proposition 6, so it follows immediately that \( \dd \tilde{s}_t^m \) and \( \dd \tilde{e}_t^m \) are the impulse responses of services and durables spending, respectively, to services and durables demand shocks with volatility \( \sigma^m \) and
persistence $\phi^r$. Thus, since $\hat{s}_i^d = \hat{s}_i^s = 0$, it follows that

$$\frac{s}{\bar{y}}\hat{s}_i^m + \frac{\bar{e}}{\bar{y}}\hat{e}_i^m$$

is the impulse response of total output to joint sectoral demand shocks $(b_t^s, b_t^d)$ with volatility $\sigma^m$ and persistence $\phi^r$. But then

$$\hat{y}_t = \xi^m s_t^m + \xi^d e_t^m$$

is the response of total output to joint sectoral demand shocks $(b_t^s, b_t^d)$ with volatilities $\sigma^s = \sigma^m \xi^s \frac{\frac{\bar{s}}{\bar{y}}}{\sigma^d = \sigma^m \xi^d \frac{\frac{\bar{g}}{\bar{y}}}}$ and persistence $\phi^r$, as claimed. \hfill \Box