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Wall Street QE vs. Main Street Lending[☆]

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ABSTRACT

Monetary and fiscal authorities reacted swiftly to the COVID-19 pandemic by purchasing assets (or "Wall Street QE") and lending directly to non-financial firms (or "Main Street Lending"). Our paper develops a new framework to compare and contrast these different policies. For the Great Recession, characterized by impaired balance sheets of financial intermediaries, Main Street Lending and Wall Street QE are perfect substitutes and both stimulate aggregate demand. In contrast, for the COVID-19 recession, where non-financial firms faced significant cash flow shortages, Wall Street QE is almost completely ineffective, whereas Main Street Lending can be highly stimulative.

1. Introduction

The US government acted swiftly and dramatically to support the US economy in response to the COVID-19 pandemic in 2020 and into 2021. Many of the Federal Reserve's actions represented a resuscitation or extension of facilities and tools it deployed to combat the Financial Crisis and Great Recession of 2007–2009, which involved purchasing assets from financial markets. In addition, both the Fed and the Treasury made a similar effort to lend directly to non-financial firms. In March 2020, for example, the Fed announced a sequence of "Main Street Lending" programs. Around the same time, the Treasury, in conjunction with the Small Business Administration, implemented the Paycheck Protection Program (PPP).

This paper represents a first attempt to assess the efficacy of the government directly lending to non-financial firms as opposed to interacting only with financial markets. We do so in a macroeconomic model that contains the minimum number of necessary frictions to study these types of policies; the rest of the model is fairly standard. Financial intermediaries are modeled as in Gertler and Karadi (2013) and Sims and Wu (2021). These intermediaries hold long-term bonds issued by non-financial firms, who are required to float debt to finance their expenditure on new physical capital. The bond market is segmented in that households cannot directly hold these long-term bonds. Intermediaries face an endogenous leverage constraint that results in excess returns of long-term bonds over the short-term policy rate. The monetary authority can purchase long-term bonds directly from intermediaries, which eases their leverage constraint. This allows intermediaries to purchase more long-term bonds, which in equilibrium results in higher bond prices and more aggregate demand. We refer to this type of asset purchase by the central bank from financial markets as "Wall Street QE".

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The main modeling contribution of this paper is to allow the government to directly lend to non-financial firms. We refer to such direct purchases/lending as "Main Street Lending". Without additional constraints relative to those described in the paragraph above, Main Street Lending turns out to be isomorphic to Wall Street QE. To account for the unique features of the COVID-19 recession, we introduce an additional constraint that restricts the amount of credit a non-financial firm can secure as a function of its cash flows. This seems particularly relevant for the early stages of the COVID-19 crisis, where government-mandated lockdowns and significant changes in consumer behavior resulted in the near-evaporation of cash flows for many non-financial firms. When this "cash flow constraint" is binding, Main Street Lending can be a highly effective way to stimulate economic activity because it loosens the constraint facing non-financial firms and allows them to continue to issue debt to finance investment. Conversely, Wall Street QE becomes almost completely ineffective in this situation. Even though asset purchases from financial markets free up space on intermediary balance sheets, intermediaries remain unwilling to purchase bonds issued by firms with low cash flows.

In a quantitative version of our model, we compare and contrast the two policies against the backdrop of the Great Recession as well as COVID-19. We model the Great Recession of 2007–2009 as a situation in which intermediaries were constrained, but non-financial firms were not. We show that Main Street Lending and Wall Street QE are equivalent ways to stimulate aggregate demand in such a scenario. For the COVID-19 crisis, we assume that both intermediaries and firms were facing binding constraints. In this situation, Wall Street QE is almost completely ineffective at stimulating variables like output, labor, and consumption. In contrast, Main Street Lending becomes far more stimulative.

While our analysis is conducted in a quantitative, medium-scale DSGE model, we view our principal contribution as more qualitative than quantitative in nature. Our model abstracts from myriad real-world features that might be important for fully quantifying the effects of QE and Main Street Lending programs. For example, we assume homogeneous production firms, and consider stark cases in which a particular kind of constraint either does or does not bind. In reality, firms were likely differentially impacted by COVID-19 shutdowns, and the implementation of the various programs that we group under Main Street Lending imposed particular restrictions that, to fully quantify, would require a model with rich firm heterogeneity. Such a model is beyond the scope of the present paper, but is a potentially important area for further research. Furthermore, uptake on Main Street Lending programs was small, and in practice these programs were retired after a short period of time, making a full quantitative accounting of the actual effects of these programs difficult. Nevertheless, viewed through the lens of our model, the combined efforts of the Federal Reserve and US Treasury to lend directly to non-financial firms in 2020 seem to be justified given the particular circumstances the economy then faced. We view our analysis as conveying a simple yet powerful message. It is not sufficient for the government to lend freely to combat an economic crisis. It is just as important for the government to lend freely to *where constraints are most binding.* In the Great Recession, this was the financial system. In 2020, it was non-financial firms.

The remainder of the paper proceeds as follows. Section 2 presents some brief background on central bank practices and provides some details concerning the Federal Reserve's and US Treasury's recent actions in response to the COVID-19 crisis. Section 3 presents the key ingredients of our model and discusses the potential differences between Wall Street QE and Main Street Lending. Section 4 presents quantitative results from our model. Section 5 concludes.

2. The Fed's emergency COVID-19 responses

In this section, we provide a brief description of some of the new facilities created and emergency actions collectively taken by the Fed and the US Treasury in response to the COVID-19 crisis. We frame our discussion in a historical context by beginning with a brief description of consensus views regarding central bank interventions and highlight how recently instituted programs represent a significant departure from the historical consensus.

Dating back to at least Bagehot (1873), a prevailing view among monetary economists is that central banks ought to lend freely to solvent but illiquid banks to support the free flow of credit in a crisis. Traditionally, central banks around the world, and in particular the Federal Reserve in the United States, only directly interacted with commercial banks who fund themselves with demand deposits. This practice of only interacting with commercial banks changed during the Financial Crisis of 2007–2009. Partly in response to the size and scope of the crisis, and partly as a consequence of the evolution of credit intermediation outside of the traditional, regulated banking sector, the Federal Reserve significantly widened its sphere of interaction. During that crisis, the Fed created various lending facilities to extend credit directly to a variety of non-bank intermediaries, such as investment banks, insurance conglomerates, and money market mutual funds, to name but a few. These non-bank intermediaries are sometimes referred to as belonging to the "shadow banking" system. While not banks in the legal sense of not funding themselves via demand deposits, they engage in liquidity and maturity transformation, perform the essential tasks of credit intermediation, and are just as susceptible (if not more, given the lack of deposit insurance) to run dynamics as traditional commercial banks. In addition to emergency lending to non-bank intermediaries, during and after the Great Recession the Federal Reserve also massively expanded the size of its balance sheet via the purchase of large quantities of non-traditional assets — chiefly longer-term Treasury securities and agency mortgage backed securities (MBS).

While controversial at the time, extension of credit beyond the regulated banking sector to other types of financial firms seems rather natural given that roughly two-thirds of credit intermediation in the United States now happens outside of commercial banks. Large-scale asset purchases, more commonly known as quantitative easing (QE), in contrast, were deployed as an antidote to the problems of the zero lower bound (ZLB) on policy rates and represented a legitimately new monetary policy tool (at least in the US). Many have found QE to be a reasonably good substitute for conventional policy at the ZLB (e.g. Wu and Xia 2016, Swanson 2018, and Sims and Wu 2020). Even before the COVID-19 crisis, most observers expected QE to become a regular component of central banks' toolkit (Brainard, 2019).

In response to the economic calamity resulting from the COVID-19 pandemic, within the span of a few weeks in March 2020 the Fed swiftly lowered the target Federal Funds Rate down to zero; increased its overnight repo operations to stabilize short-term funding markets; re-instituted dollar swap agreements with foreign central banks; used moral suasion to encourage banks to take advantage of the Fed's discount window; revived the Money Market Mutual Fund Liquidity Facility,[1] the Commercial Paper Funding Facility, the Primary Dealer Credit Facility, and the Term Asset-Backed Securities Loan Facility; and announced intentions to resume large QE purchases (a first announcement of $700 billion split between long-term Treasuries and agency MBS, later amended to an unlimited amount, or so-called "QE-infinity"). While massive in both scope and size, all of these actions represent natural extensions of the Fed's actions in 2007–2009. In particular, they only involved the Federal Reserve interacting with financial firms.

The newer, and far more controversial, actions by the Fed in response to the COVID-19 crisis involved direct lending to *non-financial firms*. These new facilities included the Primary Market Corporate Credit Facility (PMCCF), the Secondary Market Corporate Credit Facility (SMCCF), and the Main Street Lending Program (which consisted of three related facilities, the MSNLF, MSPLF, and MSELF). The PMCCF and SMCCF aimed to purchase corporate bonds either directly from non-financial firms (PMCCF) or indirectly on secondary markets (SMCCF) through exchange-traded funds (ETFs). The Main Street Lending program aimed to ensure the flow of credit to small- and medium-sized business, initially allocating up to $600 billion in available funds. In addition to the Fed's new program and facilities, the US Treasury also engaged in direct lending to non-financial firms via its Paycheck Protection Program (PPP), which was implemented by the Small Business Administration.

In practice, while the Fed did greatly expand the size of its balance sheet through its continuing QE operations, the other facilities and programs it implemented that were new to the COVID-19 crisis ended up being short-lived and uptake was modest.[2] Even though these programs ended up being small, we nevertheless think it is important to study their potential efficacy. They represented a sharp departure from conventional central banking practice, which involved *indirect* support of the economy via asset purchases on secondary markets. In contrast, the new Main Street Lending and related programs involved *direct* support of non-financial firms.

For simplicity, in what follows we shall refer to purchases of assets on secondary markets, such as QE programs instituted during the both the Great Recession and COVID-19 crisis, as "Wall Street QE". We do so because asset purchases on secondary markets involves the Fed interacting with financial firms, which is what central banks have always traditionally done. In contrast, we label the extension of credit directly to non-financial firms as "Main Street Lending". Although our model abstracts from many nuances in these programs, our objective is to understand whether and under what conditions Main Street Lending differs from Wall Street QE. We also aim to provide insight into which type of program was best-suited for the early stages of the COVID-19 crisis.

3. Model

In this section, we lay out the principal ingredients of our model. We begin by describing the standard model in which there is no Main Street Lending. Along most dimensions, the model is similar to Sims and Wu (2021). We show how, in normal times, government asset purchases (Wall Street QE) can be an effective demand stimulus. But when production firms are subject to a cash flow constraint, Wall Street QE becomes completely ineffective. We then show how direct lending from the government to firms (Main Street Lending) can be highly effective in such a situation.

Before proceeding with details, we begin with a broad, high-level overview of the model. The production side of the economy consists of a representative wholesale firm, a representative new capital goods firm, a continuum of retailers, and a representative final goods firm. A representative household consumes, saves via a one-period deposits, and supplies labor to labor unions. A continuum of labor unions repackage household labor for resale to a competitive labor packer. The wholesale firm purchases labor from the labor packer and accumulates its own capital, purchasing new capital from the representative new capital goods firm. The wholesale producer sells its output to retailers, who repackage wholesale output for resale to the final goods firm. Price and wage stickiness are introduced at the retail firm and labor union levels, respectively, which allows us to work with a representative household and a representative wholesale producer.

Financial intermediaries engage in maturity transformation between the one-period deposits of the household and the long-term bonds issued by the wholesale firm; they are structured as in Gertler and Karadi (2013). Markets are segmented in that the household does not have access to these long-term bonds; they can only be purchased by financial intermediaries. To the extent to which intermediaries are balance sheet constrained, a spread between yields on long-term bonds and short-term deposits will emerge. Similarly to Carlstrom et al. (2017), we assume that the wholesale producer must issue long-term bonds to finance a fraction of its investment. Both this constraint, as well as the balance sheet constraint on intermediaries, are key features in Sims and Wu's (2021) model.

In addition to setting the short-term nominal interest rate, the government in our model can purchase long-term bonds in open markets. We label such asset purchases as "Wall Street QE". As in Sims and Wu (2021, 2019), "Wall Street QE" can be effective by relaxing the endogenous leverage constraint facing financial intermediaries — by purchasing long-term bonds, the government frees up space on intermediary balance sheets to purchase private bonds, which results in more investment.

[1] Technically, the MMMLF was new to the COVID-19 crisis, but was very similar to the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility and the Money Market Investor Funding Facility, both established in 2008.

[2] The Paycheck Protection Program, in contrast, was quite popular, and total lending amounted to around $700 billion, which was nevertheless small relative to the Fed's QE purchases.

We introduce another constraint, an adaptation from Drechsel (2019), that limits the amount of debt the wholesale firm can issue as a function of its current cash flows.[3] We think such a cash flow constraint is a reasonable description of the state of affairs facing many non-financial firms at the height of the COVID-19 pandemic. When firms are cash flow constrained, we show that open market asset purchases – i.e. Wall Street QE – are completely ineffective. We then show how direct lending from the government, what we call Main Street Lending, can nevertheless be a highly effective demand stimulus.

In the main text, we describe only those aspects of the model that are most relevant for studying Wall Street QE and Main Street Lending. The rest of the model details are relegated to the Appendices.

3.1. Wholesale firm

The wholesale firm produces output according to:

$$Y_{w,t} = A_t K_t^{\alpha} L_{d,t}^{1-\alpha}. \tag{3.1}$$

A_t is an exogenous aggregate productivity shifter, K_t is the stock of physical capital chosen the previous period, and $L_{d,t}$ is labor input. The parameter $\alpha \in (0,1)$ captures capital's share of income. The wholesale firm accumulates its own physical capital, which obeys the law of motion:

$$K_{t+1} = \widehat{I}_t + (1-\delta)K_t. \tag{3.2}$$

New physical capital, $\widehat{I}_t$, is purchased from an investment goods firm at price P_t^k. Labor is hired at nominal wage W_t from the labor packing firm. Output is sold to retailers at price P_t^w.

The wholesale firm faces two constraints. First, it must finance a fraction, ψ, of its expenditure on new capital goods by floating long-term bonds. These long-term bonds are modeled as perpetuities with decaying coupon payments as in Woodford (2001). One unit of bonds issued today obliges the firm to a coupon payment of one dollar in the next period, κ dollars in two periods, κ^2 dollars in three periods, and so on, where $\kappa \in [0,1]$. New bond issuances trade at market price Q_t. Let $F_{w,t-1}$ denote the total coupon liability due today from past issuances. It is straightforward to show that, at time t, the total value of all outstanding bonds is $Q_t F_{w,t}$, while the quantity of new issuances can be written as $F_{w,t} - \kappa F_{w,t-1}$. What we call the investment constraint is therefore:

$$\psi P_t^k \widehat{I}_t \leq Q_t(F_{w,t} - \kappa F_{w,t-1}), \tag{3.3}$$

and is the same as in Sims and Wu (2021).

The second constraint facing the wholesale firm is that the amount of bonds that it can issue, $Q_t(F_{w,t} - \kappa F_{w,t-1})$, is constrained by *current cash flows*, defined as revenue less payments to labor. This definition follows Drechsel (2019). We refer to this constraint as a cash flow constraint:

$$Q_t(F_{w,t} - \kappa F_{w,t-1}) \leq \varphi \left(P_t^w A_t K_t^{\alpha} L_{d,t}^{1-\alpha} - W_t L_{d,t} \right), \tag{3.4}$$

where φ is an exogenous parameter.

We assume that the "investment constraint", (3.3), is binding in both of the scenarios we study: the Great Recession and COVID-19. In contrast, we think about the cash flow constraint, (3.4), as only binding in extreme circumstances. In particular, the cash flow constraint was arguably not relevant in the 2007–2009 crisis, which had its origins in the banking system. But in the environment characterizing much of 2020, with mandated lockdowns and important changes in consumer behavior, a cash flow constraint like (3.4) is likely to bind. In Section 4, we provide empirical evidence in support of this assumption.

Nominal dividends for the wholesale firm are:

$$D_{w,t} = P_t^w A_t K_t^{\alpha} L_{d,t}^{1-\alpha} - W_t L_{d,t} - P_t^k \widehat{I}_t - F_{w,t-1} + Q_t(F_{w,t} - \kappa F_{w,t-1}). \tag{3.5}$$

The firm's objective is to maximize the present discounted value of real dividends, $d_{w,t} = D_{w,t}/P_t$, discounted by $\Lambda_{0,t} = \frac{\beta^t u'(C_t)}{u'(C_0)}$, the stochastic discount factor of the household, subject to the law of motion for capital, (3.2), the investment constraint, (3.3), and the cash flow constraint, (3.4). The first order conditions are:

$$w_t = (1-\alpha) p_t^w A_t K_t^{\alpha} L_{d,t}^{-\alpha} \tag{3.6}$$

$$\lambda_{1,t} = p_t^k (1 + \psi \lambda_{2,t}) \tag{3.7}$$

$$\lambda_{1,t} = \mathbb{E}_t \Lambda_{t,t+1} \left[(1 + \varphi \lambda_{3,t+1}) \alpha p_{t+1}^w A_{t+1} K_{t+1}^{\alpha-1} L_{d,t+1}^{1-\alpha} + \lambda_{1,t+1}(1-\delta) \right] \tag{3.8}$$

$$(1 + \lambda_{2,t} - \lambda_{3,t}) Q_t = \mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \left[1 + \kappa Q_{t+1}(1 + \lambda_{2,t+1} - \lambda_{3,t+1}) \right] \tag{3.9}$$

[3] In Drechsel (2019), all debt is one-period, and the cash flow constraint applies to the *stock* of outstanding debt. In our model, firms issue long-term debt, and, as is shown below, we write the cash flow constraint in terms of the *flow* of new debt issued. Our results are nevertheless qualitatively similar if we have firms issuing short-term debt with the cash flow constraint applying to the stock of debt.

where $p_t^w = P_t^w/P_t$ is the inverse price markup, $w_t = W_t/P_t$ is the real wage, and $p_t^k = P_t^k/P_t$ is the relative price of capital measured in consumption goods. In these expressions, $\lambda_{1,t}$ is the Lagrange multiplier on the capital accumulation equation, $\lambda_{2,t} \geq 0$ is the multiplier on the investment constraint, and $\lambda_{3,t} \geq 0$ is the multiplier on the cash flow constraint. Π_t is the gross inflation rate between $t-1$ and t. (3.6) is the labor demand expression; this condition is standard. (3.7) is the first order condition for investment and relates the price of new capital goods to the multiplier on the capital accumulation constraint. $\lambda_{2,t} \geq 0$ throws a wedge into the usual relationship that the multiplier and the price of capital would be the same. (3.8) is the first order condition for physical capital. $\lambda_{3,t+1} \geq 0$ functions like a subsidy to the return on physical capital; having more capital eases the cash flow constraint in subsequent periods. (3.9) is the optimality condition for the choice of $F_{w,t}$, how many long-term bonds to issue. $\lambda_{2,t}$ and $\lambda_{3,t}$ enter this optimality condition in the same way but with opposite signs. When the cash flow constraint is not binding, then $\lambda_{3,t} = 0$ and the optimality conditions for bond issuance are the same as in Sims and Wu (2021).

3.2. Financial intermediaries

Financial intermediaries are structured as in Gertler and Karadi (2013) and Sims and Wu (2021). Here, we sketch out the principal ingredients of the problem facing financial intermediaries.

In the background, there are a mass of intermediaries indexed by i. Intermediaries stochastically exit with probability $1-\sigma$ at the end of each period. Exiting intermediaries are replaced each period by an equal number of newly-formed intermediaries who begin with startup real net worth of X. Intermediaries will differ in terms of the level of net worth, depending on how long since they were formed. But assumptions in the model guarantee that the value of an intermediary is linear in net worth — so these intermediaries are simply scaled versions of one another. This ensures that intermediaries behave identically with respect to their choices of assets to hold. For the purposes of the exposition in the text, we therefore drop i indexes and think about there being a representative intermediary.

Intermediaries fund themselves with deposits from the household D_t and accumulated net worth N_t. On the asset side of the balance sheet, they can hold bonds issued by the wholesale firm F_t, bonds issued by the government B_t (these take the same form as bonds issued by the wholesale firm, trading at market price $Q_{B,t}$), and reserve balances with the government RE_t. The balance sheet condition is:

$$Q_t F_t + Q_{B,t} B_t + RE_t = D_t + N_t. \tag{3.10}$$

Assuming an intermediary survives across periods, its net worth evolves according to:

$$N_t = \left(R_t^F - R_{t-1}^d\right) Q_{t-1} F_{t-1} + \left(R_t^B - R_{t-1}^d\right) Q_{B,t-1} B_{t-1} + \left(R_{t-1}^{re} - R_{t-1}^d\right) RE_{t-1} + R_{t-1}^d N_{t-1}, \tag{3.11}$$

where R_t^F and R_t^B are the holding period returns on private and government bonds, respectively, and R_t^{re} is the gross interest rate on reserves, set by the government. R_t^d is the gross interest rate on deposits. The holding period returns on long bonds satisfy:

$$R_t^F = \frac{1+\kappa Q_t}{Q_{t-1}}, \tag{3.12}$$

$$R_t^B = \frac{1+\kappa Q_{B,t}}{Q_{B,t-1}}. \tag{3.13}$$

So long as there exist excess returns (e.g. $R_t^F - R_{t-1}^d > 0$), a financial intermediary's objective is to maximize its terminal real net worth. Discounting is by the stochastic discount factor of the household adjusted to reflect the probability of future exit. Let V_t be the value of an intermediary in period t that is continuing to period $t+1$. This value satisfies:

$$V_t = \max_{F_t, B_t, RE_t} \ (1-\sigma)\mathbb{E}_t \Lambda_{t,t+1} n_{t+1} + \sigma \mathbb{E}_t \Lambda_{t,t+1} V_{t+1}. \tag{3.14}$$

where $n_t = N_t/P_t$ is real net worth (similarly, $d_t = D_t/P_t$, $f_t = F_t/P_t$, $b_t = B_t/P_t$, and $re_t = RE_t/P_t$ are real quantities of deposits, bonds, government bonds, and reserves). If there were no constraints, an intermediary would purchase assets up to the point of eliminating excess returns. We introduce a costly enforcement constraint to prevent that. In particular, we assume that, at the end of a period, an intermediary can default and abscond with a stochastic fraction, θ_t, of its corporate bonds and a fraction, $\theta_t \Delta$, of its government bonds, where $0 \leq \Delta \leq 1$. Creditors recover the rest of the intermediary's assets in default, including all of its reserves. To prevent default from occurring, creditors impose an endogenous leverage constraint on intermediaries of the form:

$$V_t \geq \theta_t \left(Q_t f_t + \Delta Q_{B,t} b_t\right). \tag{3.15}$$

This constraint ensures that it is more valuable for an intermediary to continue on as an intermediary as opposed to defaulting and absconding with assets. Let λ_t be the Lagrange multiplier on the constraint. The first order conditions for the intermediary are:

$$\mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} \left(R_t^{re} - R_t^d\right) = 0, \tag{3.16}$$

$$\mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} \left(R_{t+1}^F - R_t^d\right) = \frac{\lambda_t}{1+\lambda_t}\theta_t, \tag{3.17}$$

$$\mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} \left(R_{t+1}^B - R_t^d\right) = \frac{\lambda_t}{1+\lambda_t}\Delta\theta_t, \tag{3.18}$$

where Ω_t satisfies:

$$\Omega_t = 1 - \sigma + \sigma\theta_t\phi_t, \tag{3.19}$$

and ϕ_t is a modified leverage ratio and satisfies:

$$\phi_t = \frac{\mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} R_t^d}{\theta_t - \mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} (R_{t+1}^F - R_t^d)}. \tag{3.20}$$

One can show that $V_t = \theta_t \phi_t n_t$. When the constraint binds, the modified leverage ratio equals:

$$\phi_t = \frac{Q_t f_t + \Delta Q_{B,t} b_t}{n_t}. \tag{3.21}$$

(3.16) reveals that, in equilibrium, $R_t^{re} = R_t^d$. This arises because an intermediary is unconstrained in the amount of reserves it can hold. In contrast, if $\lambda_t > 0$, there will be excess returns on corporate and government bonds. The magnitude of these excess returns will differ by the factor Δ, which is an exogenous parameter. In our quantitative exercises, we assume that the constraint embodied by (3.15) is always binding.

3.3. Government

We do not draw a distinction between the monetary and fiscal authority, and instead refer only to the government. The government consumes an exogenous level of output each period, G_t. It finances this spending through a combination of lump sum taxes, debt issuance, and revenue from its monetary operations. In nominal terms, its flow budget constraint is:

$$P_t G_t + B_{G,t-1} = P_t T_t + P_t T_{G,t} + Q_{B,t}(B_{G,t} - \kappa B_{G,t-1}). \tag{3.22}$$

Government bonds are perpetuities with decaying coupon payments and are structured identically to the bonds issued by the wholesale firm. They trade at price $Q_{B,t}$. $T_{G,t}$ represents revenue from monetary operations, which we discuss below. Given G_t, $B_{G,t}$, $Q_{B,t}$, and $T_{G,t}$, lump sum taxes on the household, T_t, adjust to make (3.22) always hold.

The government can hold privately-issued bonds on its balance sheet. These assets are financed via reserves, which the government can freely set. The government's balance sheet is

$$Q_t F_{G,t} = RE_t. \tag{3.23}$$

The government sets the interest rate on reserves according to a traditional Taylor-type rule[4]:

$$\ln R_t^{re} = (1-\rho_R)\ln R^{re} + \rho_R \ln R_{t-1}^{re} + (1-\rho_R)\left[\phi_\pi(\ln \Pi_t - \ln \Pi) + \phi_y(\ln Y_t - \ln Y_{t-1})\right] + s_R \varepsilon_{R,t}. \tag{3.24}$$

As shown above, in equilibrium $R_t^{re} = R_t^d$, so we could equivalently model the government as directly setting the short-term deposit rate.

The government earns revenues from its monetary operations to the extent to which the return on private bonds exceeds the interest rate on reserves. The nominal revenue from monetary operations satisfies:

$$P_t T_{G,t} = R_t^F Q_{t-1} F_{G,t-1} - R_{t-1}^{re} RE_{t-1}. \tag{3.25}$$

Changes in government private bond holdings are what we call "Wall Street QE". Changes in such holdings involve asset purchases on an open market. We assume that $f_{G,t} = F_{G,t}/P_t$, or the real quantity of private bonds held by the government, follows an exogenous AR(1) process:

$$f_{G,t} = (1-\rho_f) f_G + \rho_f f_{G,t-1} + s_f \varepsilon_{f,t}. \tag{3.26}$$

In practice, QE purchases in the US have mostly involved central bank purchases of long-term government bonds or agency-guaranteed mortgage backed securities, though in 2020 the Federal Reserve announced facilities to purchase corporate bonds carrying credit risk. It is straightforward to modify our analysis to instead think of QE as purchases of long-term government debt; see Sims and Wu (2021) for example.

[4] For our main analysis, we ignore constraints imposed by the ZLB. See results in Section 4.4 for a discussion of the ZLB.

3.4. Wall Street QE vs. Main Street Lending

If the cash flow constraint on wholesale firms does not bind, i.e. (3.4) does not hold with equality and $\lambda_{3,t}$ consequently equals zero, then our model is essentially the same as Sims and Wu (2021). Wall Street QE, or asset purchases by the government, work by loosening the enforcement constraint on intermediaries, (3.15). Asset purchases involve a *swap* of assets where a constraint applies (corporate bonds) for another asset, reserves, which is irrelevant for the enforcement constraint facing an intermediary. This swap thus loosens the constraint facing an intermediary, allowing it to purchase more private bonds. In equilibrium, this results in higher bond prices, Q_t and $Q_{B,t}$, and correspondingly lower yields. Since we assume that the wholesale firm must float debt to finance investment, a higher bond price results in more investment. This works to stimulate overall aggregate demand.

However, when the cash flow constraint binds, Wall Street QE becomes ineffective. To see this, combine (3.4) with (3.3):

$$\psi P_t^k \hat{I}_t \leq \varphi \left(P_t^w A_t K_t^\alpha L_{d,t}^{1-\alpha} - W_t L_{d,t} \right), \tag{3.27}$$

Private investment is simply restricted by current cash flows. The mechanism through which Wall Street QE works is therefore not present, and absent general equilibrium effects, it would be completely ineffectual. Indeed, in quantitative simulations in the next section, we show that Wall Street QE is almost completely ineffective at stimulating output when firms are cash flow constrained.

In the late-spring of 2020, through a variety of fiscal and monetary programs, the US government introduced several programs to lend *directly* to non-financial firms. We show analytically how such programs might make sense in a world in which non-financial firms are cash flow constrained and traditional QE programs are ineffective. Suppose that the government can lend directly to non-financial firms. For convenience, we assume that these loans take the same form as corporate bonds, with a decaying coupon payout of κ. Let $M_{w,t}$ denote the coupon payments the wholesale firm owes to the government in period $t+1$ due to past issuances of bonds. These bonds trade at price $Q_{M,t}$, with corresponding return R_t^M. The funds generated by new issuance are therefore $Q_{M,t}(M_{w,t} - \kappa M_{w,t-1})$.

We assume that these loans from the government can be used to alleviate the investment constraint, (3.3), which is always binding. In particular:

$$\psi P_t^k \hat{I}_t \leq Q_t (F_{w,t} - \kappa F_{w,t-1}) + Q_{M,t}(M_{w,t} - \kappa M_{w,t-1}). \tag{3.28}$$

In contrast, the cash flow constraint applies only to bonds issued into the open market, $F_{w,t}$. It is consequently the same as above, (3.4). Without a cash flow constraint, Main Street Lending would have very similar effects as Wall Street QE because they both loosen this investment constraint.[5]

Unlike Wall Street QE, Main Street Lending can be highly effective when non-financial firms are cash flow constrained. To see this, combine (3.4) with (3.28):

$$\psi P_t^k \hat{I}_t \leq \varphi \left(P_t^w A_t K_t^\alpha L_{d,t}^{1-\alpha} - W_t L_{d,t} \right) + Q_{M,t}(M_{w,t} - \kappa M_{w,t-1}). \tag{3.29}$$

Increases in $M_{w,t}$ directly loosen the cash flow constraint, and allow firms to do more investment.

To incorporate Main Street Lending, we modify the government's budget constraint, (3.22), as follows:

$$P_t G_t + B_{G,t-1} + Q_{M,t}(M_{G,t} - \kappa M_{G,t-1}) = P_t T_t + P_t T_{G,t} + Q_{B,t}(B_{G,t} - \kappa B_{G,t-1}) + M_{G,t-1}. \tag{3.30}$$

$M_{G,t-1}$ denotes interest payments to the government from existing loans, and therefore enters on the right hand side of the constraint. $Q_{M,t}(M_{G,t} - \kappa M_{G,t-1})$ represents new loans issued by the government, and therefore enters on the expenditure side of the constraint.

Consistent with what was actually proposed and implemented in the immediate aftermath of the Great Recession and the pandemic recession, Wall Street QE is modeled as a monetary operation, while we collectively model Main Street Lending programs of both the Fed and Treasury (e.g. PPP) as fiscal operations. The line between traditional monetary policy and fiscal intervention has been blurry since 2020. The consolidated government balance sheet in our model reflects this feature.

For Main Street Lending, we assume that the government fixes both the available quantity of direct loans and the price (equivalently the return). This is essentially how Main Street Lending programs were implemented in practice. In particular, we assume that the real quantity of loans, $m_{G,t} = M_{G,t}/P_t$, follows an exogenous AR(1) process, similar to (3.26):

$$m_{G,t} = (1 - \rho_m) m_G + \rho_m m_{G,t-1} + s_m \varepsilon_{m,t}. \tag{3.31}$$

We refer to shocks to the real quantity, $\varepsilon_{m,t}$, as Main Street Lending shocks.

The government fixes the price of Main Street Lending at $Q_{M,t} = \tau Q_t$, where $\tau \leq 1$. This implies that Main Street Loans trade at a (weakly) higher implied interest rate than corporate bonds, i.e. $R_t^M \geq R_t^F$. Because the government is fixing both the price and setting an exogenous quantity, in equilibrium the wholesale firm will simply take all Main Street Lending, i.e. $M_{w,t} = M_{G,t}$. In fact, when the cash flow constraint binds, the wholesale firm would desire to borrow far more from the government than the supply of government lending, so long as τ is not too small.

[5] As we discuss below, the effects of Main Street Lending and Wall Street QE absent a cash flow constraint would be *exactly* the same if $Q_{M,t} = Q_t$; i.e. if loans from the government have the same expected return as privately issued bonds.

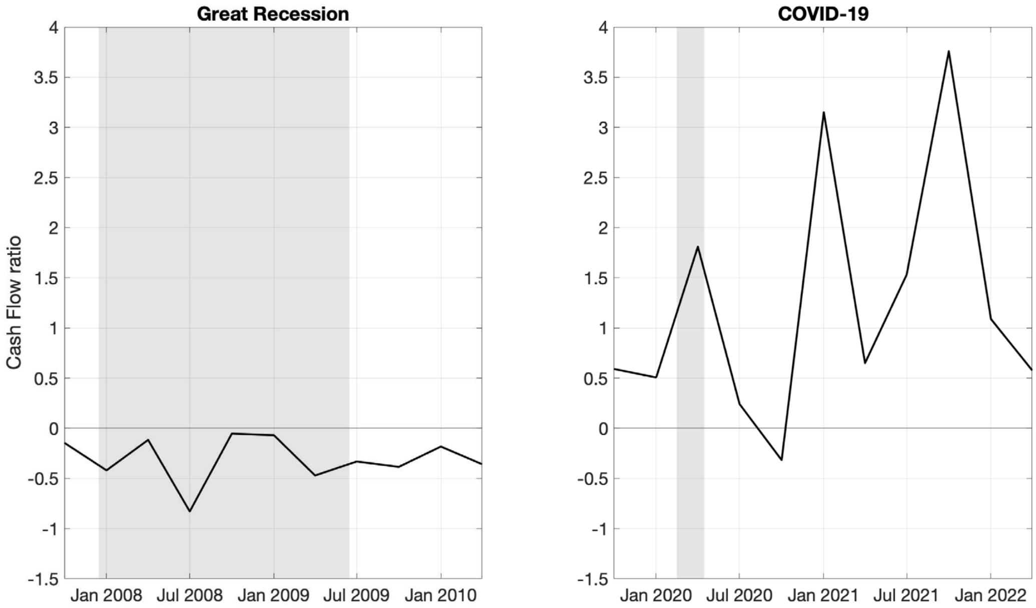

Fig. 1. Empirical Evidence on the Cash Flow Constraint.
Notes: This figure plots the ratio of long-term debt issuance to cash flows. See Appendix F for more details.

4. COVID-19 vs. the Great Recession

In this section, we quantitatively analyze the effects of Wall Street QE and Main Street Lending in two environments: the Great Recession and the COVID-19 crisis. We distinguish them by whether the cash flow constraint (3.4) is binding or not and motivate our choice by empirical evidence from firm-level data from Compustat. Fig. 1 plots an aggregate ratio of new debt issuance to firm cash flows to measure the tightness of the cash flow constraint (3.4) during both the Great Recession era as well as the COVID-episode. If the constraint goes from non-binding to binding, we should expect to see the ratio of new debt to cash flows increase; for details, see Appendix F.

We focus first on the Great Recession of 2007–2009. Nothing of note happens to the empirical ratio of new debt to cash flows during the Great Recession. Since that crisis had its origins in the financial sector, we think of the Great Recession as being characterized by intermediaries being constrained, but non-financial firms as not being subject to a cash flow constraint. In other words, we assume that (3.4) is not binding, and accordingly solve the model dropping that equation as well as the Lagrange multiplier, $\lambda_{3,t}$.

In contrast, the ratio of new debt to cash flows clearly spikes upwards at the start of the COVID-19 recession. While this upward spike quickly reverted, it is of note that there were two additional upward spikes — one late in 2020, spilling into 2021, and another in the fall of 2021. These two spikes roughly coincide with the height of the Delta and Omicron waves of COVID-19 in the US. We take the empirical behavior of the ratio of debt issuance to cash flows during the COVID-19 era as suggestive, though not dispositive, evidence that the cash flow constraint was binding during the COVID-19 pandemic. We do not formally model why this constraint was binding, but nevertheless think this captures in a convenient way the situation facing firms over much of the pandemic. A combination of government-mandated lockdowns, unwillingness of households to go to work, and changes in consumption patterns resulted in an evaporation of cash flows for many firms in certain hard-hit sectors. One could think of the cumulative effect as a large reduction in cash flows in response to some combination of shocks that caused the constraint to bind.

4.1. Calibration

Many of the parameters in the model are chosen based on consensus values from the extant literature. We highlight a few that are relatively unique to our model. Parameters governing preferences and technology are fairly standard. The unit of time in the model is a quarter. We follow Sims and Wu (2021) in calibrating parameters related to financial intermediaries, with one exception. In particular, we set the decay parameter for bond coupon payments to $\kappa = 1 - 16^{-1}$. This implies a four year duration of long-term bonds in the model, which aligns with the maturity lengths associated with the different facilities that are part of the Main Street Lending Program. We set the AR(1) parameter for both Main Street lending and Wall Street QE to 0.97. The size of the QE/lending shocks we consider amount to 1% of annual GDP. For the situation in which the cash flow constraint on production firms is binding,

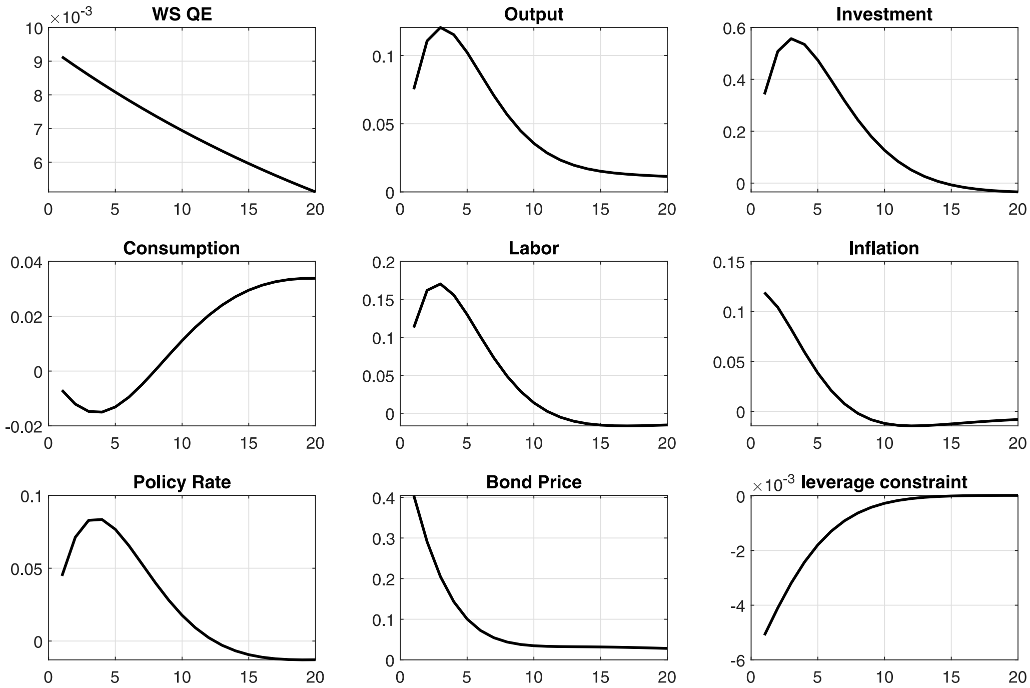

Fig. 2. Great Recession: Wall Street QE.
Notes: A shock to government private bond holdings, $f_{G,t}$, with a size of 1% of annual GDP, when the cash-flow constraint on the wholesale firm is not binding. Units of variables: government bond holding and the multiplier on the leverage constraint are in absolute deviations. Inflation and the policy rate are changes in annualized percentage points. All other variables are in percentage deviation from the steady state.

we set $\varphi = 0.60$. We assume a constant stock of outstanding government debt. We also assume the Main Street loans have the same price/return as corporate bonds; i.e. $\tau = 1$.[6] See more details in Appendix G.[7]

4.2. Great Recession

We focus first on Wall Street QE and Main Street Lending in the Great Recession period. Because of the linear solution to the model, we do not need to take a stand on what kind of shock contributed to the Great Recession. A natural candidate, however, as emphasized in Sims and Wu (2021), is a sequence of adverse credit shocks, captured by the exogenous variable θ_t. Due to concerns surrounding subprime mortgages, creditors became less willing to fund financial intermediaries, resulting in a tightening of balance sheet constraints. In the model, this would lead to a widening of credit spreads and a contraction in aggregate demand, roughly in-line with observed patterns in the data.

Fig. 2 plots impulse responses of selected variables to a Wall Street QE shock during the Great Recession in the model (when the cash flow constraint does not bind). The QE shock is a shock to purchases of privately issued debt from intermediaries. For the responses shown here, we do not impose a ZLB constraint on the short-term interest rate. Doing so would amplify the effects of the QE shock; see Fig. 6 and its associated discussion in Section 4.4. Responses of inflation and the policy rate are expressed in annualized percentage points. Responses of government bond holdings, as well as the multiplier on the leverage constraint, are expressed in absolute deviations from steady state. Inflation and the policy rates are expressed in annualized percentage points. All other responses are expressed in percentage deviations from the steady state.

The shock results in hump-shaped expansions in output, investment, labor input, and inflation. Output reaches a peak response after about a year. The path of investment is similar, albeit about four times larger. Consumption initially declines before eventually rising. Focusing on the lower right-hand part of the figure, one sees the key mechanisms through which Wall Street QE transmits to the economy. When the government purchases bonds from intermediaries, it swaps these bonds for reserves. Reserves do not factor into the leverage constraint facing intermediaries. As a consequence, the leverage constraint becomes looser, as evidenced by the decline in the Lagrange multiplier facing intermediaries. Less constrained, intermediaries purchase more bonds. This pushes

[6] Our results are qualitatively the same when $\tau < 1$.

[7] In particular, Table G.1 lists the parameter values or targeted moments. Though we solve the model about two different steady states (one in which the cash flow constraint binds, and one in which it does not), we only present one calibration. Some parameters are fixed across the two specifications, while others are pinned down by steady state targets (e.g. steady state labor input or the steady state leverage ratio) that can differ across the two specifications.

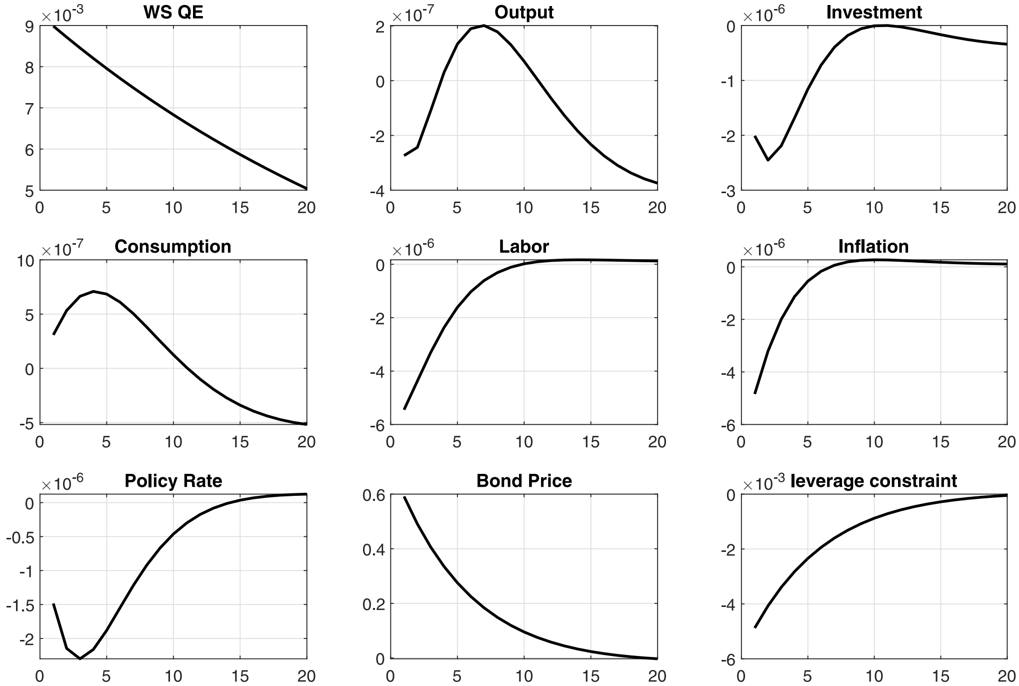

Fig. 3. COVID: Wall Street QE.
Notes: A shock to government private bond holdings, $f_{G,t}$, with a size of 1% of annual GDP, when the cash-flow constraint on the wholesale firm is binding. Units of variables: government bond holding and the multiplier on the leverage constraint are in absolute deviations. Inflation and the policy rate are changes in annualized percentage points. All other variables are in percentage deviation from the steady state.

the price of these bonds up. The higher bond price, in turn, eases the investment constraint facing the wholesale firm. This allows them to do more investment and stimulates aggregate demand.

In an environment in which the cash flow constraint is not binding, such as the Great Recession, Main Street Lending and Wall Street QE are equivalent to one another. As discussed in Section 3.4, it does not matter whether a government issues credit directly to firms or indirectly through easing balance sheet constraints on intermediaries.

4.3. COVID-19

Fig. 3 shows impulse responses to a Wall Street QE shock when both the balance sheet constraint on intermediaries and the cash flow constraint on firms are binding.[8] One observes that Wall Street QE is *approximately* neutral for the real economy. The Fed purchasing bonds from intermediaries pushes bond prices up, but with no cash flows, the lower cost of borrowing is of no use to firms, who nevertheless can still not issue debt to support their ongoing activities. The very small effects of Wall Street QE (note the units on the vertical axes in the impulse response graph) emerge due to small general equilibrium effects.

Next, consider the impulse responses to a Main Street Lending shock in a situation in which firms are cash flow constrained. These responses are depicted in Fig. 4. We consider a shock to Main Street Lending of exactly the same magnitude as the Wall Street QE shock in Fig. 3. Here one observes that Main Street Lending is even *more* stimulative than in Fig. 2. The immediate impact of the shock is a large reduction in the multiplier on the cash flow constraint. This allows firms to sell more bonds to finance investment, which results in a decline (rather than an increase) in bond prices and a large increase in aggregate demand, with output, investment, labor input, and inflation all rising.

The large increase in investment unleashed because of the immediate relaxing of the cash flow constraint allows firms to quickly accumulate more capital. On its own, this serves as a propagation mechanism for output, but there is an additional channel at play. Higher future capital stocks further loosen the cash flow constraint facing firms far off into the future, which works to reinforce the beneficial effects of Main Street Lending.

In comparing the impulse responses in Figs. 2 to 4, one notices that in the COVID-19 scenario output and investment respond maximally on impact and then revert rather quickly.[9] This is because Main Street Lending works through a *flow* channel to relax

[8] To be clear, for this exercise we solve the model about a steady state in which the cash flow constraint always binds. In Section 4.4, we consider a robustness exercise in which the cash flow constraint goes from non-binding, to binding, and back to non-binding. Doing so does not materially alter our conclusions.

[9] While the responses revert quickly, they nevertheless remain well above their pre-shock values for some time due to propagation from increases in the capital stock and subsequent easing of the cash flow constraint.

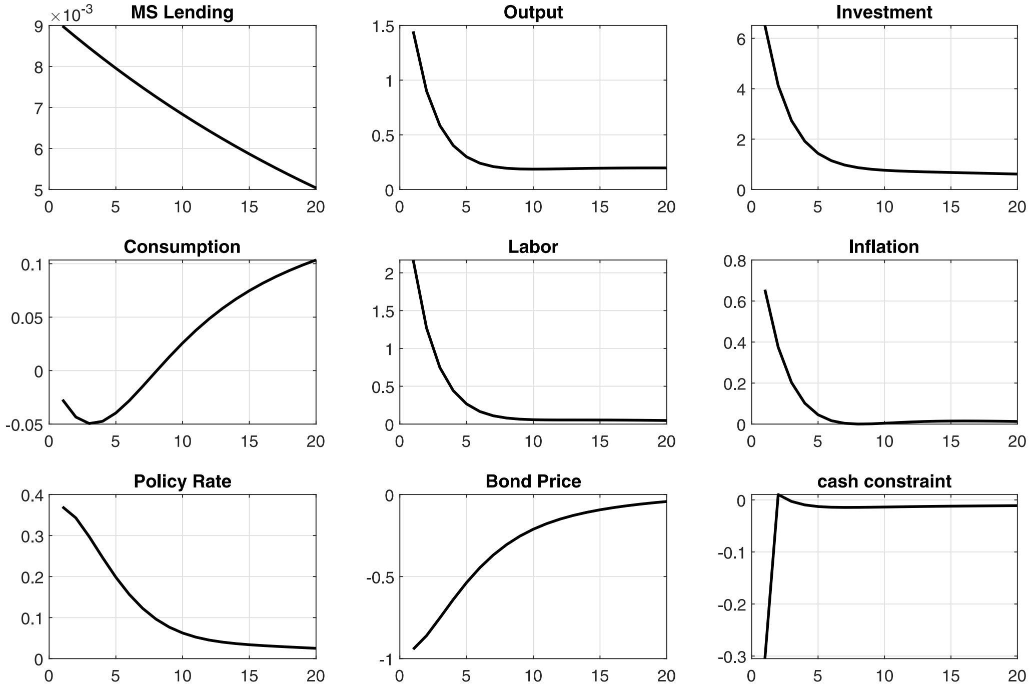

Fig. 4. COVID: Main Street Lending.
Notes: A shock to government lending, $m_{G,t}$, with a size of 1% of annual GDP, when the cash-flow constraint on the wholesale firm is binding. Units of variables: government lending and the multiplier on the cash flow constraint are in absolute deviations. Inflation and the policy rate are changes in annualized percentage points. All other variables are in percentage deviation from the steady state.

the cash flow constraint (3.4): new bond issuances are constrained by the firm's cash flows. To relax this constraint, the government needs to absorb *new* debt. In contrast, Wall Street QE works through a *stock* channel to relax the leverage constraint facing intermediaries, which applies to their stock of assets and not to the flow.

One additional point that is evident from a comparison of Figs. 2 and 4. When the cash flow constraint is binding, a Main Street Lending shock is almost an order of magnitude more stimulative for output than is a QE (or Main Street Lending) shock when the cash flow constraint is not binding. Because of the simplicity of our model, we do not wish to make too large of a point concerning the relative effectiveness of Main Street Lending. Our intuition for why the effects of a Main Street Lending shock are so much larger is quite simple. When the cash flow constraint binds, a Main Street Lending shock *directly* loosens the constraint that is relevant for firms, leading to a large change in production. When the cash flow constraint is not binding, QE impacts firms *indirectly* — by easing the endogenous leverage constraint facing intermediaries, QE increases the aggregate demand for long bonds, pushing up the price, Q_t, of bonds. This *indirectly* loosens the investment constraint. But because this is only an indirect, rather than direct, effect, the impact of a QE shock on production is much smaller.

The take-home message from these exercises is that, to simulate economic activity, it is not simply important for the government to purchase assets and lend freely, it is important that it allocates funds to where constraints are most binding. In a "balance-sheet" recession like the one induced by the Financial Crisis in 2007–2009, purchasing assets from banks makes sense. But if the key constraint is facing firms, no amount of easing bank balance sheets will stimulate the economy. In a situation like this, which we think is a reasonable description of the state of affairs over much of 2020 and into 2021, direct lending to firms can be a powerful stimulative tool.

4.4. Robustness

In this subsection, we present some additional quantitative results from our model. We begin by showing sensitivity of impulse responses to select parameter values in the model. Fig. 5 plots impulse responses of output and inflation to both QE (left two columns, compare to Fig. 2) and Main Street Lending Shocks (right two columns, compare to Fig. 4).

The first row of Fig. 5 considers sensitivity to the steady state value of θ, which governs the extent to which the leverage constraint on intermediaries is binding (see Eq. (3.15)). We consider different values of θ that target different steady state spreads: two percentage points, three percentage points (our baseline), and four percentage points. Wall Street QE is more stimulative (for both output and inflation) the bigger is the steady state long-short interest rate spread. This is intuitive: when intermediaries are more constrained, the effects of loosening their constraint are larger. In contrast, the effects of Main Street Lending (when the cash

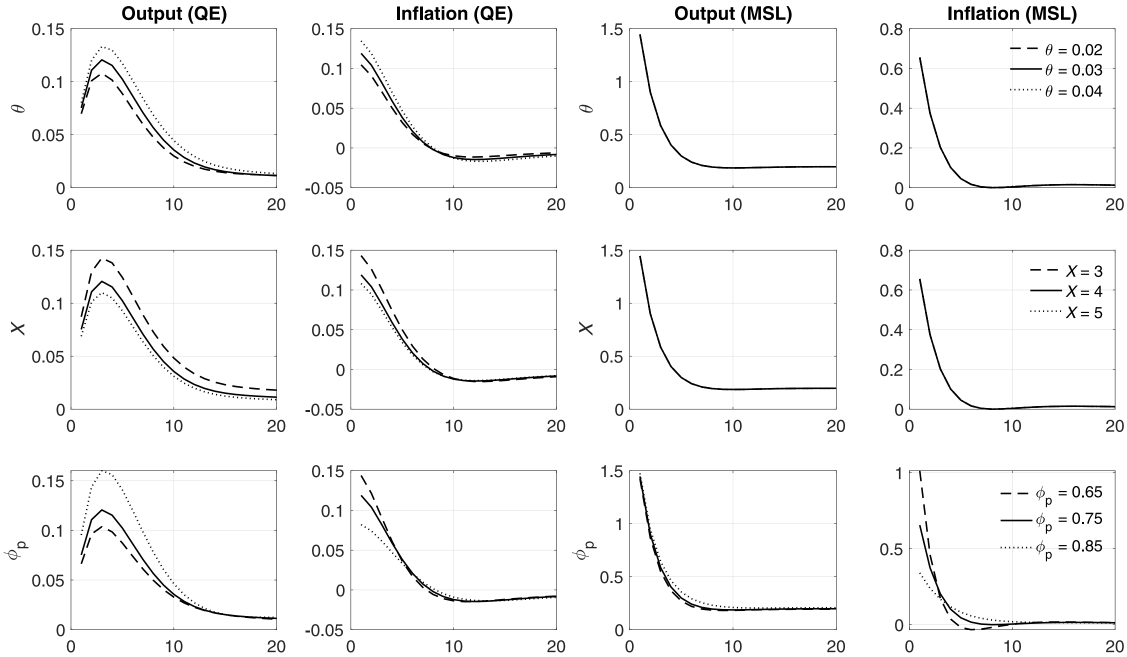

Fig. 5. Parameter sensitivity.
Notes: This figure plots impulse responses of output (first and third columns) and inflation (second and fourth columns) to a Wall Street QE shock (left two columns, when the cash flow constraint does not bind) and a Main Street Lending shock (MSL, right two columns, when the cash flow constraint binds). We do so for different values of θ, the parameter governing the tightness of the intermediaries' leverage constraint; X, the amount of startup net worth received by new intermediaries; and ϕ_p, the parameter governing price stickiness. Shock sizes of both the QE and Main Street Lending shocks are 1% of steady state GDP.

flow constraint is binding) are the same regardless of the interest rate spread. This is because the relevant constraint for the economy in this situation is unrelated to the condition of financial intermediaries.

In the second row, we consider different values of X, which is the infusion of equity to newly-born financial intermediaries. In our baseline parameterization, we pick X to target a steady state financial leverage ratio of four. Similarly to the first row, the value of X is irrelevant for the efficacy of Main Street Lending. When banks are less levered on average and the cash flow constraint on firms does not bind, Wall Street QE is slightly more stimulative for output and inflation, though qualitatively the effects are quite similar to our baseline analysis.

The final row of Fig. 5 considers alternative parameterizations of ϕ_p, which is the Calvo parameter governing price stickiness. Naturally, when prices are stickier, both Wall Street QE and Main Street Lending have larger effects on output and smaller effects on inflation. This finding is intuitive, as both kinds of shocks are demand-side stimulus.

In our baseline analysis, we abstract from the zero lower bound (ZLB) on the short-term policy rate. During both the Great Recession and COVID-19 recession, the ZLB was binding in the US. Fig. 6 plots impulse responses to a Wall Street QE shock when the short-term policy rate is constrained by zero for eight quarters in expectation (but the cash flow constraint is non-binding). We implement the ZLB using the occasionally binding constraint toolbox from Guerrieri and Iacoviello (2015), and generate the ZLB with a sequence of credit shocks (i.e. shocks to θ_t).[10] QE is naturally more stimulative for aggregate variables when the ZLB binds, with a peak effect on output that is about three times as large compared to a non-binding ZLB. These magnitudes are very similar to Sims and Wu (2021) (see, e.g., Fig. 3 in their paper). Fig. 7 shows impulse responses to a Main Street Lending shock in a similar ZLB scenario.[11] Similarly to the case of Wall Street QE, Main Street Lending has bigger effects on aggregate variables when the ZLB binds, but the magnitudes are not as large as with a QE shock. Overall, the main results of the paper are not impacted by the ZLB binding or not — qualitatively, our results concerning the efficacy of QE and Main Street Lending continue to hold.

For our analysis of the Great Recession, we assume that the economy is in a steady state in which the investment constraint binds and the cash flow constraint does not. For the COVID-19 exercise, we assume that the economy initially sits in a steady state in which both constraints bind. As noted above, there is some empirical support to the notion that the cash flow constraint for firms was binding during at least part of the COVID-19 episode. However, that empirical evidence would suggest that the cash flow constraint went from non-binding, to binding, and then back to non-binding again.

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[10] In particular, θ_t is stochastic following (E.37). We set $\rho_\theta = 0.3$ and assume a realization of $\varepsilon_{\theta,t} = 0.5$, which causes the ZLB to bind for eight quarters in expectation. The rest of the parameterization is unchanged.

[11] For this figure we generate the binding ZLB with a sequence of "cash flow shocks" to φ, discussed more below. The results are similar regardless of how we make the ZLB bind.

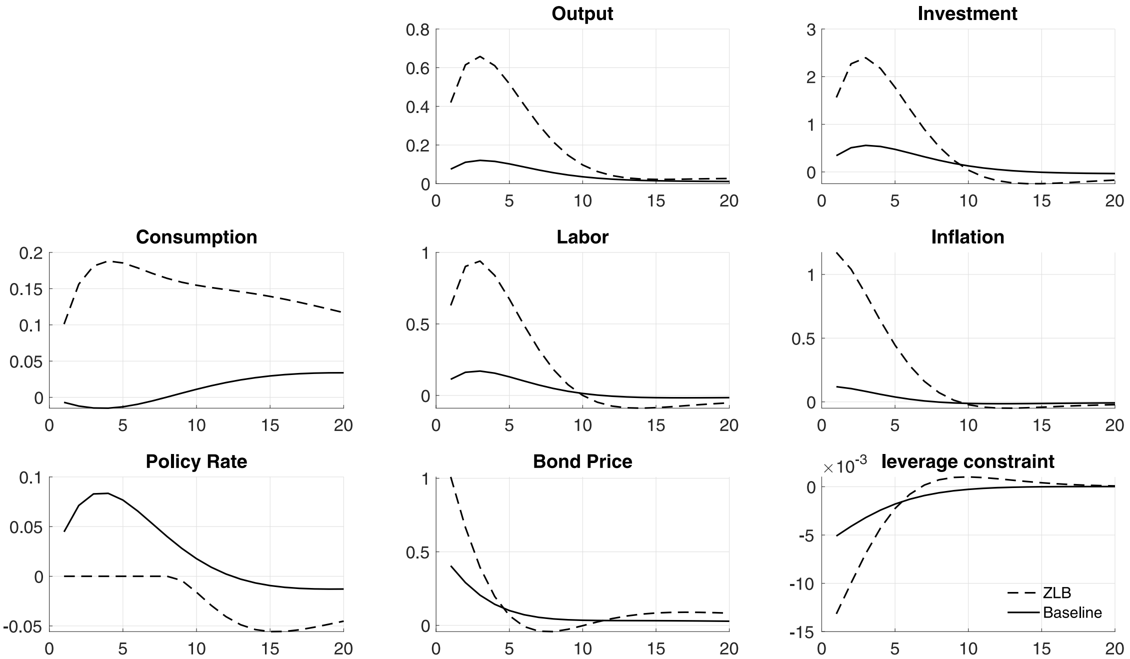

Fig. 6. Wall Street QE and the ZLB.
Notes: This figure plots impulse responses to a Wall Street QE shock (cash flow constraint not binding) with a binding zero lower bound (ZLB) on the short-term policy rate. The ZLB is enforced via a negative credit shock (i.e. a shock to θ) and binds for eight quarters.

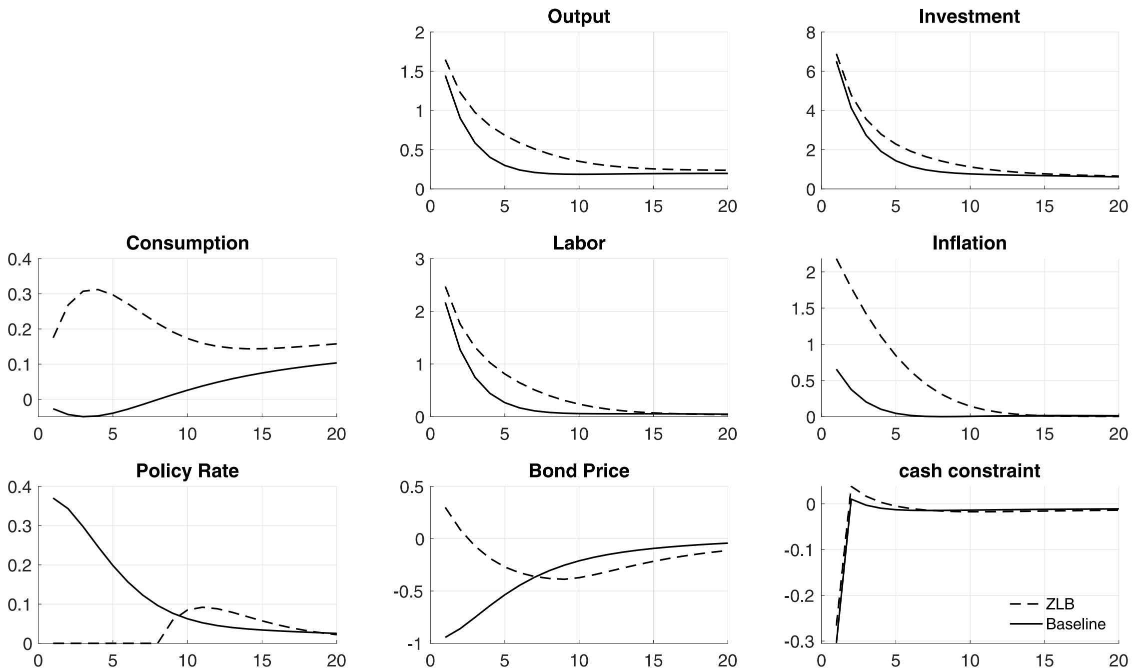

Fig. 7. Main Street Lending and the ZLB.
Notes: This figure plots impulse responses to a Main Street Lending shock (when the cash flow constraint binds) with a binding zero lower bound (ZLB) on the short-term policy rate. The ZLB is enforced via a negative cash flow shock (i.e. a shock to φ) and binds for eight quarters.

Given this suggestive evidence, one might worry that it is problematic to analyze the effects of a Main Street Lending shock around a steady state in which the cash flow constraint is always binding. To address this concern, we conduct the following exercise. We solve the model about the steady state in which the cash flow constraint is non-binding. But our solution methodology allows for

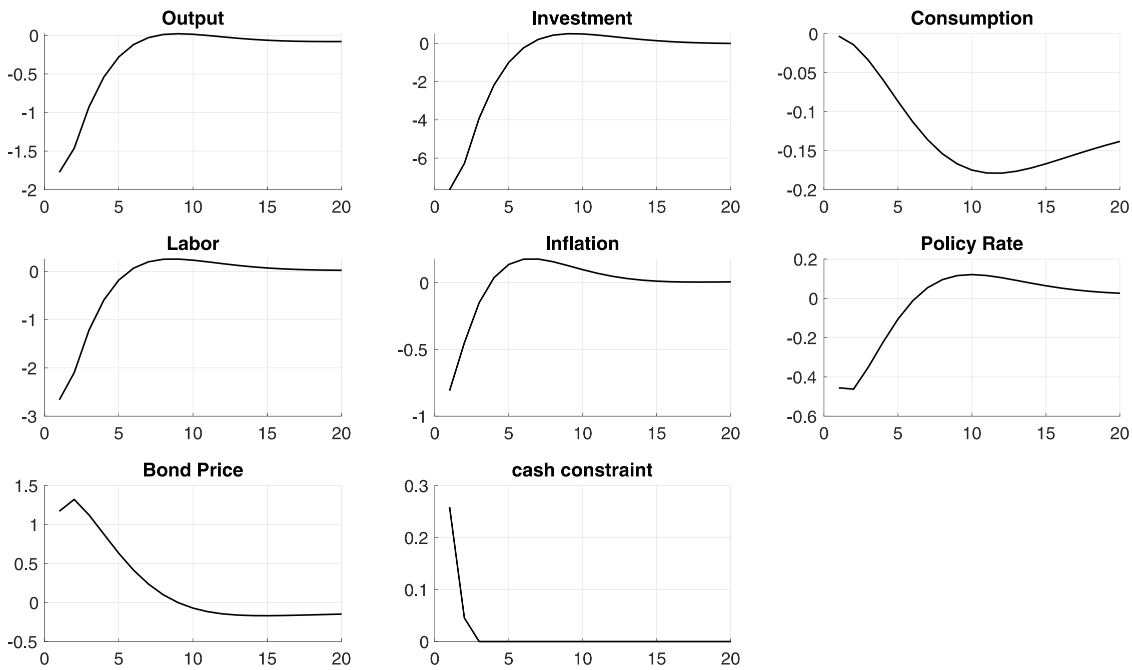

Fig. 8. Cash Flow Shock and the COVID-19 Recession.
Notes: This figure plots impulse responses to a large, negative cash flow shock (i.e. a shock to φ) that causes the cash flow constraint to go from non-binding to binding. The constraint binds for only three periods.

the cash flow constraint to occasionally bind, following Guerrieri and Iacoviello (2015) (also similar to how we implement the ZLB exercises above). We then subject the economy to a large, negative "cash flow shock". In particular, we make φ, the parameter restricting borrowing as a proportion of cash flows, stochastic following an AR(1) process, similar to other exogenous variables in the model.[12] The reduction in φ causes the cash flow constraint to bind for a short amount of time, and leads to a large, but quite transient, decline in economic activity and inflation. The impulse responses to the cash flow shock are depicted in Fig. 8. The cash flow constraint binds only for a few periods, as shown by the response of the multiplier in the lower righthand corner of the plot, which jumps up to positive but reverts to zero within three periods. The responses of aggregate variables to this shock look quite reasonable compared to the actual experience of the US economy in the early stages of the pandemic, when output, inflation, and other aggregate variables declined precipitously (but recovered quickly).

Using this piecewise linear solution with a large cash flow shock, we then subject the economy to a Main Street Lending shock, of the same size as in our baseline analysis. The Main Street Lending Shock occurs in the same period of the negative cash flow shock. Impulse responses are computed as the difference between simulations of the model with the large cash flow shock and a Main Street Lending shock from a simulation without a Main Street Lending shock. The modified impulse responses for this exercise, in which the cash flow constraint goes from non-binding, to binding, and back to non-binding, are shown in Fig. 9. The Main Street Lending shock loosens the temporarily binding cash flow constraint. Comparing the responses of aggregate variables to those shown in Fig. 4, one observes that, quantitatively and qualitatively, the responses to a Main Street Lending shock are quite similar. While qualitatively similar, the main difference in Fig. 9 is that the responses of output and other aggregate variables are less persistent, reverting to zero after a few periods. This is because the cash flow constraint ceases to bind after just a few periods, whereas in our baseline analysis the Main Street Lending shock causes the cash flow constraint to be looser for a significant amount of time. Altogether, however, the large responses to a Main Street Lending shock do not rely on our assumption that the cash flow constraint is always binding, just that it binds for some of the time when Main Street Lending is implemented.

5. Conclusion

This paper represents a first attempt at formally modeling direct lending by the central bank and fiscal authority to non-financial firms as measures to combat economics downturns. We construct a macro model with two key frictions relevant for these policies. The first is an endogenous leverage constraint on intermediaries. The second is a cash flow constraint on how much debt non-financial firms can issue. When only the first constraint on financial intermediaries binds, Wall Street QE and Main Street Lending are

[12] In particular, we assume that $\ln \varphi_t = (1-\rho_\varphi)\ln\varphi + \rho_\varphi \ln\varphi_{t-1} + \varepsilon_{\varphi,t}$. We set $\rho_\varphi = 0.3$ and assume a realization of $\varepsilon_{\varphi,t} = -0.25$. This causes the cash flow constraint to go from non-binding to binding for three quarters.

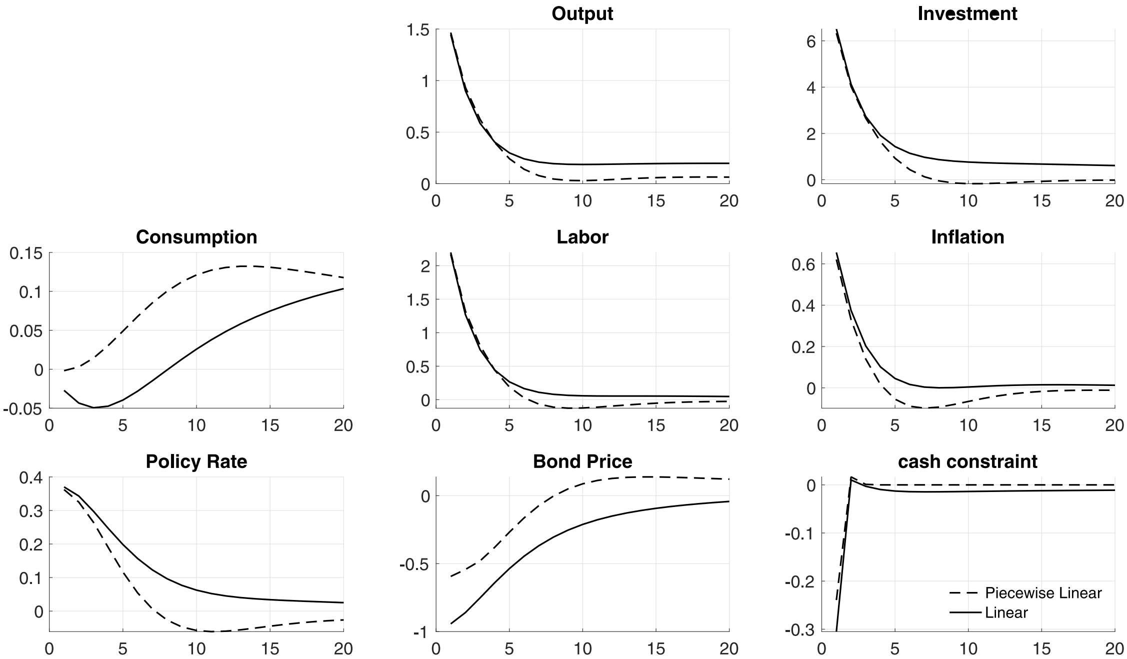

Fig. 9. Main Street Lending with occasionally binding cash flow constraint.
Notes: This figure plots impulse responses to a Main Street Lending Shock (dashed lines) that occurs simultaneously with the large cash flow shock from Fig. 8 that causes the cash flow constraint to temporarily bind. Solid lines recreate the responses in the linear solution in which the cash flow constraint always binds (these are identical to what is shown in Fig. 4).

isomorphic to one another. We think of a situation in which intermediaries are constrained but firms are not as roughly characterizing the US economy at the time of the Great Recession. In contrast, when the cash flow constraint on non-financial firms is also binding (which we think of as a defining characteristic of the early stages of the COVID-19 crisis), Wall Street QE becomes ineffective. Main Street Lending, however, becomes even more effective. By directly lending to firms, the government can loosen the constraint facing them and trigger an increase in investment and aggregate demand.

Appendix A. Household

The household consumes, supplies labor at nominal wage W_t^H to labor unions, and saves via one period deposits, D_t, with financial intermediaries. These deposits offer gross nominal return R_t^d. In nominal terms, the household's flow budget constraint is:

$$P_t C_t + D_t \leq W_t^H L_t + R_{t-1}^d D_{t-1} + PROF_t - P_t X - P_t T_t. \tag{A.1}$$

$PROF_t$ is nominal profit distributed lump sum to the household each period. It is inclusive of profit from both non-financial firms as well as exiting financial intermediaries. As discussed in the text, X is a fixed real equity transfer to newly-born financial intermediaries. T_t is a lump sum transfer/tax from the government. P_t is the price level.

The household has standard preferences. Its problem, with the budget constraint written in real terms, is:

$$\max_{C_t, L_t, D_t} \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln\left(C_t - bC_{t-1}\right) - \chi \frac{L_t^{1+\eta}}{1+\eta} \right\}$$

s.t.

$$C_t + \frac{D_t}{P_t} \leq w_t^H L_t + R_{t-1}^d \frac{D_{t-1}}{P_t} + prof_t - X + T_t$$

$b \in [0, 1)$ is a measure of internal habit formation, χ is a scaling parameter on the disutility from labor, and η is the inverse Frisch labor supply elasticity. w_t^H is the real remuneration the household receives for supplying labor. The optimality conditions are:

$$\mu_t = \frac{1}{C_t - bC_{t-1}} - b\beta \mathbb{E}_t \frac{1}{C_{t+1} - bC_t} \tag{A.2}$$

$$\Lambda_{t-1,t} = \beta \frac{\mu_t}{\mu_{t-1}} \tag{A.3}$$

$$\chi L_t^{\eta} = \mu_t w_t^H \tag{A.4}$$

$$1 = \mathbb{E}_t \Lambda_{t,t+1} R_t^d \Pi_{t+1}^{-1} \tag{A.5}$$

μ_t is the multiplier on the flow budget constraint and is given by (A.2). $\Lambda_{t-1,t}$ is the stochastic discount factor. The labor supply condition, (A.4), and Euler equation for deposits, (A.5), are standard.

Appendix B. Labor market

There are two layers to the labor market. There are a unit measure of labor unions, indexed by $h \in [0,1]$, that purchase labor from the household at nominal wage W_t^H. These unions simply repackage this labor, call it $L_{d,t}(h)$, and sell it to a competitive labor packer at nominal wage $W_t(h)$. The labor packer transforms union labor into labor available for lease to the wholesale firm at nominal wage W_t. This transformation takes place via a CES aggregator:

$$L_{d,t} = \left(\int_0^1 L_{d,t}(h)^{\frac{\epsilon_w - 1}{\epsilon_w}} dh \right)^{\frac{\epsilon_w}{\epsilon_w - 1}}, \tag{B.1}$$

where $\epsilon_w > 1$. Profit maximization gives a downward-sloping demand for each union's labor and an aggregate wage index:

$$L_{d,t}(h) = \left(\frac{W_t(h)}{W_t} \right)^{-\epsilon_w} L_{d,t} \tag{B.2}$$

$$W_t^{1-\epsilon_w} = \int_0^1 W_t(h)^{1-\epsilon_w} dh \tag{B.3}$$

Nominal dividends for union h are: $DIV_{L,t}(h) = \left(W_t(h) - W_t^H\right) L_{d,t}$. Were they freely able to adjust wages, the optimality condition would be to set $W_t(h)$ as a fixed markup over W_t^H, with the markup given by $\frac{\epsilon_w}{\epsilon_w - 1}$. But only a fraction of unions, $1-\phi_w$, are able to adjust nominal wages in a given period. This makes the problem of a union given the ability to adjust dynamic. Future dividends are discounted by the household's stochastic discount factor with extra discounting to account for the probability that a wage chosen in the present will remain in effect into the future. The optimal wage-setting condition is common across all updating unions. Let $W_t^{\#}$ denote the optimal reset wage, or $w_t^{\#} = W_t^{\#}/P_t$ in real terms. Optimal wage-setting is characterized by:

$$w_t^{\#} = \frac{\epsilon_w}{\epsilon_w - 1} \frac{f_{1,t}}{f_{2,t}}, \tag{B.4}$$

$$f_{1,t} = w_t^H w_t^{\epsilon_w} L_{d,t} + \phi_w \mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_w} f_{1,t+1}, \tag{B.5}$$

$$f_{2,t} = w_t^{\epsilon_w} L_{d,t} + \phi_w \mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_w - 1} f_{2,t+1}. \tag{B.6}$$

Appendix C. Production

In addition the wholesale firm discussed in the text, there are three other kinds of production firms — a continuum of retail firms, a final goods firm, and a new capital goods producer.

There are a continuum of retailers indexed by $f \in [0,1]$. These firms purchase wholesale output at P_t^w, repackage it, and sell it a competitive final goods firm at $P_t(f)$. The competitive final goods firm transforms retail output into final output via a CES aggregator:

$$Y_t = \left(\int_0^1 Y_t(f)^{\frac{\epsilon_p - 1}{\epsilon_p}} df \right)^{\frac{\epsilon_p}{\epsilon_p - 1}}, \tag{C.1}$$

where $\epsilon_p > 1$. Profit maximization generates a demand curve for each retailer's output and an aggregate price index:

$$Y_t(f) = \left(\frac{P_t(f)}{P_t} \right)^{-\epsilon_p} Y_t, \tag{C.2}$$

$$P_t^{1-\epsilon_p} = \int_0^1 P_t(f)^{1-\epsilon_p} df. \tag{C.3}$$

Retailers simply repackage wholesale output, earning dividend $DIV_{Y,t}(f) = \left(P_t(f) - P_t^w\right) Y_t(f)$. If they could freely adjust price, then given (C.2), the optimal price-setting rule would be to set $P_t(f)$ as a fixed markup, $\frac{\epsilon_p}{\epsilon_p - 1}$, over the price of wholesale output. But each period, only a fraction, $1-\phi_p$, of retailers can adjust their price. This makes the price-setting problem dynamic. Future dividends are discounted by the household's stochastic discount factor, adjusted for the probability that a price chosen today will remain in effect into the future. All updating retailers adjust to the same price, $P_t^{\#}$. To stationarize this, define the relative reset price as $\Pi_t^{\#} = P_t^{\#}/P_t$. The optimality conditions for the relative reset price are:

$$\Pi_t^{\#} = \frac{\epsilon_p}{\epsilon_p - 1}\frac{x_{1,t}}{x_{2,t}}, \tag{C.4}$$

$$x_{1,t} = p_t^w Y_t + \phi_p \mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_p} x_{1,t+1}, \tag{C.5}$$

$$x_{2,t} = Y_t + \phi_p \mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_p - 1} x_{2,t+1}. \tag{C.6}$$

There is a third firm in the model that produces new physical capital from final output. It uses I_t unconsumed final output as an input and produces $\hat{I}_t$ of new physical capital, which is then sold to the wholesale firm at P_t^k. The technology relating I_t to $\hat{I}_t$ is:

$$\hat{I}_t = \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t, \tag{C.7}$$

where $S(\cdot)$ has the properties $S(1) = 0$, $S'(1) = 0$, and $S''(1) = \kappa_I \geq 0$. The flow nominal dividend for the capital goods producer is $P_t^k \hat{I}_t - P_t I_t$. The nature of the adjustment cost makes the capital goods producer's problem dynamic. It discounts future profits by the household's stochastic discount factor. Its optimality condition, written in real terms, is:

$$1 = p_t^k \left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}\right] + \mathbb{E}_t \Lambda_{t,t+1} p_{t+1}^k S'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2 \tag{C.8}$$

Appendix D. Exogenous processes and aggregation

In addition to policy-related shocks, the model features two additional exogenous states with shocks, productivity, A_t, and the credit shock, θ_t. We assume that both follow AR(1) processes in the log, with the former's non-stochastic mean normalized to unity and the latter's to θ:

$$\ln A_t = \rho_A \ln A_{t-1} + s_A \varepsilon_{A,t}. \tag{D.1}$$

$$\ln \theta_t = (1 - \rho_\theta) \ln \theta + \rho_\theta \ln \theta_{t-1} + s_\theta \varepsilon_{\theta,t}. \tag{D.2}$$

The aggregate inflation rate evolves according to:

$$1 = (1 - \phi_p)\left(\Pi_t^{\#}\right)^{1-\epsilon_p} + \phi_p \Pi_t^{\epsilon_p - 1}. \tag{D.3}$$

Similarly, the aggregate real wage evolves according to:

$$w_t^{1-\epsilon_w} = (1 - \phi_w)\left(w_t^{\#}\right)^{1-\epsilon_w} + \phi_w \Pi_t^{\epsilon_w - 1} w_{t-1}^{1-\epsilon_w}. \tag{D.4}$$

Aggregate final output, Y_t, is related to wholesale output, $Y_{w,t}$, via:

$$v_t^p Y_t = Y_{w,t}, \tag{D.5}$$

where v_t^p is a measure of price dispersion:

$$v_t^p = (1 - \phi_p)\left(\Pi_t^{\#}\right)^{-\epsilon_p} + \phi_p \Pi_t^{\epsilon_p} v_{t-1}^p. \tag{D.6}$$

In a similar fashion, household supply of labor, L_t, is related to total labor used in production, $L_{d,t}$, via:

$$L_t = L_{d,t} v_t^w, \tag{D.7}$$

where v_t^w is a measure of wage dispersion:

$$v_t^w = (1 - \phi_w)\left(\frac{w_t^{\#}}{w_t}\right)^{-\epsilon_w} + \phi_w \left(\frac{w_t}{w_{t-1}}\right)^{\epsilon_w} \Pi_t^{\epsilon_w} v_{t-1}^w. \tag{D.8}$$

Bond market-clearing requires that the total stock of bonds issued by the wholesale firm are held either by financial intermediaries or the central bank:

$$F_{w,t} = F_t + F_{G,t} \tag{D.9}$$

Similar, debt issued by the government must be held by intermediaries:

$$B_{G,t} = B_t \tag{D.10}$$

Each period, the fraction $1 - \sigma$ of intermediaries exits and returns their accumulated net worth to the household. They are replaced by an equal number of intermediaries, who in aggregate are given real startup net worth of X. Accordingly, aggregate real net worth of intermediaries evolves according to:

$$n_t = \sigma \Pi_t^{-1}\left[\left(R_t^F - R_{t-1}^d\right) Q_{t-1} f_{t-1} + \left(R_t^B - R_{t-1}^d\right) Q_{B,t-1} b_{t-1} + \left(R_{t-1}^{re} - R_{t-1}^d\right) re_{t-1} + R_{t-1}^d n_{t-1}\right] + X \tag{D.11}$$

Combining the household's budget constraint, along with the aggregate balance sheet of intermediaries and the consolidated government balance sheet, yields a standard aggregate resource constraint:

$$Y_t = C_t + I_t + G_t \tag{D.12}$$

Appendix E. Full set of equilibrium conditions

For completeness, below we list the full set of equilibrium conditions in our model. These are all written in real terms (lowercase variables denote real quantities where relevant):

- Household

$$\mu_t = \frac{1}{C_t - bC_{t-1}} - b\beta\mathbb{E}_t\frac{1}{C_{t+1} - bC_t} \tag{E.1}$$

$$\Lambda_{t-1,t} = \beta\frac{\mu_t}{\mu_{t-1}} \tag{E.2}$$

$$\chi L_t^{\eta} = \mu_t w_t^H \tag{E.3}$$

$$1 = \mathbb{E}_t\Lambda_{t,t+1}R_t^d\Pi_{t+1}^{-1} \tag{E.4}$$

- Labor unions:

$$w_t^{\#} = \frac{\epsilon_w}{\epsilon_w - 1}\frac{f_{1,t}}{f_{2,t}}, \tag{E.5}$$

$$f_{1,t} = w_t^H w_t^{\epsilon_w} L_{d,t} + \phi_w\mathbb{E}_t\Lambda_{t,t+1}\Pi_{t+1}^{\epsilon_w} f_{1,t+1}, \tag{E.6}$$

$$f_{2,t} = w_t^{\epsilon_w} L_{d,t} + \phi_w\mathbb{E}_t\Lambda_{t,t+1}\Pi_{t+1}^{\epsilon_w - 1} f_{2,t+1}. \tag{E.7}$$

- Wholesale firm:

$$w_t = (1-\alpha)p_t^w A_t K_t^{\alpha} L_{d,t}^{-\alpha} \tag{E.8}$$

$$\lambda_{1,t} = p_t^k(1 + \psi\lambda_{2,t}) \tag{E.9}$$

$$\lambda_{1,t} = \mathbb{E}_t\Lambda_{t,t+1}\left[(1+\varphi\lambda_{3,t+1})\alpha p_{t+1}^w A_{t+1}K_{t+1}^{\alpha-1}L_{d,t+1}^{1-\alpha} + \lambda_{1,t+1}(1-\delta)\right] \tag{E.10}$$

$$(1 + \lambda_{2,t} - \lambda_{3,t})Q_t = \mathbb{E}_t\Lambda_{t,t+1}\Pi_{t+1}^{-1}\left[1 + \kappa Q_{t+1}(1 + \lambda_{2,t+1} - \lambda_{3,t+1})\right] \tag{E.11}$$

$$K_{t+1} = \hat{I}_t + (1-\delta)K_t \tag{E.12}$$

$$Q_t\left(f_{w,t} - \kappa\Pi_t^{-1}f_{w,t-1}\right) + Q_{M,t}\left(m_{w,t} - \kappa\Pi_t^{-1}m_{w,t-1}\right) \geq \psi p_t^k\hat{I}_t \tag{E.13}$$

$$\varphi\left(p_t^w A_t K_t^{\alpha}L_{d,t}^{1-\alpha} - w_t L_{d,t}\right) \geq Q_t\left(f_{w,t} - \kappa\Pi_t^{-1}f_{w,t-1}\right) \tag{E.14}$$

$$Y_{w,t} = A_t K_t^{\alpha} L_{d,t}^{1-\alpha} \tag{E.15}$$

- Retail firm:

$$\Pi_t^{\#} = \frac{\epsilon_p}{\epsilon_p - 1}\frac{x_{1,t}}{x_{2,t}}, \tag{E.16}$$

$$x_{1,t} = p_t^w Y_t + \phi_p\mathbb{E}_t\Lambda_{t,t+1}\Pi_{t+1}^{\epsilon_p}x_{1,t+1}, \tag{E.17}$$

$$x_{2,t} = Y_t + \phi_p\mathbb{E}_t\Lambda_{t,t+1}\Pi_{t+1}^{\epsilon_p - 1}x_{2,t+1}. \tag{E.18}$$

- New capital producer:

$$\hat{I}_t = \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right]I_t, \tag{E.19}$$

$$1 = p_t^k\left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}\right] + \mathbb{E}_t\Lambda_{t,t+1}p_{t+1}^k S'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2 \tag{E.20}$$

- Financial intermediaries:

$$\mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} \left(R_t^{re} - R_t^d \right) = 0, \tag{E.21}$$

$$\mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} \left(R_{t+1}^F - R_t^d \right) = \frac{\lambda_t}{1+\lambda_t} \theta_t, \tag{E.22}$$

$$\mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} \left(R_{t+1}^B - R_t^d \right) = \frac{\lambda_t}{1+\lambda_t} \Delta\theta_t, \tag{E.23}$$

$$\Omega_t = 1 - \sigma + \sigma \theta_t \phi_t, \tag{E.24}$$

$$\phi_t = \frac{\mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} R_t^d}{\theta_t - \mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} (R_{t+1}^F - R_t^d)} \tag{E.25}$$

$$\phi_t = \frac{Q_t f_t + \Delta Q_{B,t} b_t}{n_t} \tag{E.26}$$

$$R_t^F = \frac{1 + \kappa Q_t}{Q_{t-1}} \tag{E.27}$$

$$R_t^B = \frac{1 + \kappa Q_{B,t}}{Q_{B,t-1}} \tag{E.28}$$

- Government:

$$\begin{aligned} &G_t + \Pi_t^{-1} b_{G,t-1} + Q_{M,t} \left(m_{G,t} - \kappa \Pi_t^{-1} m_{G,t-1} \right) = \\ &T_t + T_{G,t} + Q_{B,t} \left(b_{G,t} - \kappa \Pi_t^{-1} b_{G,t-1} \right) + \Pi_t^{-1} m_{G,t-1} \end{aligned} \tag{E.29}$$

$$\begin{aligned} &\ln R_t^{re} = (1-\rho_R) \ln R^{re} + \rho_R \ln R_{t-1}^{re} + \\ &(1-\rho_R) \left[\phi_\pi (\ln \Pi_t - \ln \Pi) + \phi_y (\ln Y_t - \ln Y_{t-1}) \right] + s_R \varepsilon_{R,t} \end{aligned} \tag{E.30}$$

$$Q_t f_{G,t} = re_t \tag{E.31}$$

$$Q_{M,t} = \tau Q_t \tag{E.32}$$

$$f_{G,t} = (1-\rho_g) f_G + \rho_g f_{G,t-1} + s_f \varepsilon_{f,t} \tag{E.33}$$

$$m_{G,t} = (1-\rho_m) m_G + \rho_g m_{G,t-1} + s_m \varepsilon_{m,t} \tag{E.34}$$

$$T_{G,t} = R_t^F \Pi_t^{-1} Q_{t-1} f_{G,t-1} - R_{t-1}^{re} \Pi_t^{-1} re_{t-1} \tag{E.35}$$

- Exogenous processes:

$$\ln A_t = \rho_A \ln A_{t-1} + s_A \varepsilon_{A,t} \tag{E.36}$$

$$\ln \theta_t = (1-\rho_\theta) \ln \theta + \rho_\theta \ln \theta_{t-1} + s_\theta \varepsilon_{\theta,t} \tag{E.37}$$

- Aggregate conditions

$$1 = (1-\phi_p) \left(\Pi_t^\# \right)^{1-\epsilon_p} + \phi_p \Pi_t^{\epsilon_p - 1} \tag{E.38}$$

$$w_t^{1-\epsilon_w} = (1-\phi_w) \left(w_t^\# \right)^{1-\epsilon_w} + \phi_w \Pi_t^{\epsilon_w - 1} w_{t-1}^{1-\epsilon_w} \tag{E.39}$$

$$v_t^p Y_t = Y_{w,t} \tag{E.40}$$

$$v_t^p = (1-\phi_p) \left(\Pi_t^\# \right)^{-\epsilon_p} + \phi_p \Pi_t^{\epsilon_p} v_{t-1}^p \tag{E.41}$$

$$L_t = L_{d,t} v_t^w \tag{E.42}$$

$$v_t^w = (1-\phi_w) \left(\frac{w_t^\#}{w_t} \right)^{-\epsilon_w} + \phi_w \left(\frac{w_t}{w_{t-1}} \right)^{\epsilon_w} \Pi_t^{\epsilon_w} v_{t-1}^w \tag{E.43}$$

Table G.1
Parameter values.

Parameter	Value or Target	Description
β	0.995	Discount factor
b	0.8	Habit formation
η	1	Inverse Frisch elasticity
χ	$L = 1$	Labor disutility scaling parameter/steady state labor
α	1/3	Production function exponent on capital
δ	0.025	Depreciation rate
κ_I	2	Investment adjustment cost
Π	1	Steady state (gross) inflation
ϵ_p	11	Elasticity of substitution goods
ϵ_w	11	Elasticity of substitution labor
ϕ_p	0.75	Price rigidity
ϕ_w	0.75	Wage rigidity
b_G	$\frac{b_G Q_B}{4Y} = 0.35$	Government debt
G	$\frac{G}{Y} = 0.2$	Steady state government spending
ρ_r	0.8	Taylor rule smoothing
ϕ_π	1.5	Taylor rule inflation
ϕ_y	0.15	Taylor rule output growth
κ	$1 - 16^{-1}$	Bond duration
ψ	0.81	Fraction of investment from debt
σ	0.95	Intermediary survival probability
θ	$400(R^F - R^d) = 3$	Recoverability parameter/steady state spread
X	Leverage $= 4$	Transfer to new intermediaries/steady state leverage
Δ	1/3	Government bond recoverability
f_G	0	Steady state government bond holdings
m_G	0	Steady state loans
ρ_f	0.97	AR QE
ρ_m	0.97	AR lending
φ	0.60	Cash flow constraint
τ	1	Relative price between loans and bonds

Note: This table lists the values of calibrated parameters or the target used in the calibration.

$$f_{w,t} = f_t + f_{G,t} \tag{E.44}$$

$$b_{G,t} = b_t \tag{E.45}$$

$$Q_t f_t + Q_{B,t} b_t + re_t = d_t + n_t \tag{E.46}$$

$$n_t = \sigma \Pi_t^{-1} \left[\left(R_t^F - R_{t-1}^d\right) Q_{t-1} f_{t-1} + \left(R_t^B - R_{t-1}^d\right) Q_{B,t-1} b_{t-1} + \left(R_{t-1}^{re} - R_{t-1}^d\right) re_{t-1} + R_{t-1}^d n_{t-1}\right] + X \tag{E.47}$$

$$Y_t = C_t + I_t + G_t \tag{E.48}$$

$$\ln G_t = (1-\rho_G)\ln G + \rho_G \ln G_{t-1} + s_G \varepsilon_{G,t} \tag{E.49}$$

$$b_{G,t} = b_G \tag{E.50}$$

Eqs. (E.1)–(E.50) constitute 50 equations and 50 variables: $\Big\{ \mu_t, C_t, \Lambda_{t-1,t}, L_t, w_t^H, R_t^d, \Pi_t, w_t^{\#}, f_{1,t}, f_{2,t}, w_t, L_{d,t}, p_t^w, A_t, K_t, \lambda_{1,t}, \lambda_{2,t}, \lambda_{3,t}, p_t^k, Q_t, \hat{I}_t, f_{w,t}, Y_{w,t}, \Pi_t^{\#}, x_{1,t}, x_{2,t}, Y_t, I_t, \Omega_t, R_t^{re}, R_t^F, R_t^B, \lambda_t, \theta_t, \phi_t, T_t, T_{G,t}, Q_{B,t}, f_{G,t}, re_t, m_{G,t}, Q_{M,t}, v_t^p, v_t^w, f_t, b_t, d_t, n_t, G_t, b_{G,t} \Big\}$. When solving the model without the cash-flow constraint, we set $\lambda_{3,t} = 0$ and drop (E.14).

Appendix F. Empirical measure of cash flow constraint

We use micro-level data on firms' balance sheets from the Compustat database to construct an empirical measure of the cash flow constraint. The variables of interest are Operating Income Before Depreciation (OIBDP) and Long-Term Debt Issuance (DLTIS). To better highlight the qualitative differences between the Great Recession and the COVID-19 crisis, we restrict our sample to those industries that were likely most affected by the COVID-19 pandemic: Transportation and Warehousing (NAICS: 48–49), Arts, Entertainment, and Recreation (NAICS: 71), Accommodation and Food Services (NAICS: 72), and Wholesale Trade (NAICS: 42). All data have been seasonally adjusted using the X-13 toolbox and aggregated to the quarterly frequency. We measure the cash flow constraint in (3.4) as follows:

$$\frac{\text{Long-Term Debt Issuance (DLTIS)}}{\text{Operating Income Before Depreciation (OIBDP)}}$$

If the cash flow constraint is not binding, we would not expect to see any particular pattern in the ratio of long-term debt issuance to operating income.[13] If the constraint were to go from non-binding to binding, however, we would expect to see increases in the ratio.

Appendix G. Calibration

Table G.1 lists the parameter values, or targets used to calibrate parameters, that we assume in solving the model. Because we only focus on impulse responses to Wall Street QE and Main Street Lending shocks, and do so in a first-order solution about the steady state, other than steady state values, we do not need to specify parameter values for other exogenous processes.

Appendix H. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.euroecorev.2023.104475.

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[13] Fig. 1 plots the demeaned aggregate ratio, where both numerators and denominators are averaged across firms.