Demand Composition and the Strength of Recoveries†

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Abstract: We argue that recoveries from ordinary, durables-led recessions tend to be stronger than recoveries from recessions biased towards services, like COVID-19. The argument relies only on basic consumption theory together with output being demand-determined: Following a contraction of durables spending today, households need to replenish their durable stock tomorrow, generating an internal tendency towards recovery that is largely absent after services recessions. We find strong support for this pent-up demand mechanism in time series data, and quantify its importance using (i) a semi-structural shift-share design, and (ii) a structural model. Our results suggest that, in terms of the present discounted value of lost output, a recession as services-led as COVID-19 is between 60-80 per cent costlier than an otherwise identical, ordinary durables-led recession. Finally, we show that our shift-share also measures the expected output loss made by a policymaker who treats a services recession like an ordinary durables 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 on services remain relatively stable. Figure 1 reveals, however, that this average pattern masks substantial heterogeneity across recessions. For example, the decline in durable consumption (like cars) was particularly salient in the 1973 recession, whereas the decline in services (like food at restaurants) has been the largest contributor to consumption drops in the COVID-19 pandemic. Over the coming years, with the U.S. continuing its move towards being a services economy, aggregate booms and busts are likely to be increasingly driven by the dynamics of the services sector.

In this paper, we argue that the composition of consumption declines in recessions plays an important role in determining the strength of the subsequent recovery. In particular we claim that, everything else equal, recoveries tend to be stronger when consumption declines are concentrated among durables, and weaker when the initial decline is more biased towards services (or non-durables). The argument relies only on basic consumer theory in conjunction with aggregate output being (at least partially) demand-determined: When emerging from a durables-led recession, households need to replenish their depreciated stock of durables, resulting in a Z-shaped cycle of durable expenditures. Such “pent-up demand” effects, in contrast, are largely absent after more services-led recessions. Here, the lost consumption is simply foregone and so the overall cycle of services expenditures is V-shaped.

Our analysis proceeds in four steps. First, we formalize the argument in a multi-sector model of demand-driven fluctuations, with sectors differing only in the durability of their output. In this economy we can prove that, conditional on a recession today, the present value of future expected output is increasing in the recession’s bias towards durable sectors. Second, we provide time series evidence supporting our mechanism: In response to shocks to household spending, durables expenditure shows strong pent-up demand effects, while non-durables and services do not. Third, we quantify the effect of spending composition on recovery strength using (i) a semi-structural shift-share design and (ii) a fully parameterized version of our model. Both exercises suggest that a recession as services-led as COVID-19 will be, everything else equal, around 60 to 80 per cent costlier — in the sense of the present value of lost output — than an equally deep, ordinary durables-led recession. Fourth, we combine theory and measurement to quantify the output losses made by a policymaker who looks only at aggregate output, ignoring any information on sectoral recession incidence. In a services recession, policy needs to be easier for longer to offset the missing pent-up demand.
We begin by illustrating the basic logic of the pent-up demand mechanism in a stripped-down two-sector macro model. A representative household derives utility from her stock of durable goods and from the flow of services consumption. For simplicity we additionally assume that: (i) the two goods are neither substitutes nor complements in household preferences, and (ii) monetary policy is neutral, in the sense that it sets nominal rates to keep the real rate of interest fixed. Throughout we make a \textit{ceteris paribus} assumption: To isolate the effect of durability on recession and recovery dynamics, we consider sectors that are identical in all respects except for the durability of their output.

We use our model economy to study the responses of consumer expenditure and output to different types of demand shocks, with particular focus on the cumulative impulse response of output (CIR) as our measure of the strength of recoveries. First, to illustrate the core mechanism, we consider pure shocks to durables and services demand, respectively. Following the durables shock, spending on durables initially declines, but then temporarily overshoots due to pent-up demand effects (i.e., a Z-shaped cycle). In the limit case of a perfectly durable good, the boom tomorrow perfectly offsets the bust today, so the CIR of output is exactly zero. In contrast, following the services shock, services expenditures initially decline, but then invariably recover from below (i.e., a V-shaped cycle). Second, we consider more realistic shocks that affect demand for both goods. Since durables spending is much more elastic than

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{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.}
\end{figure}
spending on non-durables, the dynamics of aggregate output following a uniform spending shock are Z-shaped, closely resembling those of a durables-only shock. As the weight on services in the output contraction today is increased, the CIR of output becomes more and more negative, precisely because of the missing pent-up demand effects.

We then translate our conclusions on impulse responses to sectoral and aggregate shocks into a general forecasting result for the dynamics of business-cycle recoveries. To showcase the generality of our arguments we do so in the context of a much-extended, quantitative version of our macro model, now featuring: adjustment costs on durables, incomplete markets and hand-to-mouth households, an arbitrary number of goods varying in their durability, and shocks to sectoral as well as aggregate supply and demand. In this rich environment, we compute the expectation of future output conditional on the vector of sectoral output gaps today. Our main result is that, given a recession today, the expected recovery — as measured by the output CIR — is stronger if the recession is concentrated in more durable sectors, precisely because of pent-up demand effects.

The pent-up demand mechanism receives strong support in aggregate U.S. time series data. The key testable implication of our theory is that, after a negative shock that commonly affects demand for all goods, spending on durables should recover strictly faster than spending on services and non-durables. As our main empirical experiment, we test this prediction using monetary shocks as arguably the most well-studied example of a shock to private spending. We find evidence in line with the predictions of theory: 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) reduced-form forecast errors of sectoral output.1 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 quantify the effect of sectoral recession incidence on the strength of the subsequent recovery. We ask: everything else equal, how much stronger is the recovery expected to be when the composition of consumption declines resembles that of an ordinary durables-led recession compared to that of the COVID-1

1 This third experiment is closest in spirit to our theoretical result of aggregate output forecasting conditional on recessions today. However, since we cannot verify the ceteris paribus assumption empirically, we view this exercise as a supplementary check, and not as the most convincing piece of evidence.
19 recession? We answer this question with two quantitative measurement exercises.

The first approach is a simple shift-share. We prove that, even in our extended quantitative model, the behavior of aggregate consumption in a demand-driven recession of arbitrary sectoral incidence can be estimated semi-structurally, simply by suitably re-weighting and then summing the category-specific consumption responses to a uniform demand shock. Using the results from our 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 return to our quantitative model, and consider a wide range of parameter values for adjustment costs, shock persistence, and price stickiness; further, we relax the assumption of a neutral monetary policy. For each parameterization, we solve the model, and then compute expected future output paths conditional on different sectoral splits of today’s recession. The results from this structural exercise align closely with those of the semi-structural shift-share: Across the (large) parameter space entertained in our analysis, recessions biased towards services are robustly followed by weaker recoveries and thus costlier in present-value output terms than durables-led fluctuations.

Finally, we discuss the implications of our results for the design of macroeconomic stabilization policy. We again consider the quantitative model, but now with additional exogenous constraints on the policymaker’s information set. First, we force macroeconomic stabilization policy — i.e., the path of real rates — to be measurable with respect to aggregate output. In this case, following a services-led recession, the policymaker continually understimulates, as she wrongly expects a fast recovery driven by pent-up demand dynamics. We prove that our simple shift-share is a sufficient statistic for the expected output shortfall under this na"ive policy. Second, we show that perfect output stabilization is attainable with a simple rule that sets the policy instrument as a function of output in all sectors. The rule dictates that, in a services recession, policy should be easier for longer than in ordinary recessions.

**Literature.** This paper relates and contributes to several strands of literature.

First, a large literature considers the implications of sectoral heterogeneity for business-cycle dynamics. On the production side, one branch highlights heterogeneity in nominal rigidities across sectors (Carvalho, 2006; 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; Farhi & Baqaee, 2020). We instead highlight the importance of heterogeneity on the demand side, sorting goods and
sectors by their durability. Our emphasis on durable goods is shared by Barsky et al. (2007), who point out that aggregate fluctuations tend to be dominated by durables, and Berger & Vavra (2015), who document that the elasticity of durable spending varies over the cycle. Similar to our analysis, Mankiw (1982) and McKay & Wieland (2020) highlight that durables spending tends to reverse over time — the pent-up demand effects.\(^2\) We offer additional insights by analytically characterizing these effects in general equilibrium, arguing that they are quantitatively meaningful, and drawing implications for business-cycle dynamics as well as the design of stabilization policy.

Second, many papers have sought to understand the determinants of the strength and, more recently, shape of recoveries. The mechanisms discussed in previous work include: the nature of business cycle shocks (Galí et al., 2012; Beraja et al., 2019), structural forces (Fukui et al., 2018; Fernald et al., 2017), secular stagnation (Hall, 2016), 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 how the subsequent recovery is likely to shape up.

Third, our results relate to the exploding literature on the COVID-19 recession. Empirically, it has been established that this recession, at least in its early stages, was largely services-led (Chetty et al., 2020; Cox et al., 2020). We add to this line of work by connecting sectoral incidence to widely discussed shapes for 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.\(^3\) In the context of COVID-19, our focus on sectoral incidence is also shared by Guerrieri et al. (2020).

**OUTLINE.** Section 2 provides analytical characterizations of recession dynamics in a multi-sector general equilibrium model. 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 effect of demand composition on the strength of recovery. Finally, in Section 5, we discuss implications for the design of stabilization policy. Section 6 concludes, with supplementary details and proofs relegated to several appendices.

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\(^2\) On the investment side, the same reversal effects are discussed in Appendix B.1 of Rognlie et al. (2018).

\(^3\) For example, Ricardo Reis has argued for an ABC-shaped recovery (see https://threadreaderapp.com/thread/1253988696749150208.html).
2 Pent-up Demand and the Strength of Recoveries

In this section, we study business cycles in an economy with goods of heterogeneous durability. Section 2.1 outlines our general environment, Section 2.2 illustrates the basic pent-up demand mechanism in a stripped-down model variant, and Section 2.3 derives a general forecasting result on recovery dynamics by sectoral recession incidence.

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, disease transmission risk in the consumption of some goods, ...).

\textbf{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, $b_t^c$, $b_t^s$ and $b_t^d$ — 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 generic shock $b$ will be indicated using superscripts. Finally, we will use boldface notation to denote cumulative impulse response functions (CIR). For a generic variable $x_t$ in response to a generic shock $b$:

$$x^b \equiv \sum_{t=0}^{\infty} \tilde{x}^b_t$$

\textbf{Households.} Household preferences over services $s_t$, durables $d_t$ and hours worked $\ell_t$ are represented by the utility function

$$\mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \beta^t \{ u(s_t, d_t; b_t) - v(\ell_t) \} \right]$$

\footnote{As we show in Section 2.3, our results on the pent-up demand mechanism and recession forecasting extend without any change to an extended variant of this economy in which households consume $N$ different goods, some households are hand-to-mouth, and sectoral productivity is stochastic.}
where
\[ u(s, d; b) = e^{b^c} \left[ e^{b^s \tilde{c}} s^{1-\tilde{c}} + e^{b^d (1 - \tilde{d}) \tilde{c} d^{1-\tilde{c}}} \right]^{1-\gamma} - 1, \quad v(\ell) = \frac{\ell^{1+\frac{1}{\eta}}}{1 + \frac{1}{\psi}}. \]

For convenience we normalize steady-state consumption expenditure to one. Letting \( \phi \) denote the expenditure share of services consumption, we have \( \bar{s} = \phi \) and \( \delta \bar{d} = 1 - \phi \), where \( \delta \) is the depreciation rate of durables. The parameter \( \tilde{\phi} \) is then pinned down to make these expenditure shares consistent with optimal behavior (see Appendix A.1 for details).

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
\[
p^s_t s_t + p^d_t [d_t - (1 - \delta)d_{t-1}] + \psi(d_t, d_{t-1}) + a_t = w_t \ell_t + \frac{1 + r^n_{t-1}}{1 + \pi_t} a_{t-1} + q_t
\]
where the durables adjustment cost function satisfies
\[
\psi(d_{-1}, d) = \frac{\kappa}{2} \left( \frac{d}{d_{-1}} - 1 \right)^2 d \tag{1}
\]

In parts 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.

**PRODUCTION.** Both services and durable goods are produced by aggregating varieties sold by monopolistically competitive retailers. Production only uses labor, and price-setting is subject to standard nominal rigidities. Since the problem of retailers is entirely standard we relegate details to Appendix A.1. To first order, aggregate output \( y_t \) then satisfies\(^5\)
\[
\hat{y}_t = \phi \hat{s}_t + (1 - \phi) \hat{c}_t
\]

We emphasize that our set-up implies fixed real relative prices of durables and services;

\(^5\)For simplicity, we assume that durables adjustment costs are either perceived utility costs, or get rebated back lump-sum to households.
this assumption of a highly elastic supply of durable goods is consistent with the absence of (short-run) relative price responses documented in previous work (House & Shapiro, 2008; McKay & Wieland, 2020). In Section 2.3 we consider an extension of our model in which sector-specific supply shocks lead to changes in real relative prices.

**Shocks.** The disturbances $b_t^c$, $b_t^s$ and $b_t^d$ follow exogenous AR(1) processes with common persistence $\rho_b \geq 0$ and innovation volatilities $\{\sigma_{b_t^c}, \sigma_{b_t^s}, \sigma_{b_t^d}\} > 0$, respectively.

**Policy & Equilibrium Selection.** We assume that monetary policy is neutral, in the sense that it fixes the expected real rate, i.e., $\hat{r}_t = \phi\pi E_t[\hat{\pi}_{t+1}]$, with $\phi = 1$. To ensure equilibrium determinacy given this assumption, we additionally impose that output impulse responses to any shock $b$ satisfy

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

This equilibrium selection can be formally justified with the continuity argument of Lubik & Schorfheide (2004): For $\phi \to 1^+$, our equilibrium selection delivers continuity in $\phi$.\(^6\)

We will maintain this assumption on monetary policy for all analytical results. However, we relax it for the quantitative model-based analysis in Section 4.2.

### 2.2 The Pent-Up Demand Mechanism

We now use a stripped-down version of the baseline model of Section 2.1 to cleanly illustrate the pent-up demand mechanism. Specifically, we assume that: all demand shocks are perfectly transitory ($\rho_b = 0$), there are no durables adjustment costs ($\kappa = 0$), and durables and services are neither complements nor substitutes ($\zeta = \gamma$). Further, for all experiments in this section, we scale the shock volatilities $\{\sigma_{b_t^c}, \sigma_{b_t^d}, \sigma_{b_t^s}\}$ to normalize the impact impulse response of output to each shock to -1 per cent.

**Pure Sectoral Shocks.** Proposition 1 characterizes the response of aggregate output to pure sectoral demand shocks $\{b_t^c, b_t^d\}$, and Figure 2 provides a graphical illustration.

**Proposition 1.** In the stripped-down model, the impulse responses of aggregate output to

\(^6\)Equivalently, our results can be interpreted as applying to an economy with fully rigid prices and fixed nominal rates, as in Auclet et al. (2018).
one-off shocks to services and durables demand, $b_t^s$ and $b_t^d$, satisfy

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

and

$$\hat{y}_0^d = -1, \quad \hat{y}_1^d = (1 - \delta), \quad \hat{y}_t^d = 0 \quad \forall t \geq 2$$

Consider first the pure durables demand shock, $b_t^d$, 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 CIR shows that the lost output over the cycle (in present value terms) is decreasing in the durability of the durable good:

$$y^d = -1 + (1 - \delta) = -\delta$$

Matters are different for a pure services demand shock $b_t^s$, 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 CIR of output satisfies

$$y^s = -1$$

Taken together, these results imply that, in a CIR sense, the recovery from a recession biased towards services is 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.

**Common Shocks.** We now turn to studying more realistic business cycle fluctuations with mixed spending compositions. To begin, Proposition 2 characterizes output dynamics following a common aggregate demand shock.

**Proposition 2.** In the stripped-down model, the impulse response of aggregate output to a one-off shock to aggregate demand, $b_t^c$ satisfies

$$\hat{y}_t = \hat{y}_t^d + (1 - \hat{y}_t^d)\hat{y}_t^s$$
where the durables weight $\bar{\omega}_d$ is given as

$$\bar{\omega}_d = \frac{1 - \phi}{(1 - \phi) + \phi \delta (1 - \beta (1 - \delta))} > 1 - \phi \quad (2)$$

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

$$\bar{\omega}_d = 1$$

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

The solid blue lines depict impulse responses following the common demand shock. The key takeaway is that the induced dynamics closely resemble those of the durables-only shock $b^d_t$. Intuitively, ordinary demand recessions are mostly durables-led because durable spending is much more intertemporally elastic than spending on services (and non-durable goods). Formally, in (2), the durables weight $\bar{\omega}_d$ always strictly exceeds the share of durable production in total output.\(^7\) 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 CIR associated with a

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\(^7\) 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.
durables-led recession is zero, as the contraction in output at \( t = 0 \) is perfectly offset by an equally large boom at \( t = 1 \). Overall, 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; Auclert et al., 2018).

Finally, the solid orange lines in Figure 2 are the responses to a mixed demand shock \( b_t^c + b_t^d \), with the relative shock volatilities chosen so that the composition of expenditures during the recession is as the one observed in the early stages of the COVID-19 recession (see Figure 1). With durables spending accounting for little of the initial decline in output, there is only 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.

### 2.3 A General Forecasting Result

In this section we analyze the pent-up demand mechanism in richer models and discuss its implications for expected recovery dynamics. We first continue to fix \( \zeta = \gamma \), but allow for non-zero durables adjustment costs as well as arbitrary shock persistence \( \rho_b \in [0,1) \). Then, at the end of the section, we discuss extensions to economies with arbitrarily many sectors, incomplete markets, demand and supply shocks, and more general preference structures.

**Shock CIRs.** We begin by extending our results on output impulse responses and CIRs. As before, we normalize the impact impulse response of output to each shock to -1 per cent.

**Proposition 3.** Consider the model of Section 2.1 with \( \zeta = \gamma \). The CIRs of aggregate output to persistent shocks to services and durables demand, \( b_t^s \) and \( b_t^d \), satisfy

\[
\begin{align*}
  y^s_t &= -\frac{1}{1 - \rho_b}, \quad y^d_t = -\frac{1}{1 - \rho_b} \frac{\delta}{1 - \theta d}
\end{align*}
\]

where \( \theta_d \in [0,1) \) and \( \lim_{\delta \to 0} \frac{\delta}{1 - \theta_d} = 0 \). If \( \theta_d < 1 - \delta \), then the impulse responses are ranked at all horizons:

\[
\hat{y}^s_t < \hat{y}^d_t, \quad \forall t > 0 \tag{3}
\]

For the common shock \( b_t^c \), the impulse response of aggregate output satisfies

\[
\hat{y}^c_t = \bar{\omega}_d \hat{y}^d_t + (1 - \bar{\omega}_d) \hat{y}^s_t
\]
where \( \lim_{\delta \to 0} \bar{\omega}_d = 1 \).

Proposition 3 reveals that the pent-up demand logic at the heart of our argument remains present in much richer model environments.

First, by drawing out the adjustment process and adding endogenous persistence, adjustment costs invariably weaken pent-up demand effects. However, Proposition 3 reveals that, for sufficiently long-lived durables, the pent-up demand logic remains just as potent as before. Furthermore, as we discuss in detail in Appendix B.3 and Section 4.2, reasonable model parameterizations invariably imply that \( \theta_d \ll 1 - \delta \).

Second, under the impact response normalization, persistent shocks (\( \rho_b > 0 \)) simply scale the overall CIR. For sufficiently persistent shocks, spending on durables may not overshoot as in Figure 2, but — as long as \( \theta_d < 1 - \delta \) — it will always lie strictly above the corresponding service spending impulse response. And third, with \( \lim_{\delta \to 0} \bar{\omega}_d = 1 \), the dynamics of aggregate output following a common shock continue to be dominated by durables spending.

Recovery Forecasting. All results so far illustrate the pent-up demand mechanism by comparing impulse response functions conditional on different aggregate or sectoral shocks. We now map these characterizations of shock-specific impulse responses into a reduced-form forecasting result, i.e., expected recovery dynamics conditional on a recession today with a given sectoral incidence. Our key insight is that the reduced-form dynamic system induced by the model of Section 2.1 is diagonal, so there is a one-to-one correspondence between shock impulse responses and reduced-form forecasts of recovery dynamics.

Proposition 4. Consider the model of Section 2.1 with \( \zeta = \gamma \), and suppose that \( \theta_d < 1 - \delta \). Let \( u_t = (u^s_t, u^d_t)' \) denote the forecast residuals of a reduced-form VAR(\( \infty \)) in \( (\phi \widehat{s}_t, (1 - \phi) \widehat{c}_t)' \). Then, for all \( h \geq 0 \):

\[
\mathbb{E} \left[ \widehat{y}_{t+h} \mid \{ u^s_t = -\omega_s, u^d_t = -\omega_d \} \right] = (\omega_s \cdot \widetilde{y}_t^s + \omega_d \cdot \widetilde{y}_t^d)
\]

and so

\[
\mathbb{E} \left[ \sum_{h=0}^{\infty} \widehat{y}_{t+h} \mid \{ u^s_t = \omega_s, u^d_t = \omega_d \} \right] = (\omega_s \cdot \frac{1}{1 - \rho_b} + \omega_d \cdot \frac{1}{1 - \rho_b} \cdot \frac{\delta}{1 - \theta_d})
\]

\[8\] Briefly, the reason is that, for \( \theta_d = 1 - \delta \), services spending is — counterfactually — exactly as volatile as expenditures on durables (in the sense that \( \bar{\omega}_d = 1 - \phi \)).
Thus, conditional on a recession of given severity $u_s^0 + u_d^0$, expected future output is increasing in the durables share $u_d^0/(u_s^0 + u_d^0)$.

Proposition 4 considers the following thought experiment: An econometrician observes current and past sectoral output $\{\hat{s}_{t-\ell}, \hat{e}_{t-\ell}\}_{\ell=0}^\infty$. At time $t = 0$, aggregate output is unexpectedly low, relative to expectations at $t = -1$; given this surprise, the econometrician then tries to forecast the likely path of recovery. By linearity, we can recover her forecast through a VAR($\infty$). (4) - (5) reveal that this forecast is generally monotone in the durables share of the recession. Importantly, by diagonality of the system, the normalized sectoral impulse responses from Proposition 3 fully characterize the econometrician’s expectations.

Extensions. Our characterizations of impulse responses and our forecasting result generalize with little to no change to various further model extensions. We summarize the main insights here, and relegate further details to Appendix A.2 and Appendix B.2.

Several important model variations leave our results on impulse response functions and reduced-form recovery forecasting almost entirely unchanged. First, allowing for an arbitrary numbers of sectors is notationally involved, but conceptually straightforward. With sector-specific depreciation rates $\delta_i$ and adjustment costs $\kappa_i$, output CIRs scale in $\delta_i/(1-\theta_{id})$, where $\theta_{id} \in [0, \delta_i)$. The model maintains a one-to-one mapping between impulse responses and forecasts, so expected future output dynamics conditional on a recession today are now monotone in $\delta_i/(1-\theta_{id})$ as the right measure of sectoral durability. Second, market incompleteness on the household side — resulting in a fraction $\mu$ of hand-to-mouth households — scales impulse responses up or down, but leaves recovery shapes and so expected recovery dynamics entirely unaffected. And third, supply shocks to relative sectoral productivity move relative prices; in our setting, these relative price shocks induce the exact same output dynamics as shocks to demand. Thus, the characterization in Proposition 4 continues to apply in an economy subject to sectoral as well as aggregate supply and demand shocks.

The characterization of equilibrium dynamics becomes more challenging if services and durables demand are entangled in household preferences (i.e., $\zeta \neq \gamma$). However, in the empirically relevant case of net substitutes ($\zeta < \gamma$), it turns out that our results actually become even stronger: services recoveries are even weaker, and the CIR for a recession in durables demand can become negative.

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9 This property of the model is lost under alternative monetary policy rules. Nevertheless, as we show quantitatively in Section 4.2, our conclusions continue to go through largely unchanged with conventional monetary rules, partial price stickiness, and joint supply and demand shocks.
Finally, in Section 4.2, we will relax our stringent baseline assumption of a neutral monetary authority and instead consider alternative policy rules (together with varying degrees of price stickiness). In this extension we lose the ability to characterize model dynamics in closed form, but document quantitatively that pent-up demand effects continue to operate and shape expected recovery dynamics, exactly as suggested by Proposition 4.

3 Pent-Up Demand in Time Series Data

We now test the pent-up demand mechanism using 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 reduced-form forecast errors in the dynamics of aggregate sectoral consumption.

3.1 Monetary Policy Shocks

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 the model of Section 2.1, again simplified to have

\[ \hat{r}_t^n = \phi \pi E_t [\hat{\pi}_{t+1}] + m_t \]  

We assume that monetary shocks are as persistent as the common demand shock \( b_t^c \). We then get the following equivalence result.

It 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.
Proposition 5. Consider the model of Section 2.1 with $\zeta = \gamma$, extended to feature innovations to the central bank’s rule (6). The impulse responses of all real aggregates $x \in \{s, e, d, y\}$ to (i) a common demand shock $b_{ct}$ with persistence $\rho_b$ and volatility $\sigma_{bc}^2$, and (ii) a monetary shock $m_t$ with persistence $\rho_m = \rho_b$ and volatility $\sigma_m = (1 - \rho_b)\sigma_b^2$ are identical:

\[
\hat{x}_t^c = \hat{x}_t^m
\]

In our model, monetary policy shocks transmit to consumption spending exactly like the pure demand shocks $b_{ct}$ studied in Section 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 strictly faster than the recovery of services and non-durables consumption, at all times $t > 0$ and so in particular in a CIR sense. It is this core prediction that we take to the data.

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.\textsuperscript{11} We include four lags throughout, and estimate the models using standard Bayesian techniques. Details are provided in Appendix C.1.

Results. Consistent with previous work, we find that a contractionary monetary policy shock lowers output and consumption.\textsuperscript{12} Figure 3 decomposes the response of aggregate

\textsuperscript{11}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.

\textsuperscript{12}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.
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.

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 overshoot, 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 in Figure 2.

Our results of heterogeneous spending dynamics by consumption category are 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 C.2 to C.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 in particular 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; as discussed in Appendix A.2, such relative supply shocks will generate pent-up demand effects exactly like the demand shocks studied in Section 2.2. 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 C.3.

Reduced-Form Forecasts. So far, we have focussed on dynamics conditional on particular structural shocks. Appealingly, by fixing a common shock, the ceteris paribus assumption implicit in our theoretical analysis in Section 2 is automatically satisfied. We here complement these shock-specific results with empirical analogues of the reduced-form forecasts in Proposition 4. Implicitly, in looking at such reduced-form forecasts, we are assuming that either (i) sectoral dynamics are largely driven by common, aggregate shocks or
(ii) there is little association between the durability of a sector’s output and the persistence of its idiosyncratic shocks.

To implement the forecasting exercise, we estimate a high-order reduced-form VAR representation in granular sectoral output categories, and then separately trace out the implied aggregate impulse responses to reduced-form innovations in each equation, with each innovation normalized to move total aggregate consumption by one per cent on impact. Consistent with both theory and our previous empirical results, we find that innovations to durables spending move aggregate consumption much less persistently than equally large innovations to non-durables and services spending. In particular, we find that the total consumption CIR for an innovation to non-durables spending is around 80 per cent larger than the analogous durables CIR, with the corresponding number for services an even larger 120 per cent.

4 Quantifying the Effect of Demand Composition

We now quantify the effect of sectoral recession incidence by durability on the likely strength of the subsequent recovery. Formally, in the notation of Section 2.3, our objective is to learn about how the conditional forecast

$$E \left[ \tilde{y}_{t+h} | \{ u_t^s = -\omega_s, u_t^d = -\omega_d \} \right]$$  \hspace{1cm} (7)

varies with incidence $\{\omega_s, \omega_d\}$. The simple model analyzed in Section 2.2 suggests that this causal effect has the potential to be quantitatively meaningful: For a combination of shocks $\{b_t^s, b_t^d, b_t^d\}$ that yield a recession with weights $\{\omega_s, \omega_d\}$, the output CIR is

$$E \left[ \sum_{h=0}^{\infty} \tilde{y}_{t+h} | \{ u_t^s = -\omega_s, u_t^d = -\omega_d \} \right] = - [\omega_s + \omega_d \delta]$$  \hspace{1cm} (8)

A simple back-of-the-envelope calculation based on (8) 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.\(^{13}\) This number, however, is likely to be an upper bound for the actual causal effect — as discussed in Section 2.3, adjustment costs will dampen the strength of pent-up demand effects; similarly, any non-neutral monetary rule in conjunction with imperfectly rigid prices would invariably invalidate (8).

\(^{13}\)This simple calculation uses the shares of Figure 1 and assumes a quarterly durables depreciation rate of around 7 per cent.
In this section we address these concerns in two separate ways. First, in Section 4.1, we show that, even in the general model of Section 2.3, the desired causal effect can be estimated directly via aggregate impulse responses to monetary policy shocks, through a simple shift-share design. As such, this approach is entirely semi-structural, and only relies on our empirical impulse response estimates from Section 3. Second, in Section 4.2, we document that pent-up demand effects remain quantitatively meaningful across a wide range of plausible model parameterizations, including in particular model variants with richer monetary policy rules. Encouragingly, these two very different approaches paint a consistent picture: In present-value terms, a recession as services-led as COVID-19 is around 60-80 per cent costlier than a similarly deep ordinary, durables-led contraction.

4.1 Shift-Share Design

In Section 3.1, we estimated the impulse responses of all components of consumer spending to a change in the monetary policy stance and so, under the conditions of Proposition 5, to a common demand shock $b_t$. To quantify the effect of demand composition on the strength of the recovery, however, we need the responses of aggregate consumption to sectoral demand shocks. Proposition 6 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 6. Consider the model of Section 2.1 with $\zeta = \gamma$, extended to feature innovations to the central bank’s rule as in (6), and let $\tilde{s}_t^m$ and $\tilde{e}_t^m$ denote the impulse responses of services and durables spending, respectively, to a monetary policy shock. Then

$$\tilde{y}_t = \omega_s \tilde{s}_t^m + \omega_d \tilde{e}_t^m$$

is the impulse response of aggregate output to a pair of sectoral demand shocks $(b_t^s, b_t^d)$ with persistence $\rho_b = \rho_m$ and volatilities $\sigma_b^s = \frac{\sigma_m - \omega_s \bar{y}}{1 - \rho_m} \bar{s}$, $\sigma_b^d = \frac{\sigma_m - \omega_d \bar{y}}{1 - \rho_m} \bar{e}$.

Under the conditions of Proposition 6, arbitrary linear combinations of the sectoral spending responses in Figure 3 give valid general equilibrium impulse responses to sectoral demand shocks. Thus, by the one-to-one mapping in Proposition 4, we can consistently estimate the

---

For consistency, we present Proposition 6 in the context of the model of Section 2.1. However, as the proof makes clear, the result does not hinge on our particular parametric form (1) of the adjustment cost function. In particular, the result applies unchanged for adjustment costs on the flow of durable expenditures.
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.

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, while the upper bound is a fully durables-led recession. Within the grey band we highlight two particular weighted averages: (i) a recession with a consumer 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.

Recovery from a recession as tilted towards services as the COVID-19 pandemic

\[15\] In fact, since services contribute \textit{negatively} to ordinary recessions (see Figure 1), the blue line can in
is, in contrast, predicted to be much slower. In Appendix C.2, we derive qualitatively and quantitatively similar conclusions using a shift-share based on estimated impulse responses to uncertainty shocks à la Basu & Bundick (2017).

The implied causal effect of spending composition on recovery strength is large. At the posterior mode reported in Figure 4, the CIR of output in a recession as biased towards services 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.\textsuperscript{16} Overall, and as expected, our estimates of the effect of recession spending composition are somewhat smaller than suggested by the back-of-the-envelope calculation in (8), but still quantitatively meaningful.

4.2 Structural Counterfactuals

In this section we compute the reduced-form recovery forecasts (7) in fully parameterized, explicit structural models. We consider as before the model of Section 2.1, but now allow for (i) more general monetary policy rules in conjunction with imperfectly rigid prices as well as (ii) supply and demand shocks of potentially heterogeneous persistence. Both changes break the neat mapping between impulse responses and reduced-form forecasts underlying Proposition 4 and thus require us to evaluate the expectation (7) numerically.\textsuperscript{17}

**Calibration: fixed parameters.** Table 4.1 presents our calibration of a set of baseline parameters that will be kept fixed across experiments.

The three preference parameters ($\beta, \zeta, \gamma$) are standard; in particular, we continue to set $\zeta = \gamma$, so durables and non-durables are neither net complements nor net substitutes. We consider a broad notion of durables, and thus set the depreciation rate $\delta$ 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, for monetary policy, we

\textsuperscript{16}To construct the posterior credible set, we estimate a single VAR containing all consumption measures, compute the CIR ratio for each draw from the posterior, and then report percentiles.

\textsuperscript{17}To do so, we map the model’s state-space representation into a reduced-form VAR representation (see Wolf (2020) for details on the mapping). Expectations are recovered by mapping the VAR representation into the Wold representation of the observables $(s_t, e_t)'$. 

principle lie outside the grey area.
<table>
<thead>
<tr>
<th>Parameter</th>
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<th>Source/Target</th>
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</thead>
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<td>Annual Real FFR</td>
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<td>Elasticity of Substitution</td>
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<tr>
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<td>Durables Consumption Share</td>
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<td>Inflation Response</td>
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<td>Lubik &amp; Schorfheide (2004)</td>
</tr>
<tr>
<td>ρz</td>
<td>Supply Shock Persistence</td>
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<td>Lubik &amp; Schorfheide (2004)</td>
</tr>
<tr>
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<td>Lubik &amp; Schorfheide (2004)</td>
</tr>
<tr>
<td>σc/σz</td>
<td>Relative Sectoral Volatility</td>
<td>1</td>
<td>Foerster et al. (2011)</td>
</tr>
</tbody>
</table>

Table 4.1: Calibration of fixed parameters for the quantitative structural model.

consider a conventional Taylor rule:

\[ \hat{r}_t^n = \phi \hat{\pi}_t \]

Our policy rule is active, so real interest rates now drop following negative demand shocks, thus feeding back into spending on both durables and services, and breaking the diagonal structure. Finally, we take the persistence \{ρb, ρz\} and relative volatility \{σb/σz\} of demand and supply shocks from Lubik & Schorfheide (2004). With Foerster et al. (2011) estimating that, at least since the mid-1980s, sectoral shocks account for around half of the volatility of sectoral industrial production, we set the volatility of each sectoral shock \{σj\}i∈{b,z}, equal to that of the corresponding aggregate shock.\(^{18}\) We emphasize, however, that all subsequent conclusions are largely invariant to the choices of shock persistence and volatility, as discussed further in Appendix B.4.

\(^{18}\)By linearity of the model, absolute volatilities are irrelevant for all conclusions presented here.
Calibration: parameter ranges. Two parameters have so far been left unrestricted — the durables adjustment cost $\kappa$ and the slope of the New Keynesian Phillips curve $\zeta$. Since our conclusions are most sensitive to these two parameters, we illustrate a range of outcomes corresponding to a large joint support for $\{\kappa, \zeta\}$.

For reference, Ajello et al. (2020) estimate $\zeta \approx 0.02$; given this estimate, and given all other parameter values, a durable adjustment cost of $\kappa \approx 0.15$ matches the relative recession shares displayed in Figure 1, corresponding to $\theta_d \approx 0.5 \ll 1 - \delta$. To illustrate the robustness and quantitative significance of the pent-up demand logic, we consider a range of outcomes for $\zeta \in (0, 0.25)$ and $\kappa \in (0, 0.5)$, corresponding to $\theta_d \in (0, 0.68)$.

Results. For any given parameterization of our economy, we can compute the expected output CIR conditional on a recession today:

$$\mathbb{E}\left[\sum_{h=0}^{\infty} \hat{y}_{t+h} \mid \{u_s^t = -\omega_s, u_d^t = -\omega_d\}\right]$$

We compute this expectation conditional on two recessions, both of common severity $u_s^t + u_d^t = -1$, but with different sectoral incidence: an ordinary recession biased towards durables, and a COVID-19 recession biased towards services, with the shares taken from Figure 1. Figure 5 reports the percentage point gap between the two CIRs on a large grid of parameter values for adjustment costs $\kappa$ and the NKPC slope $\zeta$.

The bottom left corner — no adjustment costs, and fully rigid real interest rates — corresponds to the special case of our stripped-down model in Section 2.2. Consistent with the discussion surrounding (8), this point indicates that a recession as biased towards services as COVID-19 will tend to be around twice as expensive in CIR terms as an ordinary, durables-led recession. At our preferred estimate of $\zeta \approx 0.02$ and $\kappa \approx 0.15$, the excess cost of a services-led recession is still around 80 per cent, remarkably consistent with the results of our simple semi-structural shift-share presented in Section 4.1. Finally we see that, even across the large range of parameter values entertained here, the excess cost never dips below 70 per cent, so pent-up demand effects throughout remain quantitatively meaningful.

5 Policy Implications

We now discuss the implications of our results for the conduct of stabilization policy. Section 5.1 begins by describing the policy problem, and then in Section 5.2 and Section 5.3...
we characterize equilibrium aggregate output paths under different assumptions on central bank information and sectoral recession incidence.

5.1 Setting

We consider again the baseline model of Section 2.1 with $\zeta = \gamma$. Now, however, the monetary authority does not passively fix the real rate of interest. Instead, at the beginning of each period $t$, prior to that period’s demand shocks $\{b^c_t, b^s_t, b^d_t\}$ being realized, it announces a path of current and expected future nominal interest rates. Rather than specifying the policy problem in primitives, we simply assume that the central bank chooses a path that, given its information set today, in expectation keeps aggregate output at steady state forever.\footnote{While a natural benchmark, perfect output stabilization is generally not optimal after pure sectoral demand shocks. However, as we show Section 5.3, the actual first-best allocation is also implementable if the central bank observes sectoral output. Furthermore, perfect output stabilization is indeed optimal after common demand shocks $b^c_t$, and so output at steady state is a natural target for a central bank that observes only aggregate output, as in Section 5.2.} To focus on the problem of output stabilization, we consider the economy’s fixed-price limit.
\( (\zeta \rightarrow 0) \), so we can equivalently think of the monetary authority as setting a path of real interest rates.

In this environment, we ask: How do realized equilibrium output paths vary with (i) the information set of the central bank and (ii) the sectoral incidence of demand shocks \( \{b^c_t, b^s_t, b^d_t\} \)? In Section 5.2 we assume that the central bank only observes aggregate output, while in Section 5.3 it also considers sectoral incidence. Formally, we will assume that interest rate paths need to be measurable with respect to \( \mathcal{H}_t(y) \) and \( \mathcal{H}_t(\{\bar{s}, \bar{e}\}) \), respectively, where \( \mathcal{H}_t(x) \) is the Hilbert space spanned by \( \{x_{t-\ell}\}_{\ell=0}^{\infty} \). For both information sets, we will pay particular attention to realized output dynamics following a recession that is more biased towards services than the average recession.

5.2 Observing Aggregate Output

For our first experiment, we impose that the central bank only observes and responds to fluctuations in aggregate output, \( \hat{y}_t \). This assumption is motivated by the Federal Reserve’s practice of responding to changes — in particular shortfalls — in aggregate employment.

We assume that the economy is in steady state at time \( t = -1 \), and then at \( t = 0 \) is hit by an arbitrary combination of shocks \( \{b^c_0, b^s_0, b^d_0\} \). We let \( \hat{y}^b_t \) denote the actual impulse response of aggregate output to this shock absent any monetary stabilization (i.e., under fixed real interest rates), and we let \( \hat{y}^u_t \) denote the impulse response expected by the central bank after observing the aggregate output surprise \( u_t \equiv \hat{y}_t - \mathbb{E}[\hat{y}_t | \mathcal{H}_{t-1}(y)] \), again absent monetary stabilization. Since the reduced-form innovation \( u_t \) is invariably dominated by the economy’s most volatile and thus prominent shocks (Wolf, 2020), the impulse response to \( u_t \) is generally different from that to any particular shock combination \( \{b^c_0, b^s_0, b^d_0\} \).

**Proposition 7.** Consider the model of Section 2.1 with \( \zeta = \gamma \), and suppose that \( \mathcal{F}_t = \mathcal{H}_t(y) \). Then equilibrium aggregate output satisfies the recursion:

\[
\mathbb{E}_0[\hat{y}_t] = \hat{y}^b_t - \sum_{h=0}^{t-1} \hat{y}^u_{t-h} \mathbb{E}_0[\hat{y}_h] \tag{9}
\]

and so

\[
\mathbb{E}_0 \left[ \sum_{t=1}^{\infty} \hat{y}_t \right] = \frac{\sum_{t=0}^{\infty} \hat{y}^b_t}{\sum_{t=0}^{\infty} \hat{y}^b_t} - 1 \tag{10}
\]

Proposition 7 fully characterizes the actual equilibrium expected output path given our restrictions on the central bank information set. Figure 6 provides a graphical illustration for
the case in which the actual realized demand shocks \( \{b_0^c, b_0^s, b_0^d\} \) result in a recession biased more towards services than the average recession, so \(-\hat{y}_t^b < -\hat{y}_t^u\) for all \( t > 0 \).

(a) Output Dynamics Given \( F_0 = \mathcal{H}_0(\bar{y}) \)

(b) Output Dynamics Given \( F_1 = \mathcal{H}_1(\bar{y}) \)

Figure 6: Output dynamics assuming the central bank responds only to changes in aggregate output. The actual recession (grey) is persistent, while the recovery path expected by the central bank is boosted by pent-up demand effects (blue). The top panel shows expected outcomes and policy at \( t = 0 \), while the bottom panel is for time period \( t = 1 \). For details on the model parameterization see Appendix A.1.

The top panel shows output dynamics given the time-0 policy. At time \( t = 0 \), after the shock hit the economy, the central bank expects output to return to steady state relatively quickly (blue dashed line on the left); in truth, however, output will return to steady state much more slowly (grey line on the left). Given these expectations, the central bank provides
insufficient stimulus — its interest rate policy merely offsets the blue dashed path, not the grey path, resulting in the blue dashed line on the right. At $t = 1$, output is thus lower than expected by the central bank, so it eases again, as illustrated in the bottom panel. But yet again, and for the same reason as before, it does not ease enough. This pattern continues for all future periods: The central bank continues to re-optimize and ease further in each period, with the outcome of this iterative process fully characterized by the two expressions (9) - (10) in Proposition 7.

**Measurement.** We can combine the CIR characterization in (10) with our simple shift-share measurement in Section 4.1 to quantify the effects of incomplete central bank information on equilibrium output dynamics. The only input required to compute (10) is the ratio of the CIR of ordinary recessions, $\sum_{t=0}^{\infty} \hat{y}_u^t$, to the CIR of the recession of interest, $\sum_{t=0}^{\infty} \hat{y}_b^t$, e.g. a services-led recession like COVID-19, both absent any monetary stabilization. Under the natural assumption that the monetary authority does not offset its own shock, the CIRs corresponding to suitably re-weighted averages of the impulse responses estimated in Figure 3 will indeed recover the desired $\sum_{t=0}^{\infty} \hat{y}_u^t$ and $\sum_{t=0}^{\infty} \hat{y}_b^t$.

Concretely, we use Figure 1 to pin down the weights for ordinary durables-led recessions as well as for the COVID-19 pandemic. This measurement exercise suggests that a recession as biased towards services as the COVID-19 recession will be — even under period-by-period updating of stabilization policy — around 70 per cent costlier than an ordinary, durables-led recession.\(^{20}\)

### 5.3 Observing Sectoral Output

If instead the central bank observes and is allowed to respond to fluctuations in sectoral output gaps, then it can (in expectation) attain any desired path of aggregate output, including in particular steady-state output at all times.\(^{21}\)

**Proposition 8.** Suppose that $\mathcal{F}_t = \mathcal{H}_t(\{\hat{s}, \hat{e}\})$. Then, under our assumptions on central

\(^{20}\)The ordinary recession leads to an expected output CIR of -1, while our constrained policy in a services-led recession gives an expected output CIR of around -1.7. Without re-optimization, the output CIR would instead be $-1 + \sum_{t=0}^{\infty} (\hat{y}_b^t - \hat{y}_u^t)$, and thus increasing in the persistence of the shock.

\(^{21}\)It follows that the first-best allocation is implementable. This conclusion is an immediate implication of (i) full-information expectations of aggregate output aligning with expectations given $\mathcal{H}_t(\{\hat{s}, \hat{e}\})$, and (ii) the mapping from real interest rate paths into output paths being full-rank.
bank policy,

\[ \mathbb{E}_0 [\hat{y}_t] = 0, \quad \text{for } t = 1, 2, \ldots \] (11)

The real interest rate is set as

\[ r_t - \mathbb{E} [r_t \mid \mathcal{F}_{t-1}] = \phi_s u^s_t + \phi_d u^d_t \] (12)

where the response coefficients \( \{\phi_s, \phi_d\} \) depend on model parameters and the \( \{u^s_t, u^d_t\} \) are reduced-form VAR forecast errors.

Proposition 8 reveals that, with sectoral output observable, the central bank can attain perfect output stabilization with a rule that responds to sectoral output surprises.

6 Conclusions

Standard consumer theory predicts that the recovery from recessions biased towards services should be weaker — in the sense that the lost output over the cycle is larger — than from ordinary, durables-led contractions. The intuition is straightforward: durables expenditure declines lead to future pent-up demand, while service expenditure declines do not.

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 composition on the strength of the subsequent recovery. Our results suggest that, in present-value output terms, a recession as biased towards services as that induced by the COVID-19 pandemic in the U.S. will be be around 60 to 80 per cent costlier than a similarly deep, ordinary durables-led US recession. Consistent with those estimates, we find that the output losses associated with a stabilization policy that ignores sectoral incidence can be large. To stabilize aggregate output in the face of missing pent-up demand, monetary policy in a services recession must be easier for longer than in ordinary durables-led contractions.
References


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A Model Appendix

In this appendix we provide further details on the structural models of Section 2. First, in Appendix A.1, we elaborate on the baseline model of Section 2.1. Then, in Appendix A.2, we sketch the various model extensions discussed at the end of Section 2.3.

A.1 Detailed Model Outline

HOUSEHOLDS. The household problem is described fully in Section 2.1, up to the link between the preference parameter $\tilde{\phi}$ and the spending share $\phi$. From the steady-state first-order conditions, we get

$$\left(\frac{\tilde{\phi}}{1 - \phi}\right)^{\zeta} = \frac{1}{1 - \beta(1 - \delta)} \left(\frac{\phi}{\frac{1}{\delta}(1 - \phi)}\right)^{\zeta}$$

(A.1)

For future reference, it will be useful to let

$$c_t \equiv \left[\phi^{s_t^{1 - \zeta}} + (1 - \tilde{\phi})^{d_t^{1 - \zeta}}\right]^{1 - \zeta}$$

denote the total household consumption bundle. Note that, to first order, this bundle satisfies

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

(A.2)

PRODUCTION. We assume that both durables and services are produced by aggregating a common set of varieties sold by monopolistically competitive retailers, modeled exactly as in Galí (2015, Chapter 3). This set-up implies that real relative prices are always equal to 1 (i.e., $\hat{p}_s^{t} = \hat{p}_d^{t} = 0$). Optimal household labor supply relates real wages $\hat{w}_t$, hours worked $\hat{\ell}_t$, and the marginal utility of wealth $\hat{\lambda}_t$:

$$\frac{1}{\varphi} \hat{\ell}_t = \hat{w}_t + \hat{\lambda}_t$$

We can thus summarize the production side of the economy with a single aggregate New Keynesian Phillips curve, relating inflation $\hat{\pi}_t$ to $\hat{\ell}_t$ and $\hat{\lambda}_t$:

$$\hat{\pi}_t = \zeta \left[\frac{1}{\varphi} \hat{\ell}_t - \hat{\lambda}_t\right] + \beta \mathbb{E}_t [\hat{\pi}_{t+1}]$$

(A.3)
where \( \zeta \) is a function of the discount factor \( \beta \), the production function of retailers, and the degree of price stickiness. For much of our analysis we need to merely assume that prices are not perfectly flexible, so \( \zeta < \infty \); if so, the central bank can fix the expected real interest rate, and — under our assumptions on equilibrium selection — the NKPC (A.3) as well as the details of the production function \( y = y(\ell) \) are irrelevant for all aggregate quantities.

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 as

\[
\tilde{r}^n_t = \phi_\pi E_t [\hat{\pi}_{t+1}]
\]

The bond is in zero net supply overall.

**Equilibrium Selection.** For several exercises we consider the limit \( \phi_\pi \to 1^+ \). Since the equilibrium is indeterminate for \( \phi_\pi = 1 \), we use the equilibrium selection device of Lubik & Schorfheide (2004), imposing continuity of the equilibrium in \( \phi_\pi \). Alternatively, our results follow by imposing the additional requirement that \( \lim_{t \to \infty} \hat{y}^b_t = 0 \).

Equivalently, all conclusions are unchanged in an economy with fixed nominal prices, \( \zeta \to 0^+ \), and equilibrium selection using either continuity in \( \zeta \) or the requirement that \( \lim_{t \to \infty} \hat{y}^b_t = 0 \). A similar argument is presented in Auclert et al. (2018).

**Example Parameterization.** For our simple graphical illustration in Figure 2 we set \( \gamma = \zeta = 1, \beta = 0.99, \delta = 0.068, \rho_b = 0, \kappa = 0 \) and \( \phi = 0.9 \), with \( \tilde{\phi} \) set as in (A.1). For the policy exercise in Figure 6, we keep the same parameters, but set \( \rho_b = 0.85 \).

**A.2 Extensions**

All results presented in Sections 2.2 and 2.3 generalize straightforwardly to models with (i) arbitrarily many goods, (ii) incomplete markets and borrowing-constrained households, and (iii) supply shocks. We here sketch each of those model extensions.
Many sectors. Household preferences over consumption bundles are now given as

\[ u(d; b) = e^{b\varepsilon} \left( \sum_{i=1}^{N} e^{b\vec{\phi}_i d_{it}^1 - \gamma} \right)^{\frac{1-\gamma}{1-\epsilon}} - 1 \]

We normalize the expenditure share of good \( i \) to \( \phi_i \); the preference parameters \( \vec{\phi}_i \) are then defined implicitly via optimal household behavior, as discussed in Appendix A.1. The budget constraint becomes

\[ \sum_{i=1}^{N} \left\{ p_i^t \left[ d_{it} - (1 - \delta_i) d_{it-1} \right] + \psi_i(d_{it}, d_{it-1}) \right\} + a_t = w_t \ell_t + \frac{1 + r_{t-1}^n}{1 + \pi_t} a_{t-1} + q_t \]

and finally the linearized output market-clearing condition is

\[ \hat{y}_t = \sum_{i=1}^{N} \phi_i \hat{e}_{it} \]

All other model equations are unchanged.

Incomplete markets. The model is populated by a mass \( 1 - \mu \) of households identical to the representative household of Section 2.1, and a residual fringe \( \mu \in (0, 1) \) of hand-to-mouth households. Following Bilbiie (2018), we simply impose the reduced-form assumption that total income (and so total consumption) of every hand-to-mouth household \( H \) satisfies

\[ \phi s^H_t + (1 - \phi) c^H_t = \eta \hat{y}_t \]

Hand-to-mouth households have the same preferences as unconstrained households. Their consumption problem is thus to optimally allocate their exogenous income stream between durable and non-durable consumption, subject to the constraint that their bond holdings have to be zero at all points in time. We present the equations characterizing optimal behavior of hand-to-mouth households in Appendix B.2. All other model blocks are unaffected by the presence of hand-to-mouth households.\(^{22}\)

\(^{22}\)In particular, we assume that a union bargains for all households, leaving the NKPC unchanged as (A.3), similar to Auclert et al. (2018).
Supply shocks. We consider a simple model of (sectoral) productivity shocks in which innovations in productivity are completely passed through to goods prices. Analogously to our baseline model, we consider three shocks \( \{z^c_t, z^s_t, z^d_t\} \) with common persistence \( \rho_z \); their relative volatilities are irrelevant for all results discussed here. Assuming that monetary policy fixes the real rate in terms of intermediate goods prices, real relative prices satisfy

\[
\begin{align*}
\hat{p}^s_t &= -(z^c_t + z^s_t) \\
\hat{p}^d_t &= -(z^c_t + z^d_t)
\end{align*}
\] (A.4)

Assuming for simplicity a constant returns to scale production function for intermediate goods, the output market-clearing condition becomes

\[
\hat{y}_t = [z^c_t + \phi z^s_t + (1 - \phi) z^d_t] + \hat{\ell}_t = \phi \hat{s}_t + (1 - \phi) \hat{e}_t
\] (A.6)

All other model equations are unchanged.
B Supplementary Theoretical Results

This section offers various supplementary theoretical results. First, Appendix B.1 characterizes equilibrium outcomes for the baseline models of Sections 2.2 and 2.3 while Appendix B.2 does the same for the various model extensions discussed at the end of Section 2.3. Next, Appendix B.3 discusses calibration of the adjustment cost parameter $\kappa$ and its effects on the strength of the pent-up demand mechanism. Finally, in Appendix B.4, we compute recession CIRs under several alternative parameterizations for the quantitative model of Section 4.2.

B.1 Baseline Model

The marginal utility of wealth $\lambda_t$ satisfies

$$\hat{\lambda}_t = \hat{r}_t^n - \mathbb{E}_t [\hat{\pi}_{t+1}] + \mathbb{E}_t \left[ \hat{\lambda}_{t+1} \right]$$

Optimal consumption of services and durables is then characterized by the following two Euler equations:

$$(\zeta - \gamma)\hat{c}_t - \zeta \hat{s}_t = \hat{\lambda}_t + b^c_t + b^s_t$$  \hspace{1cm} (B.1)

$$(\zeta - \gamma)\hat{c}_t - \zeta \hat{d}_t = \frac{1}{1 - \beta(1 - \delta)} \left[ \hat{\lambda}_t + b^c_t + b^d_t + \kappa(d_t - \hat{d}_{t-1}) \right]
- \frac{\beta(1 - \delta)}{1 - \beta(1 - \delta)} \mathbb{E}_t \left[ \hat{\lambda}_{t+1} + b^c_{t+1} + b^d_{t+1} + \frac{\kappa}{1 - \delta}(d_{t+1} - \hat{d}_t) \right]$$  \hspace{1cm} (B.2)

Under our assumptions on policy and equilibrium selection, it 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.2), (B.1) and (B.2). Under the additional restriction $\zeta = \gamma$, the equilibrium dynamics of services consumption and the durable stock satisfy

$$\hat{s}_t = -\frac{1}{\gamma}(b^c_t + b^s_t)$$  \hspace{1cm} (B.3)

$$\hat{d}_t = \theta_d \hat{d}_{t-1} + \theta_d(b^c_t + b^d_t)$$  \hspace{1cm} (B.4)

where

$$\theta_d = \frac{\gamma(1 - \beta + \beta \delta) + \kappa + \beta \kappa - \sqrt{-4\beta \kappa^2 + (\gamma(-1 + \beta - \beta \delta) - \kappa - \beta \kappa)^2}}{2\beta \kappa}$$  \hspace{1cm} (B.5)
\[ \theta_b = - \frac{1 - \rho_b \beta (1 - \delta)}{\gamma [1 - \beta (1 - \delta)] + \kappa + \beta \kappa (1 - \rho_b - \theta_d)} \]  

(B.6)

Expenditure on durables is then

\[ \hat{e}_t = \frac{1}{\delta} (\hat{d}_t - (1 - \delta) \hat{d}_{t-1}) \]

Iterating forward, we find the impulse responses

\[ d_t = -\theta_b \times \sum_{\ell=0}^{\infty} \theta_b^\ell \rho_b^{t-\ell} \]

and

\[ e_t = -\frac{\theta_b}{\delta} \times \left[ \rho_b^t + [\theta_d - (1 - \delta)] \sum_{\ell=0}^{t-1} \theta_b^\ell \rho_b^{t-\ell} \right] \]  

(B.7)

B.2  Extensions

We here characterize equilibrium outcomes under the various model extensions discussed in Section 2.3 and formally described in Appendix A.2. Throughout, we assume that \( \zeta = \gamma \) and that monetary policy is neutral, exactly as in the discussion of Section 2.

***Many sectors.*** We now for each good \( i \) get the optimality condition

\[ -\gamma \hat{d}_{it} = \frac{1}{1 - \beta (1 - \delta_i)} \left[ \hat{\lambda}_t + b^*_i + b^i_t + \kappa_i (\hat{d}_{it} - \hat{d}_{it-1}) \right] 
- \frac{\beta (1 - \delta_i)}{1 - \beta (1 - \delta_i)} \mathbb{E}_t \left[ \hat{\lambda}_{t+1} + b^*_{i+1} + b^i_{t+1} + \frac{\kappa_i}{1 - \delta_i} (\hat{d}_{it+1} - \hat{d}_{it}) \right] \]

Following the same steps as in Appendix B.1, we find policy functions

\[ \hat{d}_{it} = \theta_d \hat{d}_{it-1} + \theta_b^i (b^*_i + b^i_t) \]

where \( \{\theta_d, \theta_b^i\} \) are given as in (B.5) - (B.6). Given those policy functions, the derivations of extended versions of Propositions 3 and 4 can proceed exactly as in the baseline case.

***Incomplete markets.*** The only decision of hand-to-mouth households is how to split their income at each time \( t \) between durable and non-durable consumption. Optimal behavior
is fully characterized by the optimality condition

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

Aggregating across constrained households \(H\) and unconstrained households \(R\):

\[
\hat{s}_t = (1 - \mu) \hat{s}_t^R + \mu \hat{s}_t^H \\
\hat{e}_t = (1 - \mu) \hat{e}_t^R + \mu \hat{e}_t^H
\]

This set of equations completes the equilibrium characterization. We can then arrive at the following equivalence result.

**Proposition B.1.** Let \(\eta = 1\). Then all aggregate impulse responses are exactly as in the baseline model of Section 2.1 with \(\zeta = \gamma\). For arbitrary \(\eta\), all normalized impulse responses are exactly as in the baseline model.

**Supply shocks.** Note that, with time-varying real relative sectoral prices, the optimality conditions characterizing household consumption expenditure become

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

With \(\hat{\lambda}_t = 0\) from our assumptions on equilibrium selection, it follows immediately from (A.4)-(A.5) that equilibrium consumption and so sectoral output are exactly as in the baseline model with demand shocks. The only difference is in total hours worked, which are derived residually from (A.6) to ensure overall output market clearing.

It follows that Proposition 3 applies without change to supply shocks. Finally, if supply shocks are as persistent as demand shocks (\(\rho_z = \rho_b\)), then it is straightforward to establish that the proof of Proposition 4 also works in an economy with supply and demand shocks, simply because the induced reduced-form VAR representation remains diagonal.

**Richer preferences.** We now allow for \(\zeta \neq \gamma\) — that is, durables and non-durables demand can be either substitutes or complements. For simplicity, we restrict the analysis...
of this model variant to the stripped-down case of static shocks and no adjustment costs in durable holdings (as in Section 2.2).

Optimal household consumption behavior is now fully characterized by the following system of three equations in three unknowns:

\[
\hat{c}_t = \frac{\phi}{\phi + [1 - \beta(1 - \delta)] \frac{1}{\delta} (1 - \phi)} \hat{s}_t + \frac{[1 - \beta(1 - \delta)] \frac{1}{\delta} (1 - \phi)}{\phi + [1 - \beta(1 - \delta)] \frac{1}{\delta} (1 - \phi)} \hat{d}_t \tag{B.8}
\]

\[
(\zeta - \gamma) \hat{c}_t - \zeta \hat{s}_t = b^s_c + b^s_s
\]

\[
(\zeta - \gamma) \hat{c}_t - \zeta \hat{d}_t = \frac{1}{1 - \beta(1 - \delta)} (b^c_c + b^d_d)
\]

For simplicity we assume that \( \beta = 1 \), giving weights of \( \phi \) and \( 1 - \phi \) in (B.8). Straightforward algebra then gives the good-specific shock CIRs

\[
y^s = 1 + (1 - \delta) \frac{\left(\frac{\gamma}{\zeta} - 1\right) (1 - \phi)}{1 + \left(\frac{\gamma}{\zeta} - 1\right) \phi - \frac{\gamma}{\zeta} (1 - \delta)}, \quad \text{and} \quad y^d = 1 - (1 - \delta) \frac{1 + \left(\frac{\gamma}{\zeta} - 1\right) \phi}{1 + \left(\frac{\gamma}{\zeta} - 1\right) \phi (1 - \delta)}
\]

We consider the arguably empirically relevant case of \( \zeta < \gamma \) — i.e., 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.

### B.3 Adjustment Costs and Pent-Up Demand

As revealed by Proposition 3, adjustment costs weaken the pent-up demand mechanism. However, in any reasonable model calibration, pent-up demand effects invariably remain present. The following result formalizes this claim:

**Proposition B.2.** Consider the model of Section 2.1 with \( \zeta = \gamma \). If \( \theta_d = 1 - \delta \), then

\[
\theta_b = \frac{\delta}{\gamma}
\]

The durables share after a common demand shock thus satisfies \( \bar{\omega}_d = 1 - \phi \).

If the adjustment cost \( \kappa \) is large enough to completely offset the pent-up demand mechanism, then durables spending is also not more volatile than services spending, sharply at
odds with empirical evidence. Figure B.1 provides a graphical illustration of how, in a simple baseline parameterization of the model of Section 2.1, the contribution of durables spending to aggregate consumption fluctuations varies with $\theta_d$ as a function of $\kappa$.

![Figure B.1: Contribution of durables spending to aggregate consumption fluctuations, measured as $\sqrt{\text{Var}(\bar{e} \times e_t) / \text{Var}(y_t)}$, as a function of the persistence parameter $\theta_d$. We fix $\beta = 0.99$, $\gamma = \zeta = 1$, $\phi = 0.9$, $\delta = 0.068$, $\rho_b = 0.83$ (all as in Section 4.2) and then vary $\kappa$.](image)

For durable spending to account for a (data-consistent) share of aggregate output changes of around 60-70 per cent, the persistence coefficient $\theta_d$ can be at most around 0.5, far too small to offset pent-up demand effects. The corresponding value of $\kappa$ of around 0.15 is close to our preferred estimates discussed in Section 4.2.

**B.4 Further Structural Counterfactuals**

In Section 4.2 we study the effect of pent-up demand on expected recovery dynamics as a function of the strength of adjustment costs and price stickiness, simply because these are the

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23 The relative unconditional volatility documented in Figure 1 suffices as evidence under the assumption that business cycles are largely driven by common aggregate fluctuations. A stronger test looks at relative volatilities conditional on a particular aggregate shock, e.g. to monetary policy. It is well-known that, even conditional on such common shocks, durables spending is much more volatile than non-durables spending (e.g. Christiano et al., 1999).
The model features mostly likely to neutralize the pent-up demand logic. We here complement these findings by providing an analogous plot for output CIRs as a function of shock persistence (here set to a common level $\rho_b = \rho_z$) and the monetary authority’s policy rule ($\phi_\pi$). All other parameters are fixed as in Table 4.1, and we further set $\zeta = 0.02$ and $\kappa = 0.15$, in line with the discussion in Section 4.2.

Figure B.2: Model-implied ratio of expected output CIRs conditional on a COVID-19 vs. ordinary recession. Preference, technology and shock volatility parameters are fixed as in Table 4.1, and we set $\zeta = 0.02$ and $\kappa = 0.15$. The common shock persistence $\rho_b = \rho_z$ and the Taylor rule coefficient $\phi_\pi$ are indicated on the $x$- and $y$-axis, respectively.

Results are displayed in Figure B.2. As expected, shock persistence and policy rule have a relatively small effect on the strength of pent-up demand effects, with the excess output cost of a COVID-19-style recession now concentrated in a narrow range between 80 and 95 per cent. For our purposes, the key take-away is that pent-up demand effects invariably remain strong.
C Empirical Appendix

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

C.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 CIR difference of durables- and services-led recession, we estimate a single VAR containing all consumption series.

C.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 a local 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.24 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 C.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.

24The results are unaffected with longer lag lengths, which reduce precision but ensure accurate projection at longer horizons.
Figure C.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.

Figure C.2 uses these estimates to construct a shift-share evaluation of the causal effect 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 from an otherwise identical durables-led recession; here, the estimated CIR difference is 47.9 per cent, and again the 68 per cent posterior credible set does not contain 0.

C.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, allow for a constant and a linear time trend, and use Bayesian estimation methods.

Since the oil price shock directly affects 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 C.3. Durables show the expected overshoot. At a finer sectoral level, we see 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,
Figure C.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 C.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.

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.

C.4 Reduced-Form Dynamics

We estimate a reduced-form autoregressive representation 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 CIRs of total consumption to each of the three reduced-form Wold innovations, with the impact consumption response normalized to 1.\(^\text{25}\)

\(^{25}\)For these computations, we construct aggregate consumption as a weighted average of the sectoral series, with weights of 10 per cent for durables, 65 per cent for services, and 25 for non-durables. These weights are consistent with averages in the NIPA tables over the sample period.

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Figure C.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.

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 CIRs. While not tied to any particular structural shock interpretation, this reduced-form evidence is also in line with the predictions of our basic theory.
D Proofs

D.1 Proof of Proposition 1 and Proposition 2

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 \( \lambda_t = 0 \), the equilibrium system is

\[
-\gamma \hat{s}_t = b_t^c + b_t^s
\]

\[
-\gamma \hat{d}_t = \frac{1}{1 - \beta(1 - \delta)} (b_t^c + b_t^d)
\]

Consider first the two pure sectoral shocks. With \( \sigma_b^d = \gamma \frac{\delta}{1 - \delta} [1 - \beta(1 - \delta)] \) and \( \sigma_b^s = \gamma \frac{1}{\delta} \) we get that \( \tilde{y}_0 = -1 \), as desired; given this impact contraction, and by the definition of \( \tilde{e}_t \), we find \( \tilde{y}_1^d = (1 - \delta) \). 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

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

The weights in (2) then follow from straightforward algebra. Finally, letting \( \beta \to 1 \) and \( \delta \to 0 \), the conclusion is immediate from (2).

\( \square \)

D.2 Proof of Proposition 3

It follows immediately from (B.3) that the services impulse response to a normalized services demand shock satisfies

\[
\tilde{s}_t^a = -\rho_t^b
\]  

(D.1)

The expression for the CIR follows. Next, by (B.4), the impulse response of durables expenditure to a normalized durables demand shock is given as

\[
e_t = - \left[ \rho_t^b + [\theta_d - (1 - \delta)] \sum_{\ell=0}^{t-1} \theta_d^\ell \rho_t^{1-\ell} \right]
\]

(D.2)

Summing over \( t \), the expression for the CIR follows. Also note that, as long as \( \beta \in (0, 1), \theta_d \in [0, 1) \) follows from the closed-form expression (B.5) after tedious algebra.

Next, if \( \theta_d < 1 - \delta \), then the IRF ranking in (3) is immediate from (D.1) - (D.2). Finally,
to establish that \( \lim_{\delta \to 0} \bar{\omega}_d = 1 \), we need to show that

\[
\lim_{\delta \to 0} \frac{(1-\phi)\theta_b}{\phi + (1-\phi)\theta_d} = 1
\]

To see this, note that, for \( \delta = 0 \), we get

\[
\theta_b = -\frac{1 - \rho_b \beta}{1 - \beta + \kappa + \beta \kappa (1 - \rho_b - \theta_d)}
\]

With \( \rho_b \in [0, 1) \) and \( \theta_d \in [0, 1) \), it follows that \( \theta_b \neq 0 \), and so the desired conclusion is immediate.

\[\square\]

### D.3 Proof of Proposition 4

Write the Wold representation of \( x_t \equiv (\phi \tilde{s}_t, (1 - \phi)\tilde{e}_t)' \) as

\[
x_t = \sum_{\ell=0}^{\infty} \Theta_\ell u_{t-\ell}
\]

Under the assumptions of the proposition, the services shock \( b_s^c \) only affects services spending, while the durables shock only affects durables spending, with impulse responses \( \tilde{y}_s^c \) and \( \tilde{y}_d^c \), respectively. Furthermore, since all shocks have the same persistence, the common shock \( b_c^c \) induces impulse responses proportional to \( \tilde{y}_s^c \) for services spending and \( \tilde{y}_d^c \) for durables spending. It follows that the Wold representation is diagonal, with entries

\[
\Theta_\ell = \begin{pmatrix}
\tilde{y}_s^c & 0 \\
0 & \tilde{y}_d^c
\end{pmatrix}
\]

But impulse response functions to reduced-form innovations \( u_t \) are simply the coefficients of the Wold representation, so the result follows.

\[\square\]

### D.4 Proof of Proposition 5

The consumption FOCs in the economy with monetary shocks are

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

where the marginal utility of wealth satisfies
\[\hat{\lambda}_t = \hat{r}_t^m - \mathbb{E}_t [\hat{\pi}_{t+1}] + \hat{\lambda}_{t+1}\]

and the monetary rule gives
\[\hat{r}_t^m = \mathbb{E}_t [\hat{\pi}_{t+1}] + m_t\]

We will guess and verify that, in equilibrium,
\[\hat{\lambda}_t = \frac{1}{1 - \rho_m} m_t = \frac{1}{1 - \rho_m} \rho_t^m m_0\]

The guess is verified since (i) it is jointly consistent with the monetary rule and the FOC characterizing the evolution of the marginal utility of wealth, and (ii) ensures that \(\lim_{t \to \infty} \hat{\lambda}_t^m = 0\).

Now let \(\tilde{\lambda}_t \equiv \hat{\lambda}_t - \frac{1}{1 - \rho_m} m_t\). Plugging this into the consumption FOCs, we get
\[\begin{align*}
-\gamma \hat{s}_t &= \tilde{\lambda}_t + \frac{1}{1 - \rho_m} m_t \\
-\gamma \hat{d}_t &= \frac{1}{1 - \beta(1 - \delta)} \left[ \tilde{\lambda}_t + \frac{1}{1 - \rho_m} m_t + \kappa (\hat{d}_t - \hat{d}_{t-1}) \right] \\
&\quad - \frac{\beta(1 - \delta)}{1 - \beta(1 - \delta)} \mathbb{E}_t \left[ \tilde{\lambda}_{t+1} + \frac{1}{1 - \rho_m} m_{t+1} + \frac{\kappa}{1 - \delta} (\hat{d}_{t+1} - \hat{d}_t) \right]
\end{align*}\]

In equilibrium \(\tilde{\lambda}_t = 0\). We have thus recast the system with monetary shocks in \(\tilde{\lambda}_t\) as a system with consumption demand shocks in the shifted variable \(\hat{\lambda}_t\). It follows that all variables except for \(\tilde{\lambda}_t\) and \(\hat{r}_t^m\) respond to a monetary shock exactly as they do to a consumption demand shock, as claimed.

\[\square\]

### D.5 Proof of Proposition 6

The conditions of the proposition are consistent with the requirements of Proposition 3 and Proposition 5, so it follows immediately that \(\hat{s}_t^m\) and \(\hat{e}_t^m\) are the impulse responses of services and durables spending, respectively, to services and durables demand shocks with volatility
\[ \frac{1}{1-\rho_m} \sigma_m \] and persistence \( \rho_m \). Thus, since \( \hat{s}_t^d = \hat{e}_t^s = 0 \), it follows that

\[ \frac{\hat{s}_t^m}{\hat{y}_t} + \frac{\hat{e}_t^m}{\hat{y}_t} \]

is the impulse response of total output to joint sectoral demand shocks \((b_t^s, b_t^d)\) with volatility \( \frac{1}{1-\rho_m} \sigma_m \) and persistence \( \rho_m \). But then

\[ \hat{y}_t = \omega_s \hat{s}_t^m + \omega_d \hat{e}_t^m \]

is the response of total output to joint sectoral demand shocks \((b_t^s, b_t^d)\) with volatilities \( \sigma_t^s = \frac{\sigma_m \omega_s \hat{y}_t}{1-\rho_m}, \sigma_t^d = \frac{\sigma_m \omega_d \hat{y}_t}{1-\rho_m} \) and persistence \( \rho_m \), as claimed.

\[ \square \]

**D.6 Proof of Proposition 7**

Without loss of generality we scale all impulse responses so that the impact response is 1. Since monetary policy is set before a period’s shocks are realized, we have that

\[ E_0[\hat{y}_0] = \hat{y}_0 = \hat{y}_0^b \]

At the beginning of \( t = 1 \), the monetary authority sets current and signals future expected real interest rates to offset the expected output path \( \hat{y}_t^u \hat{y}_0 \) for \( t = 1, 2, \ldots \).\(^{26}\) Thus expected output at \( t = 1 \) is given as

\[ E_0[\hat{y}_1] = \hat{y}_1^b - \hat{y}_1^u E_0[\hat{y}_0] \]

Next, at the beginning of \( t = 2 \), the monetary authority further re-adjusts current and signaled future expected real interest rates to offset the incremental shock path \( \hat{y}_t^u E_0[\hat{y}_1] \) for \( t = 2, 3, \ldots \). Thus expected output at \( t = 2 \) is given as

\[ E_0[\hat{y}_2] = \hat{y}_2^b - \hat{y}_2^u E_0[\hat{y}_0] - \hat{y}_1^u E_0[\hat{y}_1] \]

Continuing this iteration, we recover (9). Summing over \( t \)'s, we get

\[ E_0 \left[ \sum_{t=0}^{\infty} \hat{y}_t \right] = \sum_{t=0}^{\infty} \hat{y}_t^b - E_0 \left[ \sum_{t=0}^{\infty} \hat{y}_t \right] \cdot \sum_{t=1}^{\infty} \hat{y}_t^u \]

\(^{26}\)This policy is feasible since the mapping from expected real interest paths to output paths is easily seen from (B.1) - (B.2) to be invertible.
Re-arranging:

\[
\mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \hat{y}_t \right] = \frac{\sum_{i=0}^{\infty} \hat{y}_i^b}{1 + \sum_{t=1}^{\infty} \hat{y}_t^c}
\]

With \( \hat{y}_0 = \hat{y}_0^u = 1 \) we recover (10).

\[\Box\]

### D.7 Proof of Proposition 8

To prove (11), it suffices to show that

\[
\mathbb{E} \left[ \hat{y}_{t+h} \mid \{\hat{s}_{t-\ell}, \hat{e}_{t-\ell}\}_{\ell=0}^{\infty} \right] = \mathbb{E} \left[ \hat{y}_{t+h} \mid \{b_{t-\ell}^c, b_{t-\ell}^d, b_{t-\ell}^i\}_{\ell=0}^{\infty} \right]
\]

Since the system is diagonal (see the proof of Proposition 4), it equivalently suffices to show that

\[b_i^c + b_i^d \in \text{span}(\{\hat{s}_{t-\ell}\}_{\ell=0}^{\infty})\]  \hspace{1cm} (D.3)

and

\[b_i^c + b_i^d \in \text{span}(\{\hat{e}_{t-\ell}\}_{\ell=0}^{\infty})\] \hspace{1cm} (D.4)

The first result is immediate since

\[
\hat{s}_t = -\frac{1}{\gamma} (b_i^c + b_i^s)
\]

Next, recall from (B.4) that

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

Thus \(b_i^c + b_i^d \in \text{span}(\{\hat{d}_{t-\ell}\}_{\ell=0}^{\infty})\). But

\[
\text{span}(\{\hat{d}_{t-\ell}\}_{\ell=0}^{\infty}) = \text{span}(\{\hat{e}_{t-\ell}\}_{\ell=0}^{\infty})
\]

so the result follows. Now let

\[
\tilde{b}_i^t \equiv b_i^c + b_i^d - \mathbb{E} \left[ b_i^c + b_i^d \mid \{b_{t-\ell}^c + b_{t-\ell}^d\}_{\ell=1}^{\infty}\right], \quad i = s, d
\]

By (D.3) and (D.4) it follows that \(\tilde{b}_i^t \sim u_i^t\), and so (12) holds, as claimed. \[\Box\]
D.8 Proof of Proposition B.1

First set $\eta = 1$. It is then straightforward to verify that all equilibrium relations are satisfied for $\hat{x}_i = \hat{x}_i^R = \hat{x}_i^H$ for $x \in \{s, d, e, c\}$. Now consider arbitrary $\eta$. Then, following the same steps as in Bilbiie (2019), 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.

D.9 Proof of Proposition B.2

Consider the system (B.5) - (B.6). Setting $\theta_d = 1 - \delta$, and solving the system for $(\kappa, \theta_b)$, tedious algebra gives

$$\kappa = \gamma \frac{1 - \delta}{\delta}$$

and so

$$\theta_b = \frac{\delta}{\gamma}$$

as claimed. It thus follows from (B.3) and (B.7) that the spending impulse responses to a common demand shock are given as

$$s_t = -\frac{1}{\gamma} \times \rho_t^b$$

$$e_t = -\frac{1}{\gamma} \times \rho_t^b$$

establishing the claim.