The Wealth Effect View of the Great Recession: A Behavioral Macroeconomic Model with Occasional Financial Fire Sales

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Abstract

The Great Recession was fueled by a veritable collapse in consumer spending during the Global Financial Crisis. The popular *household leverage view* rationalizes the observed contraction in expenditures via tightening consumer credit, but this narrative is at odds with the fact that consumer credit only tightened very gradually post-Lehman. That is, although forced household deleveraging offers a compelling explanation for the US economy's slow recovery, it cannot account for the abrupt and deep nature of the initial downturn — the Great Recession — itself. This paper thus proposes an alternate explanation of the Great Recession, namely that it was caused by a rudimentary wealth effect. Whether the observed consumer response was forced or voluntary has important implications for policy.

Keywords: Great Recession, 2008 Financial Crisis, aggregate demand, heterogenous agents, narrow bracketing

JEL codes: E70, E44, E20

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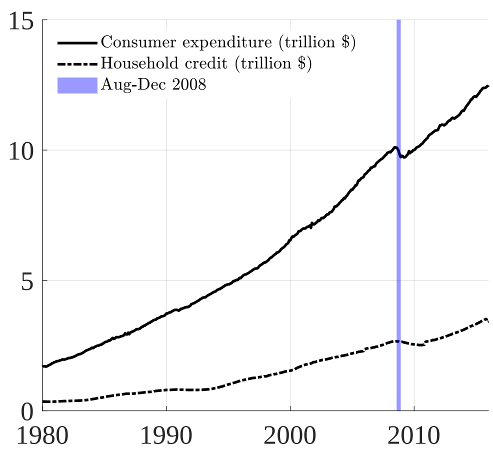
1 Introduction

It is well-understood that the Great Recession (GR) was caused by the preceeding Global Financial Crisis (GFC). Indeed, the GFC-induced collapse in household net worth severely depressed consumer expenditures (Mian et al., 2013), which in turn hampered employment via dwindling labor demand by firms (Mian and Sufi, 2014). But *why* did consumer spending contract so abruptly and sharply in late 2008 (see Figure 1)?

There are principally two reasons why consumer demand might have faltered during the GFC: Either, the observed contraction was forced — the household leverage view (HLV) — or it was voluntary — the wealth effect view (WEV). While early research had predominantly emphasized HLV (see Eggertsson and Krugman, 2012; Guerrieri and Lorenzoni, 2017), recent work by Jones, Midrigan, and Philippon (2022) suggests that tightening borrowing conditions can at most account for the US economy's slow post-Lehman recovery, but not for the abrupt and deep nature of the initial downturn — the Great Recession — itself. Indeed, the proposition that the Great Recession was *not* caused by forced deleveraging is supported by the observation that consumer expenditures contracted much more abruptly and sharply than did household credit (Figure 1).

Figure 1. Aggregate consumer expenditures and outstanding household credit



Notes: Figure 1 displays the evolution of aggregate consumer expenditures and outstanding household credit in the US between 1980 and 2019. If the extraordinary slump in consumer expenditures in late 2008 was indeed forced, as asserted by the household leverage view, we should expect — barring a major cross-sectional redistribution of credit — a one-for-one decrease in credit along with consumer expenditures. In effect, the slow and gradual decline in consumer credit after 2008 favors a narrative whereby the extraordinary slump in consumer spending was predominantly voluntary.

Theory (narrative). Following the logic of Figure 1, this paper theoretically motivates the proposition that the Great Recession was caused by an extraordinary, but predominantly voluntary contraction in consumer demand. To formulate integrated policy advice, both crisis origination and transmission are incorporated into a unified macroeconomic framework. In particular, crisis origination is modeled explicitly because recognizing potential sources of financial fragility is instrumental in ex ante crisis prevention, whereas transmission is modeled in macroeconomic general equilibrium because the primary object of interest are not the financial crises themselves, but rather their impact on the real economy.

To mimic the 2008 Financial Crisis in theory, I appeal to an occasionally binding maintenance margin constraint, which gives rise to episodic financial fire sales.[1] Specifically, when fundamentals are sufficiently weak to push investor equity below the prevailing maintenance margin, brokers issue a margin call, in which case investors must either provide additional funds or close out their position by way of a forced sale. In turn, whenever liquidity is insufficient for investors to comply with their broker's demands, the widespread issuance of margin calls leads to a 'diabolic feedback loop' between falling asset prices and ever rising margin demands.

Following a fire sale, consumer expenditures collapse due to a rudimentary wealth effect: Having lost a substantial fraction of their net worth, households respond to fire sales by immediately and significantly increasing their savings so as to restore their projected stock of retirement wealth. In turn, in accurate anticipation of the resulting slump in consumer demand, firms scale back production via reduced labor demand and capital investment.

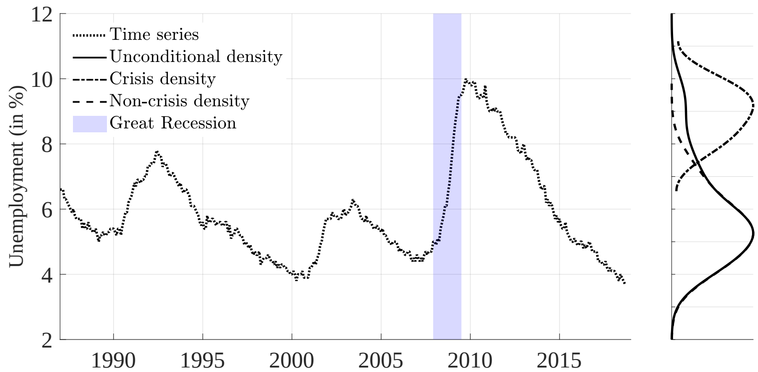
Theory (methodology). The theory proposed in this paper contains two notable methodological contributions. First, with a particular focus on unemployment, it quantitatively rationalizes the extraordinary data recorded during the Great Recession and, as such, effectively elevates the corresponding ergodic tails out of the realm of statistical outliers (Figure 2).[2] Second, the proposed framework illustrates the high degrees of state and parametric heterogeneity that can be accommodated when model primitives are chosen subject to the constraint that each optimization

[1] A maintenance margin is the minimum amount of equity required to maintain a margin account with a broker. A fire sale is a *forced* placement of a market sell order, typically executed below the corresponding asset's intrinsic value (see Shleifer and Vishny, 2011).

[2] "The most important challenge facing any macro-model is to provide insights into the deep downturns that have occurred repeatedly." (Stiglitz, 2018)

problem be computationally trivial. That is, it is relatively inexpensive to build a remarkably rich model environment so long as the theoretical agents' computational capacity is restricted to be in accordance with their real-world counterparts.[3]

Figure 2. Decomposition of unemployment in crisis and non-crisis episodes



Notes: Figure 2 depicts three (normalized) estimated ergodic densities for US unemployment in the post-Volcker/pre-COVID era. The unconditional density illustrates that unemployment exhibits a substantial 'right' tail with the two conditional densities confirming that said tail was recorded following the 2008 Financial Crisis. For purposes of partitioning the data, the "labor market crisis" episode is constructed by collecting all quarters that featured an unemployment rate higher than the previous peak in 1992. All density estimates were derived using the Gaussian kernel proposed in Botev et al. (2010) with mesh size 2^{-7}. The data were retrieved from BLS.

Related literature. This paper most closely corresponds to the existing work by Gertler, Kiyotaki, and Prestipino (2017) who incorporate occasional bank runs into macroeconomic general equilibrium, but the two presented narratives differ substantially. Most importantly, while crises transmit via a slump in consumer demand here, transmission occurs via aggregate supply in GKP, a result in line with much of the literature but at odds with the empirical evidence (see below).[4]

On the aggregate demand side, the most closely related works are Eggertsson and Krugman

[3]For example, a real-world household considering the marginal cost of incrementally increasing today's consumption realistically resorts to quantifying said cost in terms of lost savings, not in terms of lost future consumption. This is because (i) an accurate probabilistic assessment of future consumption is prohibitively expensive, (ii) savings act as a store of *value* in the sense that future consumption is increasing in current savings, and (iii) it is quantitatively convenient.

[4]The supply-side view holds that financial crises cause contractions because financing production becomes more expensive for firms, whereas the demand view holds that firms scale back production in anticipation of an impending slump in consumer demand. While early studies of the transmission of financial crises had focused on aggregate demand (Keynes, 1936) and the accompanying phenomenon of deflation (Fisher, 1933), contemporary macroeconomic theory has been dominated by supply-side narratives. For example, in the canonical "financial accelerator" literature, adverse technology shocks are exacerbated by a deterioration of corporate net worth, which ultimately disincentivizes production via deteriorating external financing conditions (see Bernanke, 1983; Bernanke and Gertler, 1989; Bernanke, Gertler, and Gilchrist, 1999). In Jermann and Quadrini (2012), the financial sector not only acts as an 'accelerator', but rather as an exogenous source of macroeconomic contractions itself (with transmission still occurring via firms and thus aggregate supply). Finally, Gertler, Kiyotaki, and Prestipino (2017) motivate financial crises endogenously. In their model, bank runs temporarily prevent banks from financing firm investment, in which case less efficient intermediaries (households) take their place, thus causing an increase in the cost of external finance.

(2012) and Guerrieri and Lorenzoni (2017), both of which trace the macroeconomic transmission of an exogenous tightening in consumer credit. However, their key assumption — that the collapse in consumer demand depicted in Figure 1 was forced — fails to account for the fact that household leverage contracted much more gradually than did consumer spending post-Lehman. Therefore, this paper proposes an alternate explanation for how the 2008 Financial Crisis morphed into the Great Recession. Prior to doing so, I now turn to placing the presented analysis in the relevant literature by examining the three chronological stages of a crisis episode: origination, transmission, and mitigation (i.e. policy).

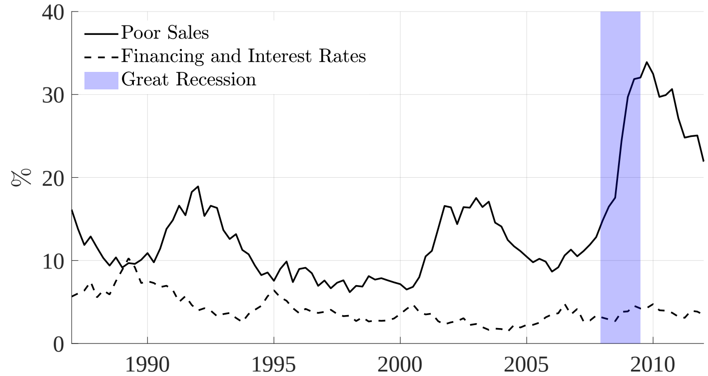
Origination. To mimic the 2008 Financial Crisis, the proposed theory's occasional crises loosely correspond to the financial fire sales described in Brunnermeier and Pedersen (2009).[5] Specifically, since financial assets are purchased on margin, asset demand is non-monotonic as brokers can force investors to sell when prices are sufficiently low (which then depresses prices even further).

Transmission (AS vs. AD). Emprically, it has been established that the 2008 Financial Crisis impacted the real sector via both aggregate demand (Mian and Sufi, 2014) and via aggregate supply (Chodorow-Reich, 2014), but which of the two channels was dominant? Three observations suggest that aggregate demand played a more important role. First, the fact that business owners' primary worry during the Great Recession were "poor sales" (Figure 3, see also Mian and Sufi, 2014). Second, negative demand and supply shocks both cause contractions in output, but their respective effects on the price level are diametrically opposite.[6] Finally, in an empirical account of roughly 200 crisis episodes over the course of the past 200 years, Benguria and Taylor (2020) find that, in general, financial crises "very clearly" tend to transmit via aggregate demand.

[5] "The fact that financial markets stabilized quickly suggests that liquidity problems caused by fire sales were indeed severe after Lehman" (Shleifer and Vishny, 2011).

[6] The fact that inflation fell below zero for the first time in five decades favors the demand-side narrative.

Figure 3. "What is the single most important problem facing your business today?"



Notes: Figure 3 reports business owners' answer to the question "What is the single most important problem facing your business today?". The fact that business owners were more worried about poor sales than securing finance during the Great Recession suggests that the relative contribution of aggregate demand in creating the recession was higher than the contribution of aggregate supply mechanisms. The data was retrieved from the online appendix of Mian and Sufi (2014).

Transmission (HLV vs. WEV). Proceeding under the premise that the Great Recession in fact did root in a slump of aggregate demand, one might wonder *why* demand contracted so sharply. In this context, the primary appeal of HLV is that credit constrained households are typically viewed as having large marginal propensities to consume (MPCs). As such, widespread forced deleveraging constitutes a natural explanation for the extraordinary episode in consumer demand depicted in Figure 1, but is it also accurate? Recent work by Jones, Midrigan, and Philippon (2022) suggests that household deleveraging can only account for ten percent of the observed drop in employment between 2008 and 2010, a result that is in line with Figure 1, but at sharp odds with HLV. Indeed, Petev et al. (2011) had shown that the extraordinary contraction in consumer demand in late 2008 was primarily driven by the wealthy, a subset of households which have historically neither been viewed as credit constrained nor as having large MPCs.[7,8] More importantly, notice that as long as a shock to income and/or wealth is sufficiently large, even small MPCs can principally yield an arbitrarily large swing in aggregate spending.[9] That is, the extraordinary dynamics in Figure 1 might have simply been caused by the extraordinary shock that was the 2008 Financial Crisis.

[7]Wealthy households incurred the largest wealth losses during the 2008 Financial Crisis, both in absolute and in relative terms (Heathcote and Perri, 2018).

[8]Kaplan and Violante (2014) rationalize the existence of "wealthy hand-to-mouth" households by appealing to illiquid investments.

[9]As local objects, MPCs should only be used to approximate consumption responses for small shocks, not for veritable wealth collapses in excess of 20% as observed on average during the 2008 Financial Crisis. Moreover, so long as the consumption function is concave, approximations using MPCs will always underestimate the true response (to a negative shock).

Mitigation (policy). In terms of its policy implications, the presented analysis largely mirrors the literature along the monetary dimension, namely in that aggressive monetary policy is found to represent a highly effective lever in preventing liquidity crises from morphing into severe economic downturns.[10] However, an important discrepancy emerges along the fiscal dimension of policy: Through the lens of HLV, the Great Recession was primarily caused by a shortage of liquidity among households, but the same is not true under WEV. In effect, policies aimed at expanding access to consumer credit only present a sensible course of action under HLV, but not under WEV.[11] Similarly, since WEV views the Great Recession as being the product of an extraordinary wealth shock rather than that of high MPCs, fiscal policy only plays a subordinate role in fighting crises such as the one in late 2008.[12] In particular, unconventional fiscal policy presents a third-best option only after, in no particular order, aggressive monetary policy (ex post) and financial regulation (ex ante). In summary, given the limited potency of fiscal policy, this paper emphasizes the importance of instituting policies that can contain emerging financial crises before they ever even reach the real sector.

The remainder of the paper is organized as follows: Section 2 presents a macroeconomic framework formalizing the referenced wealth effect view of the Great Recession. Section 3 describes the pursued calibration strategy. Section 4 examines quantitatively the macroeconomic transmission of a typical financial fire sale episode and discusses various monetary policy options. Section 5 concludes.

[10]This finding coincides with the prevailing view that the Fed's use of quantitative easing was key in preventing the 2008 Financial Crisis from morphing into a Great Depression type downturn. Indeed, Friedman and Schwartz (1963) argue that the Great Depression would have been less pronounced had the Federal Reserve been more accommodative, a result echoed by both Christiano, Motto, and Rostagno (2003) and Romer and Romer (2013). In effect, it is unsurprising that the Fed was substantially more accommodative in 2008 than it had been during the onset of the Great Depression when it had iteratively raised rates (between 1928 and 1932). Assessing the new and unconventional tools deployed during the Great Recession, Kuttner (2018) concludes that the Fed's actions were appropriate in that the actually incurred costs are "dwarfed by the costs of the more protracted recession [...] that likely would have occurred in the absence of the unconventional policies". This narrative is supported theoretically by both Gertler and Karadi (2011) and Wu and Xia (2016) who find that unconventional policy was key in supporting the economy during the crisis.

[11]As such, WEV rationalizes the outright stimulus payments enacted under the American Recovery and Reinvestment Act (ARRA) of 2009.

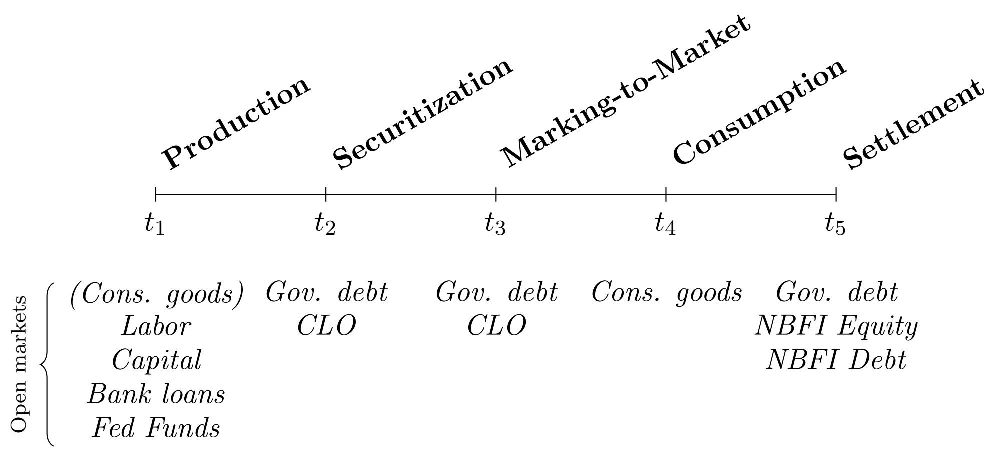
[12]Parker et al. (2013) find that the 100 billion dollar tax rebates disbursed under the Economic Stimulus Act of 2008 caused a (partial equilibrium) increase in personal consumption expenditures between 1.3 and 2.3 percent in Q2 and between 0.6 and 1.0 percent in Q3, a response well below what would have been required to contain the observed collapse in consumer demand depicted in Figure 1.

2 A behavioral macroeconomic model

The proposed theory unfolds as an infinitely repeated game evolving sequentially each period (Figure 4). Markets are incomplete in that trading exclusively takes place in recurrent spot markets, most of which only allow access to certain types of agents.

In subperiod t_1, firms engage in production with households supplying labor to the consumption goods sector and the capital goods sector. Consumption sector firms finance their operations via loans originated and distributed by banks. Following their issuance, all commercial loans are pooled and securitized into a collateralized loan obligation (CLO) at t_2. At t_3, the occasional observation of a noisy (taste shock) signal induces financial markets to reprice the CLO. At this stage, if the CLO's price falls below a certain threshold, a margin call is issued in which case a fire sale might ensue. At t_4, as the actual taste shock materializes, market clearing determines the price of the consumer goods produced at t_1. Lastly, at t_5, all outstanding nominal claims are settled, the central bank announces a new risk free rate, the government auctions off a new bond, and all working-age households repartition their accumulated (nominal) wealth into equity and debt holdings.

Figure 4. Intratemporal timeline



Notes: Figure 4 depicts the proposed theory's five subperiods. Since production (t_1) precedes the realization of consumer demand (t_4), loan repayment is uncertain when corporate loans are issued.

Due to the complex nature of the world which they populate, households are assumed to *narrowly bracket*[13] in that they they break down a complex, but implicit overarching problem into various explicit, but possibly incongruent smaller problems: First, they choose to supply labor

[13]Given the "mass of evidence, and the ineluctable logic of choice in a complicated world, [households] choose an option in each case without full regard to the other decisions" (Rabin and Weizsäcker, 2009).

across various corporate sectors so as to maximize their labor income, namely because they understand that future consumption is increasing in such income. Second, taking as given the outcome of the first stage, they choose what fraction of their earnings to spend on consumption and how much to save for retirement. Lastly, the accumulated stock of retirement wealth is partitioned into equity and debt based on the individual household's appetite for risk.[14]

Subperiod t_1: Bisectorial production

Households' firm-specific labor input x_{hft} consists of three multiplicative components: a firm-specific labor supply indicator $n^S_{hft} \in \{0,1\}$, time-invariant worker skill $q_h \geq 0$, and exerted worker effort $e_{ht} \in [0,1]$. When deciding which firm to supply labor to, each household considers a vector of firm-specific nominal wage offers $\{W_{hft}\}$. A worker's wage offers may depend on their skill with the latter being observed by the capital producers, but not by consumption goods producers.[15] Workers who choose to supply labor to the consumption goods sector may fail to get matched, in which case they receive a predetermined fraction λ_U of the lowest prevailing consumption sector wage in the form of government-issued unemployment benefits.[16] Given the described environment, households are assumed to maximize their labor income according to the following "worst case scenario" criterion,

$$\max_{\{n^S_{hft}\} \in \{0,1\}} \left\{ \min_{\omega \in \Omega} \hat{W}_{ht}(\omega) - \zeta \mathbb{1}\left[n^S_{ht} = 0\right] \right\} \tag{1}$$
$$\text{s.t.} \quad n^S_{ht} = \sum n^S_{hft} \in \{0,1\}$$

where $\hat{W}_{ht}(\omega)$ denotes the ex post realized wage received by household h, and choosing voluntary unemployment carries a uniform, time-invariant utility cost of $\zeta > 0$. Given this problem, workers optimally supply labor to the highest paying capital producer if the corresponding contract-implied wage exceeds the prevailing unemployment benefits and to the highest paying consumption goods producer otherwise (i.e. there is no voluntary unemployment).

[14]Although each household faces all three referenced decisions in any given period, the described sequence of events effectively unfolds over the course of two periods. In the first period, households seek to maximize labor income. In the second period, they receive their paycheck and decide what fraction of their earned income to save for retirement and how to (re)partition their accumulated retirement wealth.

[15]Thus, capital sector wages may account for individual productivity, whereas consumption sector wages must be pooled at the firm level.

[16]A minority of households fail to get matched because firms are unwilling to lower wages below a certain threshold due to adverse selection in quits (i.e. the best workers quit first; see Weiss, 1980).

Once hired, workers are assumed to exert effort based on what they perceive as "fair" compensation (see Akerlof and Yellen, 1990). In the capital goods sector, where remuneration is transparently linked to individual performance, fairness is not questioned. In the consumption goods sector, where there is no such transparency, wage cuts may be perceived as unfair. Specifically, I assume that workers retaliate against nominal wage cuts by curbing their effort as follows:

$$e_{ht} = \begin{cases} \mathbb{1}[\hat{W}_{ht} \geq \lambda_W W^C_{ft-1}] & \text{if} \quad \sum_{J^C} n_{hft} = 1 \\ 1 & \text{otherwise} \end{cases}$$

where J^C denotes the set of consumption goods producers and W^C_{ft-1} is the highest consumption sector wage paid in the previous period. In effect, consumption sector firms never find it optimal to lower their current wage offer below $\lambda_W W^C_{ft-1}$.[17]

Finally, production in the two sectors is given by,

$$y^C_t = \sum_{J^C} \overbrace{[k_{ft}]^\alpha \left[\mu^{LF} \int x_{hft}\ dh\right]^{1-\alpha}}^{y_{ft}}$$
$$y^K_t = \sum_{J^K} \underbrace{z^K_t \mu^{LF} \int x_{hft}\ dh}_{y_{ft}}$$

where $x_{hft} = n_{hft} q_h e_{ft}$ is labor output, k_{ft} denotes physical capital, J^K is the set of capital goods producers, z^K_t represents technology, and μ^{LF} denotes the mass of workers in the labor force.

Capital goods sector. $|J^K| > 1$ capital firms maximize contemporaneous nominal profits Π_{ft} by choosing a capital rental price Q_{ft} and a wage contract $W_{ft}(x)$. For each $f \in J^K$, we have,

$$\max_{Q_{ft}, W_{ft}(x)} \Pi_{ft} \quad \text{s.t.}$$
$$\text{Profits:} \quad \Pi_{ft} = \min\left\{\bar{k}^D_t(Q_{ft}), k_{ft}\right\} Q_{ft} - \int W_{ft}(x_{hft})\ dh$$
$$\text{Accumulated capital:} \quad k_{ft} = (1-\delta^D) k_{ft-1} + y_{ft}$$
$$\text{New capital:} \quad y_{ft} = z^K_t \mu^{LF} \int x_{hft}\ dh$$

where $\bar{k}^D_t$ denotes residual demand corresponding to the capital rental price Q_{ft}.[18] Given the Bertrand-nature of this market, equilibrium is characterized by a uniform, market clearing price

[17]The proposed specification thus effectively motivates the rigidity proposed by Schmitt-Grohé and Uribe (2016).
[18]If multiple firms choose the same rental price of capital, residual demand is allocated proportionally.

strategy $Q_{ft} = Q_t$ and a uniform wage contract $W_{ft}(x) = W_t^K(x) \equiv z_t^K Q_t x$ for each $f \in J^K$ (see Appendix A).[19] In effect, we have that a worker's capital sector wage offer is, quite reasonably, increasing in their skill q_h (recall $x_{hft} = n_{hft} q_h e_{ht}$).

Consumption goods sector. $|J^C| > 1$ consumption sector firms hire labor and rent capital to produce a homogenous, non-durable consumption good. Production is financed via a bank loan l_{ft} at the interest rate R_{ft}^L. At the time of production, loan repayment is uncertain because aggregate demand is subject to a consumer taste shock ξ_t which materializes later in the period.[20] Firms engage in oligopolistic Cournot-type competition and are assumed to maximize expected profits as follows,

$$\max_{l_{ft}, n_{ft}^D, W_{ft}} \quad \mathbb{E}_{t_1}\left[\tilde{\Pi}_{ft}\right] \quad \text{s.t.}$$

$$\begin{aligned}
\text{Profits:} \quad & \tilde{\Pi}_{ft} = y_{ft} \overbrace{\tilde{\chi}_t^k \left[\textstyle\sum_{J^C} y_{jt}\right]^{-\tilde{\chi}_t^r}}^{\tilde{P}_t^C} - l_{ft} R_{ft}^L \\
\text{Production:} \quad & y_{ft} = [k_{ft}]^\alpha \left[\mu^{LF} n_{ft}^D q_{ft} e_{ft}\right]^{1-\alpha} \\
\text{Capital rentals:} \quad & k_{ft} = (l_{ft} - \mu^{LF} n_{ft}^D W_{ft})/Q_t \\
\text{Labor:} \quad & n_{ft}^D \leq \int n_{hft}^S \, dh \\
\text{Av. worker productivity:} \quad & q_{ft} = \left[\int n_{hft}^S q_h \, dh\right] / \left[\int n_{hft}^S \, dh\right] \\
\text{Worker effort:} \quad & e_{ft} = \mathbb{1}[W_{ft} \geq \delta^W W_{t-1}^C]
\end{aligned}$$

where $\tilde{\Pi}_{ft}$ are forecasted profits based on an isoelastic projection of aggregate demand parameterized by $(\tilde{\chi}_t^k, \tilde{\chi}_t^r)$, and W_{t-1}^C is the (highest) consumption sector wage paid in the previous period.[21]

A detailed discussion of the firms' optimal decision rules is relegated to Appendix A, but I now briefly examine the crucial role played by heterogenous worker productivity in generating involuntary unemployment. For this, recall that workers supply labor to the highest paying capital producer if and only if their contract-implied wage offer exceeds the prevailing unemployment

[19] Since competition operates along the price dimension, other capital producers' output $\{y_{jt}^K\}_{j \neq f}$ may not be taken as given since labor can be poached by offering a more lucrative wage contract.

[20] Following the realization of the taste shock (in subperiod t_4), firms compete for customers via price which implies Walrasian market clearing in equilibrium. The resulting realization of the consumer good's price $\hat{P}_t^C(y_t^C, \xi_t)$ pins down the return of each firm's bank loan: $\hat{R}_{ft}^L = \min\{R_{ft}^L,\ y_{ft}^C \hat{P}_t^C / l_{ft}\}$.

[21] For purposes of realism and computation, firms approximate actual (conditional) demand $\hat{P}_t^C(y_t^C; \xi_t)$ with a function of the isoelastic type $\tilde{P}_t^C(y_t^C; \xi_t) \equiv \tilde{\chi}_t^k(\xi_t)[y_t^C]^{-\tilde{\chi}_t^r(\xi_t)}$. The two objects $(\tilde{\chi}_t^k(\xi_t), \tilde{\chi}_t^r(\xi_t))$ are recovered numerically via a local symmetric difference quotient near last period's aggregate output. At this stage, the expectation is taken with respect to $G_{\xi_t|\xi_{t-1}}$.

benefits and to the highest paying consumption goods producer otherwise. Thus, since each worker's capital sector wage offer is given by $W_{ht}^K = z_t^K Q_t q_h$, the highest prevailing consumption sector wage W_t^C attracts all workers with $q_h \leq \lambda_U W_t^C / z_t^K Q_t$. In effect, there exists a marginal worker $h^\star$ with skill $q_t^\star \equiv \lambda_U W_t^C / z_t^K Q_t$ such that relatively high skilled workers ($q_h > q_t^\star$) supply labor to the capital goods sector, whereas relatively low skilled workers ($q_h \leq q_t^\star$) supply labor to the consumption goods sector. With the obvious notation, we have,

$$q_t^C = \mathbb{E}[q|q \leq q_t^\star], \qquad q_t^K = \mathbb{E}[q|q > q_t^\star]$$

It is then evident, since higher wages attract higher skilled workers, that average worker productivity in the consumption goods sector, $q_t^C = \mathbb{E}\left[q|q \leq \lambda_U W_t^C / z_t^K Q_t\right]$, is increasing in W_t^C. Crucially, this dependence of worker productivity on the prevailing wage may prevent firms from lowering their wage offers below a critical threshold, say $\underline{W}_t^C$, namely if the corresponding decrease in the wage bill is mirrored by a more-than-proportional decrease in worker productivity. In particular, this is because effective labor costs would be *decreasing* in the wage below said threshold such that offering $W_{ft} < \underline{W}_t^C$ is strictly dominated by offering $\underline{W}_t^C$ (see Appendix A or Weiss, 1980).

Banks. The primary role of banks is to finance production in the consumption goods sector by way of commercial loans.[22] To motivate 'originate-and-distribute', it is assumed that banks maximize their own 'worst-case' future value as captured by the value of future equity E_{bt+1},

$$\max_{l_{bft}, R_{bft}^L, a_{bft}^L, a_{bt_1}^S, v_{bt_1}^B} \ \min_{\xi_t \in \Xi} \{E_{bt+1}\} \quad \text{s.t.}$$

$$\begin{aligned}
\text{Future equity:} \quad & E_{bt+1} = \overbrace{v_{bt_1} + a_{bt_1}^S V_t^S}^{\text{risk free assets}} + \overbrace{\sum_{J^C} \left[l_{bft} - a_{bft}^L P_{bft}^L\right] \tilde{R}_{bft}^L}^{\text{risky assets (loans)}} - \overbrace{d_{bt_1}^T}^{\text{deposits}} - \overbrace{v_{bt_1}^B R_t^{FFR}}^{\text{borrowed res.}} \\
\text{Total reserves:} \quad & v_{bt_1} = v_{bt_0} - a_{bt_1}^S P_t^S + v_{bt_1}^B \\
\text{Total deposits:} \quad & d_{bt_1}^T = d_{bt_0}^{HH} + d_{bt_0}^{NB} + \sum_{J^C} (d_{bft_1}^F - a_{bft}^L P_{bft}^L) \\
\text{Newly issued deposits:} \quad & d_{bft_1}^F = l_{bft} \\
\text{Realized loan return:} \quad & \tilde{R}_{bft}^L = \min\{R_{bft}^L,\ y_{ft} \tilde{P}_t^C / l_{bft}\} \\
\text{Reserve requirement:} \quad & d_{bt_1}^T \leq v_{bt_1} / \lambda_{RR}
\end{aligned}$$

[22] Each time banks issue a loan, previously nonexistent deposits are created (see McLeay et al., 2014; Werner, 2014). Under a reserve requirement, as stipulated by the Fed until 3/2020, the central bank can principally curb aggregate lending by reducing the amount of reserves in the system (see Blinder and Stiglitz, 1983; Bernanke and Blinder, 1992), but boosting reserves to expand such lending may be unsuccessful because banks need not, or may be unable to, use the newly created reserves to issue more deposits (see Tobin 1963).

Since banks are highly 'risk averse', they do not wish to be exposed to the idiosyncratic risk associated with any singular commercial loan such that they endogenously follow an 'originate-to-distribute' model in which each newly issued loan is immediately sold in its entirety, $a^L_{bft} = 1$, at the prevailing secondary market price P^L_{bft} (which is taken as given).[23] In effect, commercial loan rates are *not* determined by the issuing bank's risk preferences, but rather by their prevailing price on secondary markets. Assuming Bertrand competition in the market for commercial loans, we must have $l_{bft} = P^L_{bft}$ such that corporate loan rates effectively determined in the secondary market.[24]

Subperiod t_2: Securitization

The financial sector allows households to indirectly (via NBFIs) hold claims in firms in the form of a collateralized loan obligation (CLO). The latter is originated by an investment management company which pools all commercial loans in a special purpose vehicle, whose shares are then sold to NBFIs at t_2. The CLO's face value V^R_t and actual payoff $\tilde{V}^R_t$ are given by,

$$V^R_t = \sum_{J^C} V_{ft} = \sum_{J^C} l_{ft} R^L_{ft}$$
$$\tilde{V}^R_t = \sum_{J^C} \tilde{V}_{ft} = \sum_{J^C} l_{ft} \tilde{R}^L_{ft}$$

In turn, the CLO's price is determined by a Walrasian auctioneer with supply fixed and NBFI demand governed by,

$$\max_{d^{NB}_{it_2}, a^S_{it_2}, a^R_{it_2}} \quad d^{NB}_{it_2} + a^S_{it_2} V^S_t + a^R_{it_2} \mathbb{E}_{t_2}\left[\tilde{V}^R_{it}\right] \quad \text{s.t.}$$
$$\text{Budget constraint:} \quad d^{NB}_{it_2} + a^S_{it_2} P^S_t + a^R_{it_2} P^R_{t_2} \leq d^{NB}_{it_0} + a^S_{it_0} P^S_t$$
$$\text{Liquidity constraint:} \quad d^{NB}_{it_2} \geq \delta_L w^D_{it_0}$$
$$\text{Financing:} \quad \underbrace{d^{NB}_{it_0} + a^S_{it_0} P^S_t}_{w^A_{it_0}} = w^E_{it_0} + w^D_{it_0}$$

where the amount of available equity and debt financing, $w^E_{it_0}$ and $w^D_{it_0}$, is predetermined at this stage. As long as NBFIs are sufficiently liquid, the above risk neutral objective implies the

[23]See Gorton and Pennacchi (1995) for a historical account of the originate-to-distribute model and the typical moral hazard concerns associated with it. Brunnermeier (2009) argues that originate-to-distribute led to a significant deterioration of lending standards in the early 2000s and thus played a major role in the creation of the "housing bubble" prior to the Great Recession.

[24]Similarly, the rate on borrowed reserves — the Fed Funds rate (FFR) — must be equal to the predetermined risk free rate: $R^{FFR}_t = R^S_t \equiv V^S_t / P^S_t$, which is known and exploited by the central bank in its setting of monetary policy. Indeed, this equality approximately holds in the data.

following equilibrium condition,

$$P^R_{t_2} = \frac{\mathbb{E}_{t_2}[\tilde{V}^R_t]}{R^S_t} \tag{2}$$

with $R^S_t \equiv V^S_t / P^S_t$. In turn, since the investment management company appraises the commercial loans based on their value as part of the CLO, we have,

$$\begin{aligned} P^L_{ft} &= \left[\frac{l_{ft}}{\sum_{J^C} l_{ft}}\right] \overbrace{\left[\frac{\mathbb{E}_{t_2}[\tilde{V}^R_t]}{R^S_t}\right]}^{P^R_{t_2}} \\ &= \frac{\mathbb{E}_{t_2}[\tilde{V}_{ft}]}{R^S_t} \end{aligned}$$

Ultimately, each firm's commercial loan is thus indirectly priced as follows,

$$\begin{aligned} R^L_{ft} &= V_{ft}/l_{ft} \\ &= V_{ft}/P^L_{ft} \\ &= R^S_t \underbrace{\left[\frac{V_{ft}}{\mathbb{E}_{t_2}[\tilde{V}_{ft}]}\right]}_{\text{credit markup}} \end{aligned}$$

such that if chances of repayment are high, the credit markup and interest rate are low and v.v.

Subperiod t_3: Marking-to-market, margin call, and fire sale

With probability π_s, financial markets observe a taste shock signal $\xi'_t \sim G_{\xi'_t|\xi_t}$ at the beginning of t_3. If observed, the signal is processed in Bayesian fashion[25] with NBFIs revising their portfolios accordingly,

$$\max_{a^S_{it_3}, a^R_{it_3}, d^{NB}_{it_3}} \quad d^{NB}_{it_3} + a^S_{it_3} V^S_t + a^R_{it_3} \mathbb{E}_{t_3}[\tilde{V}^R_t] \quad \text{s.t.}$$

$$\begin{aligned} \text{Repriced assets:} \quad & w^A_{it_3} = d^{NB}_{it_3} + a^S_{it_3} P^S_{t_3} + a^R_{it_3} P^R_{t_3} \\ \text{Residual equity:} \quad & w^E_{it_3} = w^A_{it_3} - w^D_{it_0} \\ \text{Maintenance margin:} \quad & w^E_{it_3} \geq \lambda_{MM} w^A_{it_3} \\ \text{Liquidity constraint:} \quad & d^{NB}_{it_3} \geq \lambda_L w^D_{it_0} \end{aligned}$$

[25] Specifically,

$$\Pr(\xi_t|\xi'_t, \xi_{t-1}) = \frac{\Pr(\xi'_t|\xi_t, \xi_{t-1}) \Pr(\xi_t|\xi_{t-1})}{\Pr(\xi'_t|\xi_{t-1})}$$

such that $G_{\xi_t|\xi'_t,\xi_{t-1}}$ can be inferred from $G_{\xi_t|\xi_{t-1}}$ and $G_{\xi'_t|\xi_t}$.

Analogously to (2), the CLO's new equilibrium price would then seemingly be given by,

$$P_{t_3}^R = \frac{\mathbb{E}_{t_3}[\tilde{V}_t^R]}{R_t^S} \tag{3}$$

However, if the maintenance margin requirement is violated, the broker issues a *margin call* $MC_{it} \in \{0, 1\}$ demanding that the NBFI bring its account up to the minimum maintenance level,

$$\begin{aligned} MC_{it} &= \mathbb{1}(w_{it_3}^E < \lambda_{MM} w_{it_3}^A) \\ &= \mathbb{1}(w_{it_3}^A - w_{it_0}^D < \lambda_{MM} w_{it_3}^A) \\ &= \mathbb{1}(w_{it_3}^A < \left[\frac{1-\lambda_{IM}}{1-\lambda_{MM}}\right] w_{it_0}^A) \\ &= \mathbb{1}\left(w_{it_3}^A < \lambda_{MC} w_{it_0}^A\right) \end{aligned}$$

with a corresponding liquidity demand of $\Delta_{it}^{MC} = w_{it_0}^D - w_{it_3}^E[1-\lambda_{MM}]/\lambda_{MM} > 0$.[26] In the face of a margin call, the NBFI's otherwise prevailing liquidity constraint — $d_{it_3}^{NB} \geq \lambda_L w_{it_0}^D$ — is lifted and replaced with a non-negativity constraint — $d_{it_3}^{NB} \geq 0$ — so as to facilitate the required consolidation. However, if existing liquidity is insufficient to cover the broker's demands, the NBFI must procure new liquidity, either by issuing new debt or by selling part of its portfolio.[27] It is assumed that issuing new debt is not possible at this stage such that, if existing liquidity is in fact insufficient, the broker proceeds by *selling out* part of the NBFI's portfolio.

$$\begin{aligned} SO_{it} &= \mathbb{1}(d_{it_2}^{NB} < \Delta_{it}^{MC}) \\ &= \mathbb{1}\left(w_{it_3}^A < \lambda_{MC}[1-\lambda_{MM}\lambda_L] w_{it_0}^A\right) \\ &= \mathbb{1}\left(w_{it_3}^A < \lambda_{SO} w_{it_0}^A\right) \end{aligned}$$

such that $\lambda_{SO} < \lambda_{MC}$ so long as $\lambda_L > 0$. We thus have, quite reasonably, that all sellouts are preceded by margin calls, but not all margin calls are followed by a sellout.[28]

During a sellout, since NBFIs lack demand deposits and neither households nor firms engage in financial markets directly, the only remaining option is to sell to the central bank. However, under a conventional monetary policy regime, the central bank only purchases the government-issued

[26] Since equity is invariant to repurchases of debt, t_3 equity can be used to determine the maximum amount of debt that can be supported under the prevailing maintenance margin requirement, $w_{it_3}^E[1-\lambda_{MM}]/\lambda_{MM}$.

[27] See Brunnermeier and Pedersen (2009) for a discussion of the two corresponding notions of funding liquidity and market liquidity.

[28] That is, unless $\lambda_L = 0$, in which case each margin call triggers a sellout because NBFIs do not intrinsically wish to hold any liquidity.

security at the previously announced price target. Thus, under such a monetary regime, NBFIs can satisfy their broker's margin call if and only if they have sufficient treasuries to cover their liquidity gap, $\Delta_{it}^{G} = \Delta_{it}^{MC} - d_{it_2}^{NB}$.[29] If they do not, the broker proceeds to sell out the CLO in a *fire sale.*

$$\begin{aligned} FS_{it} &= \mathbb{1}(a_{it_2}^{S} P_{t_3}^{S} < \Delta_{it}^{G}) \\ &= \mathbb{1}\left(w_{it_3}^{A} < \lambda_{FS} w_{it_0}^{A}\right) \end{aligned}$$

where $\lambda_{FS} < \lambda_{SO}$ because each fire sale is preceded by a sellout, but not each sellout is followed by a fire sale.

In a fire sale, since there exists no private buyer for the CLO, the Walrasian auctioneer fails to locate a market-clearing price because excess supply *increases* as the auctioneer lowers the price. That is, unless there is some sort of intervention, the auctioneer will drive the CLO's price to zero. To prevent financial markets from collapsing in such a manner, it is assumed that the monetary authority does in fact intervene during a fire sale. Specifically, motivated by the Fed's inception of its agency MBS purchase program in late 2008, the central bank purchases the CLO's entire excess supply at a predetermined haircut λ_{HC} below its perceived intrinsic value $\mathbb{E}_{t_3}[\tilde{V}_t^R]/R_t^S$.

Subperiod t_4: Consumption

Households live for T^L periods such that there are T^L overlapping generations at each point in time. Over the first T^R periods of life, households belong to the working-age population and supply labor to firms. While in the labor force, workers accumulate retirement savings by investing part of each period's liquid income into illiquid financial claims. At retirement, the stock of previously accumulated financial wealth is liquidated and deposited in the corresponding household's bank account. During retirement, households receive a pension from the government and draw down their accumulated savings until the age of T^L, at which point they are replaced by a new household.

Since accumulated savings are illiquid until retirement, households cannot boost next period's consumption by saving more this period.[30] Instead, the relevant benefit associated with the cost of decreasing consumption today c_{ht} is given by a corresponding increase in projected retirement wealth $\tilde{w}_{ht}^{P}$, where $\tilde{w}_{ht}^{P}$ serves as a household's best estimate of the effectively available funds at the

[29] Notice that the sale of any convex combination $\left[(\Delta_{it}^S, 0), (0, \Delta_{it}^R)\right]_\lambda$ with $\Delta_{it}^S = \Delta_{it}^G / P_{t_3}^S$, $\Delta_{it}^R = \Delta_{it}^G / P_{t_3}^R$ and $\lambda \in [0,1]$ would principally suffice to comply with the broker's margin demand.

[30] This assumption is not necessary, but it serves as a convenient way of emphasizing the point that the primary reason why households save is to accumulate wealth for retirement, not to shift consumption from today to tomorrow.

time of their retirement.[31] Specifically, as proposed by the Bureau of Labor Statistics' guidelines on how to save for retirement (see Appendix C), $\tilde{w}^P_{ht}$ is derived via cumulative compounding using a benchmark return of $\tilde{R}^A_t$. In particular, if τ^R_{ht} denotes household h's remaining number of periods in the labor force at time t, we have,

$$\tilde{w}^P_{ht} = w^A_{ht_0}[\tilde{R}^A_t]^{\tau^R_{ht}} + s_{ht} w^L_{ht_0} \sum_{i=1}^{\tau^R_{ht}-1} [\tilde{R}^A_t]^{i-1} \tag{4}$$

where $w^A_{ht_0}$ is the beginning of period stock of (illiquid) retirement balances, $w^L_{ht_0}$ are the current (liquid) balances to be split between consumption and saving, and s_{ht} is the chosen savings rate. That is, households base their retirement balance projection on the assumption that until retirement, they will save the exact same nominal amount each period and that all such savings will generate a projected return of $\tilde{R}^A_t$.[32] Once derived, the projection $\tilde{w}^P_{ht}$ is evaluated relative to a predetermined retirement goal w^G_{ht} which captures the fact that accumulated savings substitute for labor income during retirement,

$$w^G_{ht} = (T^L - T^R)(1 - \lambda_R)\hat{W}_{ht-1}$$

where $\lambda_R \hat{W}_{ht-1}$ is the projected per-period retirement benefit received from the government.[33] Finally, to generate the desired aggregate demand uncertainty that renders the commercial loans risky, utility derived from projected retirement savings is subject to an aggregate shock ξ_t.

$$\max_{s_{ht}} \begin{cases} u(c_{ht}; \gamma^c) + \xi_t v\left(\dfrac{\tilde{w}^P_{ht}}{w^G_{ht}}; \gamma^w_h\right) & \text{if in labor force} \\ u(c_{ht}; \gamma^c) + v\left(s_{ht} - \dfrac{\tau^L_{ht}}{\tau^L_{ht}+1}; \gamma^s\right) & \text{if retired} \end{cases}$$

$$\begin{aligned} \text{s.t.} \quad & c_{ht} = [w^L_{ht_0}(1 - s_{ht})]/P^C_t \\ & \tilde{w}^P_{ht} = w^A_{ht_0}[\tilde{R}^A_t]^{\tau^R_{ht}} + s_{ht} w^L_{ht_0} \sum_{i=1}^{\tau^R_{ht}-1} [\tilde{R}^A_t]^{i-1} \\ & w^G_{ht} = (T^L - T^R)(1 - \lambda_R)\hat{W}_{ht-1} \end{aligned}$$

[31] The latter generate utility because households find retirement consumption too difficult to assess probabilistically, but they understand that such consumption is strictly increasing in accumulated retirement wealth. An alternate specification might endogenize a household's retirement age with utility decreasing in such an age.

[32] For example, suppose you saved \$5,500 each year until retirement in 35 years and your money earned 7% annually. In that case, your projected retirement balance would be \$760′303 (see Appendix C).

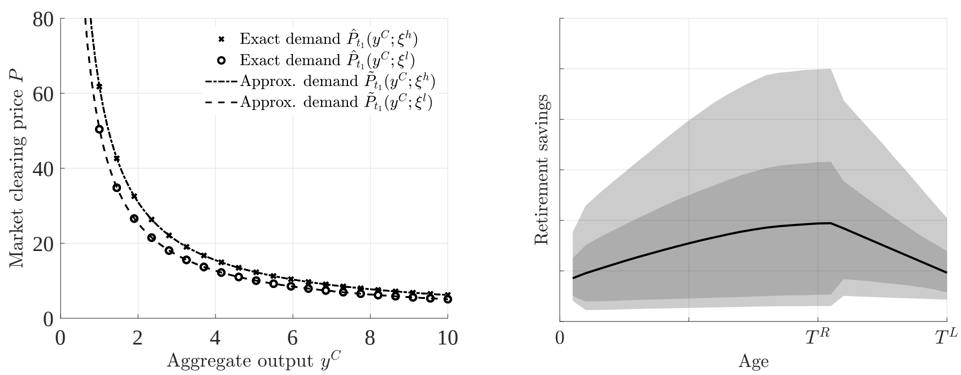
[33] As discussed shortly, the true retirement benefit is calculated as a fraction of the current going wage W_{t-1} on a period-to-period basis.

where the consumption good's ultimately transacted nominal price P_t^C is determined via Walrasian market clearing: $\int_{J^{HH}} c_{ht} = \sum_{J^C} y_{ft}$. To generate aggregate demand that is approximately isoelastic (see Figure 5), u and v are specified as follows,

$$u(x;\alpha) = x^{\alpha} \qquad \alpha \in (0,1)$$
$$v(x;\alpha) = \frac{1}{\alpha}\left[1 - \exp(-\alpha x)\right] \qquad \alpha > 1$$

Figure 5 illustrates the the two main implications of the household's proposed utility function, namely that agg. consumer demand is approx. isoelastic and that lifetime wealth is bell-shaped.

Figure 5. Aggregate demand and the lifecycle of household wealth in the cross-section



Notes: Figure 5A illustrates two points. First, the proposed consumption-savings problem generates aggregate demand that is approximately isoelastic. Second, the taste shock ξ_t exogenously shifts aggregate demand, which induces aggregate uncertainty at the time of production. Figure 5B depicts the bell-shaped life cycle of household wealth as captured by the cross-sectional mean and two confidence bands corresponding to the 68th and 95th percentile.

Subperiod t_5: Settlement

Following the sale of consumer goods at the market clearing price, firms calculate their realized income and profits. Both firms and the government repay their debts such that NBFIs are credited with demand deposits in the amount of $d_{it_5}^{NB} = d_{it_3}^{NB} + a_{it_3}^S V_t^S + a_{it_3}^R \hat{V}_t^R - \int_{J^{HH}} \mathbb{1}(\tau_{ht}^R = 1) w_{hit_5}^F$, where the last summand represents the deposits being withdrawn by the most recent retirees. In turn, households calculate their end-of-period illiquid and liquid balances as follows,

$$w_{ht_5}^F = \mathbb{1}(\tau_{ht}^R \geq 1)\left[w_{ht_0}^L(1 - s_{ht}) + \sum_{J^{NB}} w_{hit}^D \hat{R}_t^D + w_{hit}^E \hat{R}_{it}^E\right]$$
$$w_{ht_5}^L = \underbrace{(1-\tau_I)\hat{W}_{ht}}_{\text{Post-tax wage}} + \underbrace{\gamma_h^o \sum_{J^F} \hat{\Pi}_{ft}}_{\text{Profits}} + \underbrace{\mathbb{1}(\tau_{ht}^R = 1) w_{ht_5}^F}_{\text{Retirement}} + \underbrace{\mathbb{1}(\tau_{ht}^R < 1)\left[w_{ht_0}^L(1 - s_{ht})\right]}_{\text{Drawing down retirement balance}}$$

where $\gamma_h^o \overset{i.i.d.}{\sim} G_o$ denotes a household's time-invariant share of firm ownership. At this stage, all working-age households must decide how to (re)partition their illiquid retirement savings across debt and equity claims vis-à-vis NBFIs in the next period. In particular, when deciding on their preferred portfolio composition, households face a fundamental tradeoff between maximizing projected returns and — since equity carries more risk — limiting risk exposure. Taking as given the interest rate associated with debt R^D_{t+1}, a projected asset return $\tilde{R}^A_{t+1}$, and various NBFIs' leverage L_{it+1}, households are assumed to navigate the alluded tradeoff as follows,

$$\max_{i, w^D_{ht+1_0}} \quad \overbrace{w^D_{ht+1_0} R^D_{t+1} + w^E_{ht+1_0} \tilde{R}^E_{it+1}}^{\text{proj. future illiquid wealth}} - \gamma^r_h \overbrace{\left[\frac{w^F_{ht+1_0}}{2}\right]\left[\frac{w^E_{ht+1_0}}{w^F_{ht+1_0}}\right]^2}^{\text{risk adj.}} \quad \text{s.t.}$$

$$\text{Equity:} \quad w^E_{ht+1_0} = w^F_{ht+1_0} - w^D_{ht+1_0}$$

$$\text{Return on equity:} \quad \tilde{R}^E_{it+1} = \tilde{R}^A_{t+1} + \left(\tilde{R}^A_{t+1} - R^D_{t+1}\right) L_{it+1}$$

where $w^F_{ht+1_0} = \mathbb{1}(\tau^R_{ht} > 1) w^F_{ht_5}$ and risk aversion is idiosyncratic and parameterized by $\gamma^r_h \in (0, \infty)$. On the other side of the market, NBFIs are assumed to maximize their projected return on equity subject to an *initial* margin requirement δ_I (to be relaxed by a *maintenance* margin δ_M as described previously),

$$\max_{L_{it+1}} \quad \tilde{R}^A_{t+1} + \left(\tilde{R}^A_{t+1} - R^D_{t+1}\right) L_{it+1}$$

$$\text{s.t.} \quad L_{it+1} \leq \delta_I$$

Since equilibrium requires $\tilde{R}^A_{t+1} > R^D_{t+1}$, NBFIs strictly prefer debt finance such that we have a corner solution with $L_{it+1} = L_t = \delta_I$ for each i. In turn, with both sides of the market taking prices as given, the equilibrium interest rate emerges via Walrasian tatônnement (see Appendix A).

Finally, to close the model, I now examine the process by which the government rolls over its debt. First, to avoid immediate default, the newly issued bond must at least cover the government's prevailing liquidity gap,

$$V^S_{t+1} = \max\{\underbrace{V^S_t + \underbrace{\underbrace{(X_t - T_t)}_{\text{Primary deficit}} - \Pi^{CB}_t}_{\text{Deficit}}}_{\text{Liquidity gap}}, \underbrace{\sum_{J^{NB}} (1 - \lambda_L[\delta_I/(1+\delta_I)]) d^{NB}_{it_5}}_{\text{Liquidity provision}}\} R^T_{t+1}$$

where X_t are government expenditures and T_t denotes tax revenue. Specifically, we have $T_t = \int_{J^{HH}} \tau_I \hat{W}_{ht} \, dh$ and, since retired ($n^R_{ht} = 1$) and unemployed ($n^U_{ht} = 1$) households receive a pre-tax wage of $\lambda_R W_t^C$ and $\lambda_U W_t^C$ respectively, $X_t = \int_{JHH} n_{ht}^R \hat{W}_{ht} + n_{ht}^U \hat{W}_{ht}\, dh$. Moreover, Π_t^{CB} represents any profit generated by the central bank in its purchase of risk free and, in case of a financial fire sale, risky securities. In addition, beyond just covering its liquidity gap, the Treasury may opt to issue more debt, namely to facilitate the central bank's implementation of monetary policy. To see the role played by government debt in the implementation of monetary policy, I now examine the final optimization problem of the period, which captures NBFIs' bidding behavior during the sovereign debt auction,

$$\begin{aligned}
\max_{R_{it+1_0}^{S,bid}, a_{it+1_0}^{S,bid}} \quad & d_{it+1_0}^{NB} + a_{it+1_0}^S V_{t+1}^S \\
\text{s.t.} \quad & d_{it+1_0}^{NB} = d_{it_5}^{NB} - a_{it+1_0}^S V_{t+1}^S / R_{it+1}^{S,bid} \\
& d_{it+1_0}^{NB} \geq \lambda_L [\delta_I/(1+\delta_I)] d_{it_5}^{NB} \\
& a_{it+1_0}^S = a_{it+1_0}^{S,bid} \mathbb{1}(R_{it+1_0}^{S,bid} \leq R_{t+1}^T)
\end{aligned}$$

where the last constraint illustrates the central bank's ability to set interest rates. Specifically, it is optimal for NBFIs to submit a bid equal to R_{t+1}^T because otherwise they either receive no shares of the issue or, since government debt is not scarce, they overpay unnecessarily.[34] That is, the reason that the government might issue more debt than necessary to cover its liquidity needs is because, otherwise, the central bank might not be able to increase interest rates as desired.

Lastly, we require a monetary rule pinning down the central bank's interest rate target. For this, I assume that the central bank pursues some unconditional interest rate target $\bar{R}^T$ and solely focuses on unemployment,[35]

$$R_{t+1}^T = \max\left\{\bar{R}^T (1 - n_t^u)^{\lambda_N}, 1\right\}$$

such that the time-varying target R_{t+1}^T rises as unemployment falls n_t^u. Finally, changes in R_{t+1}^T are interpreted as a permanent level-shifts (by households and NBFIs) such that ROA projections are revised as follows: $\tilde{R}_{t+1}^A = R_{t+1}^T + \bar{\nu}_t$ with $\bar{\nu}_t$ denoting a historical average of the risk premium. This concludes the period.

[34]It is assumed that the central bank puts in a bid for the entire bond at R_{t+1}^T thereby rendering the security risk free. The bond is allotted proportionally among the highest bidders, but NBFIs are prioritized over the central bank.

[35]Since the taste shock is entirely absorbed by the price margin, inflation is too volatile be serve as a meaningful target. Introducing price commitment and/or a spatial reallocation of households along a circular city should mitigate this problem.

3 Calibration

Given the paper's focus on the occasional crisis episodes, I proceed by calibrating the proposed framework by conditioning on whether the economy is in a state of crisis or not. The relevant statistics are summarized in Table 1 with κ^c and κ^{nc} denoting crisis and non-crisis statistics respectively.

TABLE 1. EMPIRICAL TARGETS

π_{crisis}	Ergodic crisis probability, annual	0.017
$\pi_{\text{recession}}$	Ergodic recession probability, annual	0.3
κ_1^c	Nominal wealth lost during crisis	0.2
κ_2^c	Output gap, crisis trough	-0.04
κ_3^c	Unemployment, crisis peak	0.1
κ_4^c	Unemployment, recovery duration (in quarters)	40
κ_1^{nc}	Unemployment, non-crisis mean	0.05
κ_2^{nc}	Labor share in capital goods sector	0.12
κ_3^{nc}	Gini coefficient (income), ergodic mean	0.4
κ_4^{nc}	Aggregate consumption/income, ergodic mean	0.66
κ_5^{nc}	Annualized equity risk premium $\tilde{R}_t^E - R_t^D$	0.1
κ_6^{nc}	Unemployment, ergodic standard deviation	0.007
κ_7^{nc}	Unemployment, quarterly persistence	0.86

Notes: Table 1 summarizes the set of empirical statistics targeted by way of calibration. For this, I distinguish between crisis moments κ_i^c and non-crisis moments κ_j^{nc}.

The listed crisis frequency is taken from Barro's treatment of "rare disasters" (2006) with a corresponding targeted labor market recovery duration of ten years. Additional crisis targets include an extraordinary nominal wealth loss as observed during the 2008 Financial Crisis, as well as the extraordinary output gap and unemployment peak recorded during the Great Recession.[36] Data on unemployment and labor shares are obtained from the US Bureau of Labor Statistics, whereas all other data are taken from FRED. Refer to Appendix D for a more detailed discussion.

Table 2 summarizes the calibrated parameter values given the chosen time unit of one quarter. Capital depreciation δ_D is chosen to generate a slow unemployment recovery of ten years. To match the unemployment peak following a crisis, the nominal wage rigidity parameter is set to be $\lambda_W = 0.99$ such that firms optimally do not lower (nominal) wages by more than one percent per quarter. The chosen unemployment benefit targets the ergodic mean of unemployment. The cross-sectional distribution of skill G_q, risk preference G_s, and firm ownership G_o are set as follows:

[36] Output is detrended via first differencing.

To obtain a full employment labor share in the capital goods sector of 12%, G_q was calibrated to induce a unique maximizer $\underline{x}$ of $\underline{f}_q(x) \equiv \mathbb{E}[q|q < x]/x$ at $x = 0.88$. In turn, G_s is set to generate the desired consumption share of income of 66%, whereas G_o is set to yield the targeted Gini coefficient for income.

TABLE 2. CALIBRATION

	Panel A: Literature	
α	Capital share	0.4
	Panel B: Specific targets†	
δ_D	Capital depreciation	0.05
λ_W	Nominal wage rigidity	0.99
λ_U	Unemployment benefit	0.22
λ_R	Retirement benefit	0.5
λ_N	Central bank reaction parameter	0.16
γ^c	Consumption exponent	0.1
γ^w	Retirement savings parameter	3
γ^r	Risk aversion parameter	0.125
γ^o	Ownership parameter (G_o: log-normal)	$\mathcal{N}^L(-0.5, 1)$
q	Skill parameter (G_q: rectified normal)	$\mathcal{N}^R(1, 1.5)$
$\bar{R}^T$	Unconditional quarterly interest rate target	0.0125
	Panel C: Regulatory parameters	
λ_{RR}	Required reserves (*M0* liquidity, bank)	0.1
λ_M	Liquidity constraint (*M1* liquidity, NFBI)	0.1
λ_{IM}	Initial margin (equity, NBFI)	0.2
λ_{MM}	Maintenance margin (equity, NBFI)	0.1
	Panel D: Metaparameters	
$\lvert J^C \rvert$	Size of consumption goods sector	100
T^L	Number of overlapping generations	30
T^R	Retirement age	20
N^{HH}	Effective number of households	450
μ^{HH}	Measure of households	10
	Panel E: Exogenous drivers	
$\hat{\rho}_k$	Capital technology persistence	0.905
$\hat{\sigma}_k$	Capital technology shock volatility	0.005

Notes: The set of calibrated parameters are partitioned into four subsets. First, the capital share of production in the consumption goods sector is set as is common in the literature. Second, nine parameters are set to target specific statistics from the data. The liquidity requirements are set based on observed practice, whereas the margin requirements deviate from observed practice in order to generate occasional fire sales. The metaparameters are chosen to scale the economy subject to the limitations imposed by computational constraints.

The liquidity requirements are set equal to values that constitute common practice, whereas the margin requirements are chosen to induce the occasional financial fire sales taking as given the volatility in commercial loan repayment.[37]

The number of consumption sector firms serves as a natural measure for sectoral competition and was chosen to generate the desired credit spread on the commercial loans.[38] Finally, the number of overlapping generations was set to 30 to limit computational expense while the corresponding retirement age ensures a time-invariant working-age to total population ratio of $\frac{2}{3}$.

The effectively simulated number of households was finite for computational reasons, and set equal to 50 per generation.[39] The time-invariant measure of households μ^{HH} and the initial level of *M0* only serve as tools to scale the economy, in real and nominal terms respectively, and were chosen to normalize initial output and the initial wage to unity.

Capital technology is assumed to evolve according to an AR(1) process with ergodic mean μ_k, persistence parameter ρ_k, and a normally distributed shock with standard deviation σ_k.

$$z_t^K = (1-\rho_k)\mu_k + \rho_k z_{t-1}^K + \varepsilon_t^K, \quad \varepsilon_t^K \overset{\text{i.i.d.}}{\sim} \mathcal{N}(0, \sigma_k)$$

Finally, the taste shock is given by a Markov chain of state size two, good and bad. In the 'good' state ξ^{good}, households care less about retirement savings such that aggregate demand is high and vice versa. The Markov chain is calibrated to induce an ergodic demand slump probability of $\pi_{\xi_t=\xi^{\text{bad}}} = \pi_{\text{recession}} = 0.3$. In turn, the signal frequency π_{signal} and its accuracy — as given by the probability that the signal corresponds to the true state $\pi_{\xi_t'=i|\xi_t=i}$ — are set to match the annual disaster frequency $\pi_{\text{crisis}} = 0.017$ from Barro (2006).[40]

[37]The initial and maintenance margin are set to be lower than the actual thresholds of 50% and 25% required under the Federal Reserve Board's Regulation T because the corporate sector setup does not generate enough loan repayment volatility to induce a margin call at those values. This is primarily due to the fact that loans are not only identical ex ante, but also ex post.

[38]Since capital goods firms, NBFIs and banks compete in Bertrand fashion, their corresponding number is irrelevant as long as it is greater than 1.

[39]Given the vast dimensionality of the model, I do not solve for policy or price functions across the entire state space. However, finding such functions is not necessary because even though each optimization problem takes the form of a functional equation, the latter are never self-referential as they are in the canonical Bellman setup. In consequence, this means that equilibrium at each point in the state space can be found irrespectively of equilibrium at any other point. The model is thus simulated by recursively solving for equilibrium anew each period. Exploiting parallelization, each period then takes roughly 30 seconds to simulate across 24 cores on Vanderbilt's computing cluster. Notice that the combination of household heterogeneity and the life cycle nature of the model introduces an additional layer of complexity because the number of simulated households is finite. To prevent generational cycles arising from time-invariant sources, it is crucial that parameterization be equivalent across all generations.

[40]It is ensured (via the margin parameters) that a financial crisis emerges if and only if a bad state is followed by a bad signal that is actually observed).

$$\pi_{\text{crisis}} = \underbrace{\pi_{\text{signal}}}_{\text{Signal}} \underbrace{\left(\pi_{\xi'_t=\xi^{\text{bad}}|\xi_t=\xi^{\text{good}}} \pi_{\xi_t=\xi^{\text{good}}|\xi_{t-1}=\xi^{\text{bad}}} + \pi_{\xi'_t=\xi^{\text{bad}}|\xi_t=\xi^{\text{bad}}} \pi_{\xi_t=\xi^{\text{bad}}|\xi_{t-1}=\xi^{\text{bad}}}\right)}_{\text{Likelihood that the observed signal is bad given a bad previous state}} \underbrace{\pi_{\xi_{t-1}=\xi^{\text{bad}}}}_{\text{Prev. state}}$$

The resulting process for the taste shock is summarized in Table 3.

TABLE 3. THE TASTE SHOCK

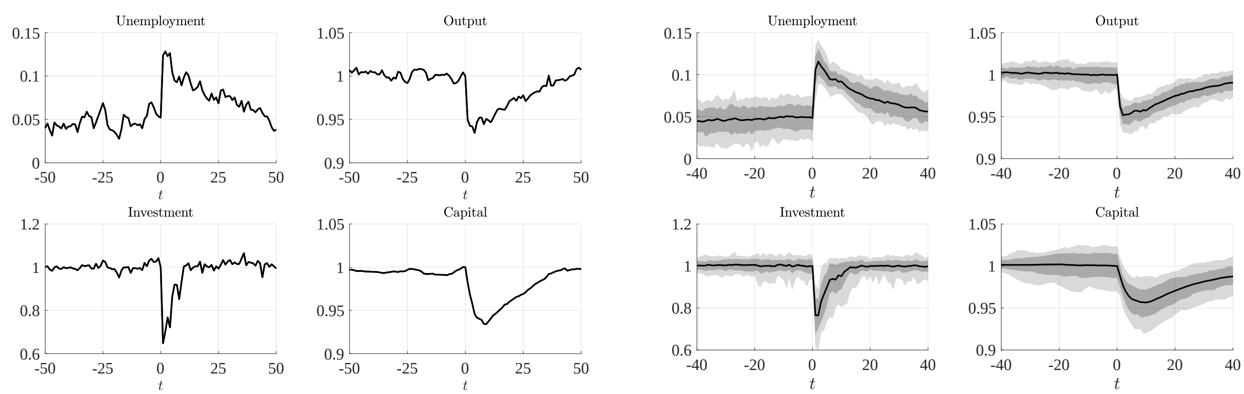
π_{signal}	Signal frequency (i.i.d.)	0.05
$\Xi = \{\xi^{\text{good}}, \xi^{\text{bad}}\}$	Taste shock space	$\{0.01, 0.5\}$
$\pi_{\xi_t=i\|\xi_{t-1}=i}$	Markov chain	$\{0.86, 0.2\}$
$\pi_{\xi'_t=i\|\xi'_t\in\Xi,\xi_t=i}$	Signal accuracy	$\{0.95, 0.997\}$

†$i \in \Xi$

4 Discussion

In this section, I leverage the calibrated version of the proposed framework to examine quantitatively the macroeconomic transmission of a 'typical' financial fire sale. For this, consider Figure 6, which depicts a singular sample path (Panel A) as well as two confidence bands for a large number of independent simulations (Panel B), each with a financial fire sale occurring at $t = 0$.

Figure 6. Macroeconomic transmission of a singular vs. 'average' financial fire sale

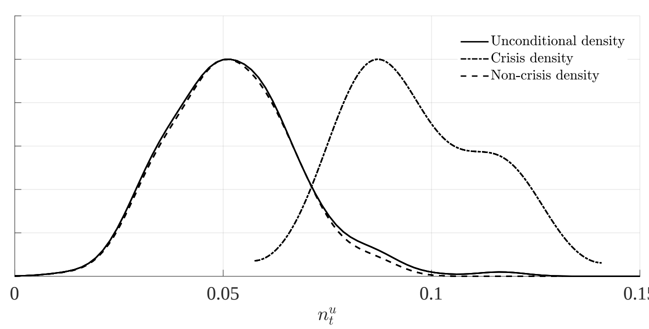


Notes: Figure 6 tracks the macroeconomic transmission of a singular (Panel A) and an 'average' (Panel B) financial fire sale. In either case, the intuition is as follows: Households respond to the fire sale by drastically curbing their consumer demand, to which firms respond, since they do not wish to disgruntle workers with nominal wage cuts, by curbing their demand for labor and capital investment. By the time that the nominal wage constraint no longer binds, around five periods after the initial shock, the depleted capital stock continues to depress labor productivity such that labor demand only slowly reverts back to its steady state level.

In Figure 6, first notice that the economy exhibits business cycles even in absence of a financial fire sale, namely due to perturbations to technology (supply) and household preferences (demand). However, these 'regular' cycles pale in comparison to the extraordinary episodes following a financial crisis. In particular, following a fire sale (at $t=0$), unemployment immediately doubles from 5% to 10% with output and investment collapsing by 5% and 25% on average. These extraordinary dynamics are chiefly driven by firms curbing their demand for labor as nominal wages only fall by 1% per quarter. In turn, although the nominal wage rigidity at the root of the initial economic downturn only binds for a few quarters, excess unemployment persists because the deflated capital stock continues to depresses labor demand until capital converges back to its steady state.

The main insight from Figure 6 is that, despite their rarity, policy ought to account for the possibility of a financial crisis, namely because their effects can be so severe that the relevant macroeconomic variables' crisis and non-crisis densities hardly overlap. Indeed, much like the unconditional ergodic density of unemployment in Figure 2 features a substantial right tail due to the 2008 Financial Crisis and the ensuing Great Recession, the model-implied ergodic density of unemployment in Figure 7 features a similar tail due to the rare occurrence of a financial fire sale. In particular, although it may be tempting to discount the referenced tail as a collection of statistical outliers, its profound implications for welfare render it of utmost economic importance.

Figure 7. Model-implied ergodic unemployment



Notes: Following the same procedure as Figure 2, Figure 7 decomposes model-implied unemployment into three ergodic densities. Qualitatively, the densities look as desired: the unconditional density features a substantial right tail that is recorded during the rare, but extraordinary downturns following the financial fire sales.

The observation that the 'crisis mode' of the unconditional unemployment density in Figure 7 is much less pronounced than its empirical counterpart in Figure 2 is no coincidence: recall that the targeted crisis frequency was taken from Barro (2006), whereas Figure 2 only features data since 1987. Thus, the relevant densities to compare are the two conditional densities.

Policy counterfactual

Much like the Great Depression, the Great Recession was caused by a preceding financial crisis, but the two downturns differed substantially along various dimensions including their accompanying monetary response. Indeed, a popular narrative of the Great Depression is that it was so severe because monetary policy acted in an amplifying, rather than in a mitigating fashion.[41] This section thus examines whether the Great Recession would have been more severe had monetary policy been less accommodating.

To understand the role of monetary policy in mitigating the fire-sale-induced economic downturns depicted in Figure 6, notice that the central bank, as the ultimate creator of the economy's numéraire, possesses an array of tools to intervene (Table 4). For example, a natural first step to address a margin-induced liquidity crisis is to boost equity by lowering the interest rate target. If this is insufficient to halt the margin calls, the central bank may alternatively choose to inject liquidity via repurchase agreements, outright purchases, or via (possibly uncollateralized) emergency lending.[42]

TABLE 4. AVAILABLE MONETARY POLICY TOOLS IN FACE OF A FIRE SALE

Tool	Channel	Effect
No unconventional policy	-	NBFI bankruptcy
Cut risk free target rate	Equity	Price increase of S and R
Repurchase agreement	Liquidity	Collateralized lending against R
Outright purchase of R	Liquidity	Reallocation of R
Emergency lending	Liquidity	(Un-)collateralized lending

Notes: Table 4 lists various unconventional monetary policy tools at the central bank's disposal. Cutting the risk free interest raises asset prices, which may be sufficient to avert an impending fire sale. In addition, the central bank may opt to enter into a (reverse) repurchase agreement, purchase the CLO outright, or engage in emergency lending.

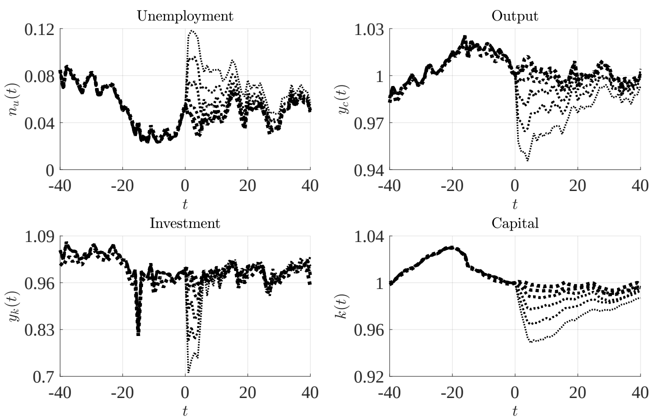
Motivated by the Fed's inception of its agency MBS purchase program in 2008, the following counterfactual is generated under the assumption that once a fire sale is imminent, there exists a critical price threshold below which the central bank starts purchasing the CLO outright on the

[41] Friedman and Schwartz (1963) view monetary policy as a primary root of the length and depth of the Great Depression, a perspective supported by Romer and Romer (2013) and Christiano, Motto, and Rostagno (2003).

[42] In case of an outright purchase, the central bank takes possession of the security ex ante, prior to the realization of its payout, whereas both repurchase agreements and emergency lending constitute a form of collateralized short-term lending, in which case the central bank assumes the risk of receiving the proceeds of the security ex post.

open market. Specifically, to produce the desired set of counterfactual series, I fix a path for the two exogenous drivers — technology and taste shocks — and then simulate the 'same' economy across various monetary policy regimes as captured by their corresponding intervention thresholds (Figure 8).[43]

Figure 8. Macroeconomic transmission of a fire sale across various monetary policy regimes



Notes: Figure 8 illustrates the macroeconomic transmission of the same financial fire sale across various policy regimes as captured by their respective intervention thresholds. Specifically, bolder lines correspond to earlier price thresholds at which the central bank starts absorbing the CLO's excess supply during the fire sale. Evidently, the earlier the central bank intervenes, the smaller is the nominal impact of the fire sale, and the more muted the resulting macroeconomic transmission. For example, if the central bank is willing to purchase the CLO at its intrinsic value (no haircut), the latent macroeconomic downturn effectively vanishes altogether.

Figure 8 depicts the main policy implication of the paper's proposed framework, namely that more aggressive monetary interventions during a financial fire sale lead to less severe economic downturns. In effect, the framework rationalizes and strongly supports the unconventional measures taken by the Federal Reserve in the fall of 2008. In fact, following the logic of Figure 8, it would seem that an earlier inception of quantitative easing — sometime between mid September and late November of 2008 — might well have reduced the length and depth of the Great Recession, thus rendering the fiscal stimulus that followed unnecessary.[44]

The fact that the central bank is capable to attenuate and even entirely prevent the macroeconomic transmission of an emerging financial crisis in the presented theory is unsurprising in that financial fire sales are liquidity crises. The reason that the central bank is well-equipped to back-

[43] Conceptually, the various price thresholds may be thought of as representing varying durations until the central bank decides to intervene.

[44] Parker et al. (2013) find that the 100 billion dollar tax rebates disbursed under the Economic Stimulus Act of 2008 caused a (partial equilibrium) increase in personal consumption expenditures between 1.3 and 2.3 percent in Q2 and between 0.6 and 1.0 percent in Q3, a response well below what would have been required to contain the observed collapse in consumer demand depicted in Figure 1.

stop such crises is that it, as the ultimate creator of money, can effectively create (funding and/or market) liquidity out of thin air. At the same time, it is also worth noting that any successful intervention by the central bank must, in one way or another, stop the widespread issuance of (further) margin calls with the latter lying at the root of the described crises. As such, for purposes of future crisis prevention, policy makers might wish to consider suspending the use of margin calls during system-wide liquidity shortages.[45]

While crucial from a global policy perspective, the monetary and financial considerations above do not yield any insights as to why it is important to distinguish between the household leverage view (HLV) and the wealth effect view (WEV) of the Great Recession. In particular, this is because the described policy prescriptions' implicit underlying objective was to *prevent* latent economic downturns by immediately thwarting financial crises as they emerge. However, alternatively, one might wish to examine policy makers' options — especially along the fiscal dimension — in order to *mitigate* the real effects of a financial shock that is taken as given (see Jermann and Quadrini, 2012). In a final step, I thus now discuss the fiscal implications of WEV.

The main difference between HLV and WEV lies in their respective interpretation of the consumer response to the 2008 Financial Crisis depicted in Figure 1: HLV asserts that the observed contraction in consumer expenditures was forced by a corresponding contraction in consumer credit, whereas WEV posits that households voluntarily curbed their expenditures so as to recoup their dwindling stock of retirement wealth. Thus, HLV suggests that policy aimed at expanding consumer credit and/or a relatively moderate fiscal stimulus might suffice to avert a Great-Recession-type downturn, but the same is not true under WEV. In particular, this is because WEV emphasizes the effects of financial crises on household wealth rather than on household liquidity and, as such, deemphasizes the role played by large MPCs (in fueling the ensuing economic downturns). Through the lens of WEV, fiscal policy thus only ever ought to play a subordinate role in fighting an ongoing financial crisis. In particular, resorting to the use of unconventional fiscal policy represents a third-best option after, in no particular order, deploying aggressive monetary policy and instituting measures to prevent financial crises from occurring in the first place, i.e. financial regulation.

[45] A suspension or outright ban on maintenance margins would force lenders to absorb more risk such that the cost of leverage would almost surely increase, an implication that may (or may not) be viewed as undesirable.

5 Concluding remarks

I have formalized the narrative that the Global Financial Crisis transmitted to the real sector via a *voluntary* (unlike under HLV) contraction in consumer demand: the wealth effect view of the Great Recession (WEV). The proposed framework yields several insights regarding optimal policy during an emerging or ongoing financial crisis. In particular, since the wealth effect view deemphasizes the importance of large MPCs, unconventional fiscal policy only presents a third-best option, after deploying aggressive monetary policy and instituting measures to prevent financial crises from occurring in the first place, i.e. financial regulation. For example, since maintenance margins lie at the root of the financial and economic crises examined herein, policy makers may wish to consider temporarily suspending or generally limiting the use of such margins.

A Equilibrium

A.0 Recursive pseudo general equilibrium

The recursive economy studied in this paper features markets that are incomplete and/or which fail to clear *in equilibrium*. Before examining the various markets in more detail, I thus first define the relevant equilibrium concept. For this, consider an environment whereby "an action by one agent affects [...] the domain of actions of other agents" (Arrow and Debreu, 1954).[46]

Pseudo-game. A pseudo-game is a tuple $\Gamma_P = [\overbrace{I, \{\Sigma_i\}_{i\in I}, \{u_i\}_{i\in I}}^{\Gamma}, \{A_i\}_{i\in I}]$, where Γ is a game and $A_i : \Sigma_{-i} \rightrightarrows \Sigma_i$ maps other agents' selected actions into permissible actions for player i.

Pseudo-Nash equilibrium. A strategy profile $\sigma = \{\sigma_i\}_{i\in I}$ is said to be a pseudo-Nash equilibrium (PNE) of Γ_P if $u_i(\sigma_i, \sigma_{-i}) \geq u_i(\sigma_i', \sigma_{-i})$ for all $i \in I, \sigma_i' \in A_i(\sigma_{-i})$.

Competitive equilibrium. A market is said to be competitive if it exhibits zero excess demand in PNE. A pseudo-game is said to be in competitive equilibrium (CE) if PNE induces zero excess demand in each market.

Walrasian equilibrium. A market is said to be Walrasian if there exists an auxiliary market participant — the Walrasian auctioneer — who sets the price in order to clear the market (WE). A pseudo-game is said to be of the Walrasian type if each market features a Walrasian auctioneer.

Importantly, PNE need not imply CE or WE such that the observation of market clearing failures need not imply disequilibrium (in the pseudo-Nash sense). In particular, since some markets studied in this paper are neither Walrasian nor competitive, the relevant overarching concept of equilibrium, recursive pseudo general equilibrium (RPGE), must permit excess demand.

Pseudo general equilibrium. A pseudo-game is said to be in pseudo general equilibrium (PGE) if the price in each market is determined endogenously via pseudo-Nash equilibrium.

Recursive pseudo general equilibrium. A recursive economy is said to be in recursive pseudo general equilibrium (RPGE) if each price in each market is determined endogenously via pseudo-Nash equilibrium in (each subperiod of) each period.[47]

[46] e.g. the price set by a Walrasian auctioneer restricts the set of permitted strategies by the market participants.
[47] RPGE is quite general in that it encompasses both "dynamic stochastic" (DSGE) as well as "recursive-dynamic computable" (RDCGE) setups.

A.1 Market for consumer goods: Aggregate supply

At t_1, with aggregate demand still uncertain, consumption sector firms must decide how much to produce. For this, they take as given other firms' announced production schedule and thus solve,

$$\left(\frac{\partial}{\partial k_{ft}^{C}}, \frac{\partial}{\partial n_{ft}^{C}}\right)\left(\mathbb{E}_{t_1}[\tilde{S}_{ft}^{C}] - [k_{ft}^{C} Q_t + \mu^{LF} n_{ft}^{C} W_{ft}^{C}] R_{ft}^{L}\right) = (0,0)$$

which implies

$$\frac{\partial \mathbb{E}_{t_1}[\tilde{S}_{ft}^{C}]}{\partial y_{ft}^{C}} \frac{\partial y_{ft}^{C}}{\partial k_{ft}^{C}} \Big/ \frac{\partial \mathbb{E}_{t_1}[\tilde{S}_{ft}^{C}]}{\partial y_{ft}^{C}} \frac{\partial y_{ft}^{C}}{\partial n_{ft}^{C}} = \frac{Q_t R_{ft}^{L}}{\mu^{LF} W_{ft}^{C} R_{ft}^{L}}$$

$$\implies \frac{\partial y_{ft}^{C}}{\partial k_{ft}^{C}} \Big/ \frac{\partial y_{ft}^{C}}{\partial n_{ft}^{C}} = \frac{Q_t}{\mu^{LF} W_{ft}^{C}}$$

and therefore, given the Cobb-Douglas form of production, constant expenditure shares for capital and labor,

$$k_{ft}^{C} Q_t = \left(\frac{\alpha}{1-\alpha}\right) \mu^{LF} n_{ft}^{C} W_{ft}^{C} \tag{5}$$

Thus, since prices are taken as given and production is CRS, production costs are linear with constant marginal costs δ_t^C. To find δ_t^C, I exploit the optimal capital-labor share and calculate the cost of producing a benchmark output with $n_{ft}^{C} = 1$,

$$\begin{aligned} \delta_t^C &= \frac{\left[\left(\mu^{LF} \frac{\alpha W_t^C}{(1-\alpha) Q_t}\right) Q_t + \mu^{LF} W_t^C\right] R_t^L}{\left[\mu^{LF} \frac{\alpha W_t^C}{(1-\alpha) Q_t}\right]^{\alpha} \left[\mu^{LF} q_t^C\right]^{1-\alpha}} \\ &= \frac{Q_t^{\alpha} [W_t^C]^{1-\alpha} R_t^L}{\alpha^{\alpha}(1-\alpha)^{1-\alpha} [q_t^C]^{1-\alpha}} \end{aligned}$$

such that production costs are linearly increasing in the borrowing rate R_t^L.[48] In effect, consumption sector firms implicitly solve,

$$\max_{y_{ft}^{C}} \ \mathbb{E}_{t_1}\left[y_{ft}^{C} \tilde{\chi}_t^{k}(\xi_t) \left[\sum\nolimits_{J^C} y_{jt}^{C}\right]^{-\tilde{\chi}_t^{r}(\xi_t)}\right] - \delta_t^C y_{ft}^{C}$$

Appealing to symmetry, it can then be shown that individually optimal output solves the

[48] As per usual, monetary policy does not have any real effects unless nominal frictions prevent markets from clearing. In particular, when prices are entirely flexible, all exogenous changes in R_t^T are absorbed by a proportional level shift in W_t^C and Q_t in equilibrium. However, since fire sales are transmitted to the real sector via the nominal downward wage friction, the central bank can mitigate the real effects of a crisis by lowering the interest rate target and thereby absorbing part of the nominal shock. Conversely, the monetary authority could hypothetically also generate unemployment by sharply increasing the interest rate target at any given time.

following equation,

$$\mathbb{E}_{t_1}\big[\,\overbrace{\tilde{\chi}_t^k(\xi_t)\,\big[y_t^C\big]^{-\tilde{\chi}_t^r(\xi_t)}}^{\tilde{P}_t^C(\xi_t)}\big(1-\tilde{\chi}_t^r(\xi_t)/N^C\big)\,\big]=\delta_t^C \tag{6}$$

such that optimal aggregate supply is increasing and decreasing in the aggregate demand parameters $\tilde{\chi}_t^k$ and $\tilde{\chi}_t^r$ in equilibrium. Finally, notice that (6) can be rewritten as,

$$\mathbb{E}_{t_1}\left[\tilde{P}_t^C(\xi_t)\left(1-\frac{\tilde{\chi}_t^r(\xi_t)}{N^C}\right)\right]=\delta_t^C$$

which reduces to a zero-expected-profits condition as competition intensifies, $N^C\to\infty$.

A.2 Market for consumer goods: Aggregate demand

At t_4, the realization of the taste shock ξ_t pins down aggregate demand $D(P)$ and, as such, each firm's residual demand as a function of other firms' prices and inventory $\{P_{jt}^C, y_{jt}^C\}_{j\neq f}$. It is assumed that, at this stage, firms compete in Bertrand fashion and that, if multiple firms offer the same price, residual demand is allocated proportionally. We thus have,

$$\max_{P_{ft}^C}\; P_{ft}^C\min\left\{y_{ft}^C, y_{ft}^{C,d}\right\}\quad\text{s.t.}$$

$$\text{Residual demand:}\quad y_{ft}^{C,d}=D(P_{ft}^C)-\sum_{J^C}y_{jt}^C\mathbb{1}(P_{jt}^C<P_{ft}^C)-\frac{\sum_{J^C}y_{jt}^C\mathbb{1}(P_{jt}^C=P_{ft}^C)}{\sum_{J^C}y_{jt}^C\mathbb{1}(P_{jt}^C=P_{ft}^C)+y_{ft}^C}$$

In effect, no firm will optimally choose to set their price below the market clearing price $P^\star=\{P\in\mathbb{R}|D(P)=\sum_{J^C}y_{jt}^C\}$ at which point y_{ft}^C can be sold in its entirety irrespective of the competition's pricing. However, depending on others' actions, a firm could principally find it profitable to charge a price above $P^\star$, namely if the others' prices were relatively high. However, in equilibrium, all firms will follow a uniform market clearing price strategy,

$$P_{ft}^C=P^\star\text{ for each }\; f\in J^C$$

By contradiction: Suppose that, in equilibrium, $\exists f$ such that $P_{ft}^C>P^\star$. Then, if $y_{ft}^C<y_{ft}^{C,d}$, firm f deviates by raising its price. If $y_{ft}^C=y_{ft}^{C,d}$, some firm j has zero sales, $y_{jt}^{C,d}=0$, and thus optimally deviates by lowering its price. Finally, if $y_{ft}^C>y_{ft}^{C,d}>0$, firm f is the/a marginal seller and thus optimally deviates by lowering its price so long as sales decrease when the marginal price rises. I now show that this is true.

To see that aggregate sales, or household expenditures, are weakly decreasing in the marginally available price P_0^C, suppose that the latter induces a particular household to save s_0 and consume $c_0 = w^L(1-s_0)/P_0^C$. Assuming an interior solution, the optimality condition associated with this decision is given by,

$$\overbrace{\gamma^c c_0^{\gamma^c-1}\frac{w^L}{P_0^C}}^{\text{marg. pain}} = \overbrace{\xi_t \exp\left(-\gamma^w \tilde{w}^P(s_0)/w^G\right) a}^{\text{marg. gain } m(s_0)}$$

where $a > 0$ is a constant such that $m' < 0$ with s_0 being the only non-predetermined argument of m. Now, suppose that the price increased to $P_1^C = \lambda P_0^C$, $\lambda > 1$, but that the household responds by spending more, i.e. $s_1 \leq s_0$. We then have $c_1 \geq c_0/\lambda$, which implies,

$$\begin{aligned}
\gamma^c c_1^{\gamma^c-1}\left[\frac{w^L}{P_1^C}\right] &\leq \gamma^c\left(\frac{c_0}{\lambda}\right)^{\gamma^c-1}\left[\frac{w^L}{\lambda P_0^C}\right] \\
&= \lambda^{-\gamma^c} m(s_0) \\
&< m(s_0) \\
&\leq m(s_1)
\end{aligned}$$

such that the marginal benefit of saving strictly exceeds its marginal cost *at any* $s_1 \leq s_0$. Thus, as the marginal price rises, the respective household will respond by increasing its savings or, equivalently, decreasing its expenditures (unless it was already at the corner $s_0 = 0$). In turn, since the same logic applies across all households, we have $\partial D(P^C)P^C/\partial P^C \leq 0$ or, equivalently, $\tilde{\chi}_t^r(\xi_t) \leq 1$ over the entire domain of P^C. Finally, on the subset of the domain where there exists at least one household not at the corner $s_0 = 0$, such as in market clearing equilibrium, the inequality is strict. We have $\partial D(P^C)P^C/\partial P^C|_{P^\star} < 0$ as desired.

A.3 Market for capital

In this section, I show that equilibrium in the capital goods sector is characterized by a uniform, market clearing capital rental price $Q_{ft} = Q_t^\star$ for each f and a sectoral wage schedule of $W_t^K(y_{ht}^K) \equiv \max_f \left\{W_{ft}^K(y_{ht}^K)\right\} = y_{ht}^K Q_t$ for each h. To see this, recall that capital producers maximize contemporaneous profits by choosing a price Q_{ft} and an individual wage offer $W_{ft}(x)$,

$$
\begin{aligned}
\max_{Q_{ft}, W_{ft}(x)} \quad & = \min\left\{\bar{k}_t^D(Q_{ft}), k_{ft}\right\} Q_{ft} - \int W_{ft}(x_{hft})\ dh \quad \text{s.t.} \\
\text{Accumulated capital:} \quad & k_{ft} = (1-\delta^D)k_{ft-1} + y_{ft} \\
\text{New capital:} \quad & y_{ft} = z_t^K \mu^{LF} \int x_{hft}\ dh \\
\text{Residual demand:} \quad & \bar{k}_t^D(Q_{ft}) = k_t^C(Q_{ft}) - \sum_{J^K} k_{jt}\mathbb{1}(Q_{jt} < Q_{ft}) - \frac{\sum_{J^K} k_{jt}\mathbb{1}(Q_{jt} = Q_{ft})}{\sum_{J^K} k_{jt}\mathbb{1}(Q_{jt} = Q_{ft}) + k_{ft}}
\end{aligned}
$$

I proceed by showing existence constructively: suppose that for each h, the highest available wage contract, offered by at least two firms, is given by $W_{ft}^K(y_{ht}^K) = y_{ht}^K Q_t^\star$, where $Q_{ft} = Q_t^\star$ for each f and $Q_t^\star$ clears the market. Then, each employed worker generates zero marginal profits and has a competitive outside option (the other firm). In this instance, lowering wage offers is not profitable because current employees will simply opt to work for another firm. Conversely, poaching a worker from another firm by offering a higher wage may increase a firm's output, but only at the cost of negative marginal profits: If Q_{ft} is left unchanged (or lowered below $Q_t^\star$), all product is still sold, but the marginal sale does not cover the marginal labor costs. Conversely, if Q_{ft} is raised above $Q_t^\star$, the market no longer clears and firm sales fall (see below). In either case, the deviating firm's profits fall such that no firm has an incentive to alter their wage offer. Similarly, no firm has an incentive to change their capital rental price so long as aggregate sales are decreasing in the price (see below).

Having shown existence, I now prove uniqueness. For this, I first show that, in equilibrium, all capital rentals must occur at a uniform price: $Q_{ft} = Q_t$ for all f satisfying $k_{ft} > 0$ and $\bar{k}_{ft}^D(Q_{ft}) > 0$. By contradiction: Suppose that in equilibrium, $\exists i,j$ such that $Q_{it} > Q_{jt}$ and $k_{jt}, k_{it} > 0, \bar{k}_{it}^D(Q_{it}) > 0$. Then, if markets clear, j may, irrespective of wages paid, increase profits by raising Q_{jt} to Q_{it}. In case of excess demand, both firms find it profitable to raise their price. Finally, in case of excess supply, j may increase profits by raising Q_{jt} to $Q_{it} - \varepsilon$, a contradiction.

In turn, suppose if $Q_t \neq Q_t^\star$. Then, if $Q_t < Q_t^\star$, firms respond by raising their price while still renting all their capital, whereas if $Q_t > Q_t^\star$, firms respond by lowering their prices to absorb the entire market. Thus, we must have $Q_t = Q_t^\star$ in equilibrium.

Lastly, I now show that capital expenditures $k_t^C(Q_t)Q_t$ are in fact strictly decreasing in Q_t. To see this, first consider the following FOC from the consumption sector firm,

$$\alpha \mathbb{E}_{t_1}\left[\tilde{\chi}_t^k(\xi_t)\left[N^C y_{ft}^C\right]^{-\tilde{\chi}_t^r(\xi_t)}\left(1-\frac{\tilde{\chi}_t^r(\xi_t)}{N^C}\right)\right] y_{ft}^C = k_{ft}^C Q_t R_{ft}^L \tag{7}$$

When comparing different partial equilibria (taking as given two different values of Q_t), it is useful to analyze the behavior of both sides of (7). First, recall $\tilde{\chi}_t^r(\xi_t) \leq 1$, which implies that the left hand side of (7) is (at least weakly) increasing in y_{ft}^C. Similarly, the left hand sides of (8) and (9) are strictly decreasing in k_{ft}^C and n_{ft}^C respectively,

$$\alpha \mathbb{E}_{t_1}\left[\tilde{\chi}_t^k(\xi_t)\left[N^C y_{ft}^C\right]^{-\tilde{\chi}_t^r(\xi_t)}\left(1-\frac{\tilde{\chi}_t^r(\xi_t)}{N^C}\right)\right] \frac{y_{ft}^C}{k_{ft}^C} = Q_t R_{ft}^L \tag{8}$$

$$(1-\alpha) \mathbb{E}_{t_1}\left[\tilde{\chi}_t^k(\xi_t)\left[N^C y_{ft}^C\right]^{-\tilde{\chi}_t^r(\xi_t)}\left(1-\frac{\tilde{\chi}_t^r(\xi_t)}{N^C}\right)\right] \frac{y_{ft}^C}{n_{ft}^C} = \mu^{LF} W_{ft}^C R_{ft}^L \tag{9}$$

Thus, by contradiction: Suppose Q_0 and $Q_1 > Q_0$ give rise to two firm-bank equilibria as given by the individual strategies $(W_0, n_0, k_0, l_0, y_0; R_0)$ and $(W_1, n_1, k_1, l_1, y_1; R_1)$ satisfying $k_1 Q_1 = a k_0 Q_0$ with $a \geq 1$. From (5), we then know that $n_1 W_1 = a n_0 W_0$ and thus $l_1 = a l_0$. In turn, since $Q_1 > Q_0$, we must have $k_1 < a k_0$. Similarly, we know from the labor market setup that, in equilibrium, $n_1 > n_0$ implies $W_1 \geq W_0$ such that, because $n_1 W_1 = a n_0 W_0$, we must have $n_1 \leq a n_0$. Combining $k_1 < a k_0$ and $n_1 \leq a n_0$ then yields $y_1 < a y_0$, which implies that expected (projected) sales per unit of the loan have decreased, $\mathbb{E}_{t_1}[\tilde{S}(y_1)]/l_1 < \mathbb{E}_{t_1}[\tilde{S}(y_0)]/l_0$. Thus, unless there exists no taste shock $\xi_t \in \Xi$ such that sales fall short of the original bank loan principal $l_0 R_0$[49], whether $y_1 > y_0$ or $y_1 \leq y_0$, we must have $R_1 > R_0$ because the loan's riskiness has increased. However, notice that $y_1 > y_0$ implies $k_1 > k_0$ or $n_1 > n_0$ and thus, by (8) or (9), $R_1 < R_0$. At the same time, $y_1 \leq y_0$ implies, by (7), $R_1 \leq R_0$. We have a contradiction such that aggregate capital expenditures must be decreasing in their price: $\partial k_t^C(Q_t) Q_t / Q_t < 0$.

A.4 Market for labor

Workers supply labor to the consumption goods sector if the unemployment benefits exceed their respective outside option $\lambda_U W_t^C > q_h z_t^K Q_t$. Thus, aggregate labor supply in the consumption goods sector is given by,

$$n_t^{C,s} = \Pr\left(q_h < \lambda_U W_t^C / z_t^K Q_t\right)$$

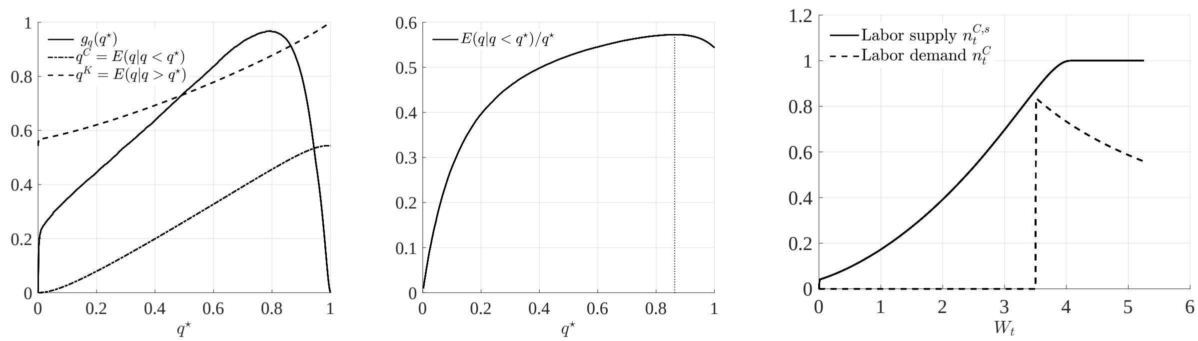
[49] If there were no risk associated with l_0 and l_1, we would have $R_0 = R_1 = R^S$, but this is contextually irrelevant as the primary purpose of the taste shock is to create such risk.

such that labor supply is, quite reasonably, increasing in the offered wage. On the other side of the market, labor demand is given by,

$$\begin{aligned} n_t^C &= \sum_{J^C} n_{ft}^C \\ &\overset{(5)}{=} \left[\frac{(1-\alpha)Q_t}{\mu^{LF}\alpha W_t^C}\right] \underbrace{\sum_{J^C} k_{ft}^C}_{k_t^C} \end{aligned}$$

which *appears* to be decreasing in the prevailing wage. However, since firms *choose* the wage subject to $W_t^C \geq \max\left\{\underline{W}_t^C, \lambda^W W_{t-1}^C\right\}$, labor demand need not actually be decreasing in W_t^C over the latter's entire domain (see Figure 9C). In particular, this is because firms might not find it profitable to lower wages by more than a certain amount (due to concerns relating to worker effort) or because decreasing the wage might depress average worker productivity more than proportionally (due to adverse selection).[50] For a motivating discussion of the two alluded frictions, see Appendix B.

Figure 9. Cross-sectional labor productivity and adverse selection in the labor market



Notes: Panels A and B of Figure 9 depict average sectoral labor productivity for a rectified Gaussian distribution. As can be seen from Panel B, consumption goods producers will never find it optimal to set wages so as to attract less than approximately 87% of workers, namely because per-dollar-output effectively starts increasing below said point. In turn, as captured in Panel C, the underlying adverse selection mechanism can give rise to excess labor supply/involuntary unemployment *in equilibrium* (see Weiss, 1980).

[50] Following the procedure found in Weiss (1980), suppose there exists a wage offer $W^o < \underline{W}_t^C = qz_tQ_t$, a labor demand n^o, and a corresponding output y^o that maximize the firm's payoff. Holding labor costs $C^o = W^o n^o$ fixed, the firm may alternatively employ $n^\star = C^o/\underline{W}_t^C < n^0$ workers at $\underline{W}_t^C$. From (2), we know that $q^C(\underline{W}_t^C)/\underline{W}_t^C > q^C(W^0)/W^0$ and thus, since labor costs are fixed, $q^C(\underline{W}_t^C)n^\star > q^C(W^o)n^o$ in which case the firm produces $y^\star > y^o$ at the same cost C^o. By continuity of production and the strictly decreasing labor cost, the firm may alternatively also produce y^o at a reduced labor cost. Therefore, as long as the firm maximizes some measure of contemporaneous profit, we have induced a contradiction and thus shown that offering any $W^0 < \underline{W}_t^C$ is strictly dominated by the strategy of offering $\underline{W}_t^C$ and employing $n^\star$. For example, consider **??** which depicts a distribution of worker skill that induces an interior maximum of the relevant object $\mathbb{E}[q|q < q^\star]/q^\star$.

A.6 Market for debt and equity financing

Given the auctioneer's announcement R_t^D, households maximize a risk adjusted measure of projected asset returns, whereas funds maximize projected return on equity. The household's optimality condition is given by,

$$\tilde{R}_{it}^E - \tilde{R}_t^D \geq \gamma_h^r \left[\frac{w_{ht_0}^E}{w_{ht_0}^F} \right]$$

which implies,

$$\frac{w_{ht_0}^E}{w_{ht_0}^F} = \min \left\{ \frac{1}{\gamma_h^r} [\tilde{R}_{it}^E - \tilde{R}_t^D], 1 \right\}$$

such that the optimal equity share is, quite reasonably, increasing in the projected risk premium $\tilde{R}_{it}^E - \tilde{R}_t^D$ and decreasing in γ_h^r. Finally, the equilibrium interest rate R_t^D clears the market for financial claims,

$$\int_{JHH} w_{ht_0}^E = \frac{1}{1+\delta_I} \int_{JHH} w_{ht_0}^F$$

as implied by $L_{it} = \delta_I$ and, thus, $\tilde{R}_{it}^E = \tilde{R}_t^A + [\tilde{R}_t^A - R_t^D]\delta_I$ for each i.

B Downward nominal wage rigidity

In the proposed framework, the key assumption linking the occasional, fire-sale-induced nominal demand slumps to real economic downturns is the downward nominal rigidity in wages, which raises real wages during economic downturns such as the Great Recession (Figure 10).[51] Indeed, "the existence of wage stickiness is not in doubt" (Kahneman et al., 1986) such that it is unsurprising that wage frictions constitute an integral part of the modern New Keynesian toolkit.[52]

Although modern New Keynesian theory makes extensive use of various types of wage rigidity, macro has done little to motivate such frictions endogenously.[53] In an effort to close this gap, I

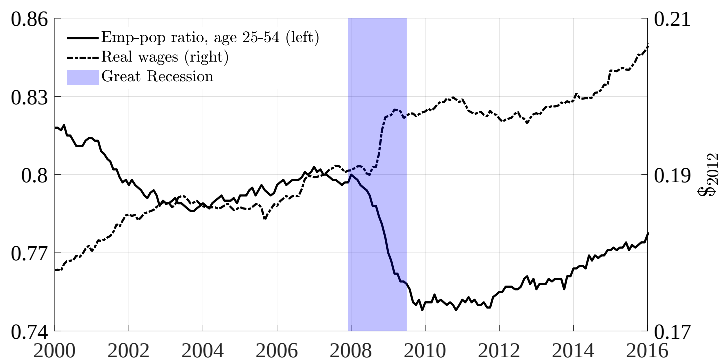
[51] In his *General Theory*, Keynes (1936) explored the possibility that wages may be nominally rigid, thus challenging the prevailing view that unemployment was voluntary during the Great Depression (see Tobin, 1972). Indeed, Akerlof et al. (1996) and Bernanke and Carey (1996) find that the Great Depression was amplified if not entirely caused by nominally downward rigid wages. See McLaughlin (1994), Akerlof et al. (1996), Card and Hyslop (1997), Lebow et al. (2003), Fehr and Goette (2005), Dickens et al. (2007), Daly et al. (2011), Daly et al. (2012), Barattieri et al. (2014), Fallick et al. (2016) for studies establishing the existence of such rigidities empirically.

[52] Recent examples of New Keynesian DSGE models with symmetric wage rigidities include Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007). Asymmetric downward rigidities, which have gained traction following the Great Recession, are explored in Kim and Ruge-Murcia (2011), Schmitt-Grohé and Uribe (2016), and Na et al. (2018).

[53] For this, microeconomic theory typically emphasizes 'efficiency wages', or the notion that labor productivity is increasing in the wage: "you get what you pay for" (Solow, 1979). To generate such a dependence, Weiss (1980) pairs heterogenous labor productivity with asymmetric information to induce adverse selection, whereas Shapiro and

appeal to the empirical literature that has studied *why* wages are downward rigid. Specifically, in a survey of 184 firms, Campbell and Kamlani (1997) find that there are two primary reasons why firms are hesitant to cut wages, namely that workers are expected to respond by curbing their effort ('endogenous worker effort') and that the best employees are expected to quit first ('adverse selection').[54] In this spirit, I assume that workers respond to nominal wage cuts by exerting less effort such that firms will generally refrain, when confronted with a lack in nominal demand, from lowering nominal wages and opt to shed labor instead.[55]

Figure 10. US employment and real wages between 2000 and 2016



Notes: Figure 10 depicts the evolution of US employment and CPI-adjusted, average hourly wages between 2000 and 2016. During the Great Recession, real wages experienced an immediate and substantial spike while employment underwent a rapid and substantial decline. The proposed theory rationalizes this development as follows: Since worker effort is sensitive to nominal wage cuts, firms react to nominal slumps in consumer demand by curbing their demand for labor (rather than lowering nominal wages). All data was retrieved from FRED.

C The consumption-savings decision

In the proposed framework, households do not maximize expected lifetime utility over a stream of current and future consumption. First and foremost, this is because deriving a model-implied distribution over future consumption is extraordinarily challenging if not impossible for an average person. Nevertheless, most households undoubtedly understand that future consumption, retirement consumption in particular, is strictly increasing in accumulated savings. Thus, rather than worrying about future consumption directly, the proposed objective's relevant marginal benefit as-

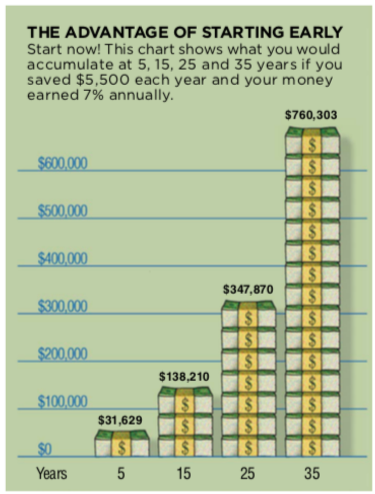
Stiglitz (1984) give workers the ability to shirk. Potential other sources of efficiency wages are costly labor turnover (Stiglitz, 1974) or endogenous worker effort as motivated via a "gift exchange" (Akerlof, 1982) or via "fairness" (Akerlof and Yellen, 1990).

[54]In similar efforts, Bewley (1999) and Blinder and Choi (1990) find strong evidence in support of the worker effort hypothesis, but the latter find no evidence that firms fear adverse selection in *hiring*. They hypothesize, however, that adverse selection may play a larger role in *quits*, a suspicion substantiated by Campbell and Kamlani (1997).

[55]Indeed, Kahneman et al. (1986) find that nominal wage cuts are often perceived as 'unfair'.

sociated with the marginal cost of decreasing consumption today is given by the projected increase in accumulated retirement balances. This modeling choice entails the conceptual drawback that future consumption only generates utility implicitly — though retirement balances — but its main conceptual benefit is that it is in line with ordinary experience. In fact, the household's retirement projection (4) directly derives from the US Department of Labor's guidance on how to save for retirement (Figure 11).[56]

Figure 11. Retirement savings guidance from the US Department of Labor (DOL)



Notes: Figure 11 illustrates the US Department of Labor's publication "Top 10 Ways to Prepare for Retirement". The household's retirement projection (4) precisely represents the geometric sum formula underlying Figure 11.

D Data

The model was parameterized using quarterly US data from 1987 until 2017. The analysis is limited to this time period as the institutional monetary policy changes undertaken by former Fed chair Volcker are widely believed to have muted the business cycle (see Stock and Watson, 2002).[57] All labor market data was obtained from the Bureau of Labor Statistics (BLS), whereas the other series were sourced from the Federal Reserve of St. Louis database (FRED), the Federal Reserve Board (FRB), or Yahoo Finance. The following contains the origin of all data series displayed in the respective figures.

[56] In essence, the exercise illustrates the (nominal) marginal benefit of saving more today, again assuming that one saves the exact same amount each period until retirement.

[57] Failing to account for such structural breaks effectively invalidates any moment matching efforts though a violation of the underlying requirement of ergodicity.

TABLE 5. DATA†

Fig.	Series	Frequency (level), source
1.	Unemployment	Monthly (2008=0), LNS14000000 via BLS
	Employment	Monthly (2008=0), LNS12300000 via BLS
	Employment, 25-54	Monthly (2008=0), LNS12300060 via BLS
2.	Unemployment	Quarterly, LNS14000000 via BLS
3.	Answers	Quarterly from Amir Sufi's Website
10.	Employment	Monthly, LNS12300060 via FRED
	Wages	Monthly, AHETPI via FRED
	CPI	Monthly, PCEPILFE via FRED

†Notes: Figure 2 plots a Gaussian kernel density estimate of US unemployment since 1987. The estimate is constructed as in Botev et al. (2010) with a mesh granularity of 2^{-7}. The employed input frequency is reduced to quarterly because the model is parameterized to match quarterly data.

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