Wall Street vs. Main Street QE[*]

Eric Sims
Notre Dame and NBER

Jing Cynthia Wu
Notre Dame and NBER

Current draft: June 12, 2020

Abstract

The Federal Reserve has reacted swiftly to the COVID-19 pandemic. It has resuscitated many of its programs from the last crisis by lending to the financial sector, which we refer to as "Wall Street QE." The Fed is now proposing to also lend directly to, and purchase debt directly from, non-financial firms, which we label "Main Street QE." Our paper develops a new framework to compare and contrast these different policies. In a situation in which financial intermediary balance sheets are impaired, such as the Great Recession, Main Street and Wall Street QE are perfect substitutes and both stimulate aggregate demand. In contrast, for situations like the one we are now facing due to COVID-19, where the production sector is facing significant cash flow shortages, Wall Street QE becomes almost completely ineffective, whereas Main Street QE can be highly stimulative.

Keywords: Main Street Lending Program, COVID-19, Great Recession, quantitative easing, DSGE

1　Introduction

The Federal Reserve has acted swiftly and dramatically to support the US economy in response to the ongoing COVID-19 pandemic. Many of its recent actions represent a resuscitation or extension of facilities and tools it deployed to combat the Financial Crisis and Great Recession of 2007-2009, which involved lending to, or purchasing assets from, financial firms. The Fed has also introduced a set of new tools that have significantly expanded its sphere of influence. In particular, in March 2020, it announced intentions to lend directly to non-financial firms and to purchase debt issued by such firms. Direct interaction with non-financial firms marks a significant break with central banking tradition, and is likely to invite more controversy than the myriad tools the Fed developed to fight the last crisis.

This paper represents a first attempt to asses the efficacy of the Fed directly lending to non-financial firms as opposed to interacting only with financial intermediaries. We do so in a macroeconomic model that contains the minimum number of necessary frictions to study central bank balance sheet policies; the rest of the model is fairly standard. Financial intermediaries are modeled as in Gertler and Karadi (2013) and Sims and Wu (2020b). 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. Central banks can purchase long-term bonds directly from intermediaries, which eases their leverage constraint. This allows them 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 a financial intermediary as "Wall Street QE."

The main modeling contribution of this paper is to allow the central bank to directly lend to, or more precisely purchase bonds from, non-financial firms. We refer to such direct purchases/lending as "Main Street QE." Without additional constraints relative to those de-

scribed in the paragraph above, Main Street QE is isomorphic to Wall Street QE. To account for the unique features of the ongoing crisis, 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 in the current environment, where government-mandated lockdowns and significant changes in consumer behavior have resulted in the near-evaporation of cash flows for many non-financial firms. When this "cash flow constraint" is binding, Main Street QE 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 intermediaries free up space on their 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 types of QE 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 and Wall Street QE are equivalent ways to stimulate aggregate demand in such a scenario. For the current COVID-19 crisis, we assume that both intermediaries and firms face binding constraints. In this situation, Wall Street QE is almost completely ineffective at stimulating variables like output, labor, and consumption. In contrast, Main Steet QE becomes far more stimulative. Viewed through the lens of our model, and in light of the circumstances the economy is now facing, the Fed's recent actions to lend directly to non-financial firms could have a substantial positive impact on aggregate demand. More generally, our analysis provides a simple yet powerful message. It is not sufficient for a central bank to lend freely to combat an economic crisis. It is just as important for the central bank to lend freely to *where constraints are most binding.* In the Great Recession, this was the financial system. In 2020, it is 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 recent actions. Section 3 presents the key ingredients of our model and discusses the potential differences between Wall Street and Main Street QE. 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 the Fed has set up, and some of the actions it has taken, in response to the COVID-19 crisis. We frame our discussion in an 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 view.

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 members of 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 direct lending, 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), were deployed as an antidote to the problems of the zero lower bound (ZLB) on policy rates. 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 2020a). Even before the current 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 quantitative easing 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 involve the Federal Reserve interacting with financial firms.

---

[1]Technically, the MMMLF is new to the current crisis, but is 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.

The newer, and far more controversial, actions by the Fed in response to the COVID-19 crisis involve direct lending to *non-financial firms*. These new facilities include the Primary Market Corporate Credit Facility (PMCCF), the Secondary Market Corporate Credit Facility (SMCCF), and the Main Street Lending Program (which consists of three related facilities, the MSNLF, MSPLF, and MSELF). The PMCCF and SMCCF will purchase corporate bonds either directly from non-financial firms (PMCCF) or indirectly on secondary markets (SMCCF) through exchange-traded funds (ETFs). In total, the present size of these two programs is \$750 billion. Through the different facilities associated with the Main Street Lending Program, the Fed plans to make another \$600 billion in credit directly available to small- and medium-sized non-financial firms.

All of these new programs involve the Federal Reserve taking on a significant degree of credit risk, which itself represents a departure from most previous Federal Reserve actions. The PMCCF and the different facilities associated with the Main Street Lending Program are further differentiated from prior Fed actions in that they involve direct lending to non-financial firms. While the SMCCF entails the assumption of significant credit risk, the Fed is purchasing ETFs on secondary markets, and hence not *directly* supporting the activities of non-financial firms the way it is with the PMCCF and the Main Street Lending Program. In that sense, the SMCCF can be considered a straightforward extension of "traditional" QE operations, wherein the Fed purchases previously issued government and agency-backed debt securities, but is now also purchasing privately-issued securities carrying some credit risk. The direct extension of credit to non-financial firms, in contrast, is quite different.

For simplicity, we refer to the extension of credit or purchases of assets on secondary markets, including the traditional QE programs instituted during the Great Recession, as "Wall Street QE" because it involves the Fed interacting with financial firms. In contrast, we label the extension of credit or purchases of assets directly from non-financial firms as "Main Street QE." Although our model abstracts from some nuances in these programs, our objective is to understand whether and under what conditions Main Street QE differs from

Wall Street QE. We also aim to provide insight into which type of QE is best-suited for the current COVID-19 crisis.

3 Model

In this section, we lay out the principal ingredients of our model. Along most dimensions, the model is similar to Sims and Wu (2020b). In the main text, we describe only those aspects of the model that are most relevant for studying Wall Street and Main Street QE. The rest of the model details are relegated to Appendix A.

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 producers 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, Fuerst and Paustian (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 (2020b) model.

In addition to setting the short-term nominal interest rate, the central bank in our model can purchase long-term bonds either from financial intermediaries or directly from the wholesale firm. We label the former as "Wall Street QE" and the latter as "Main Street QE." As in Sims and Wu (2020b, 2019), "Wall Street QE" can be effective by relaxing the endogenous leverage constraint facing financial intermediaries – by purchasing long-term bonds, the central bank frees up space on intermediary balance sheets to purchase private bonds, which results in more investment. The main difference in our model relative to the setup in Sims and Wu (2020b) is that, similarly to Drechsel (2019), we introduce a constraint that limits the amount of debt the wholesale firm can issue as a function of its current cash flows.

"Main Street QE" involves the central bank directly lending to the firm, which relaxes its cash flow constraint and allows it to issue more debt and thereby finance more investment. When firms are cash flow constrained, as they likely are now in the midst of the COVID-19 pandemic, Main Street QE can be highly effective. At the same time, Wall Street QE becomes ineffective – even though this type of QE frees up space on intermediary balance sheets to buy private debt, they remain unwilling to do so when firms have very low cash flows.

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 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 P_t^k. Labor is hired at nominal wage W_t from the labor packing firm. Output is sold to retailers at 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 (2020b).

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 present environment in the midst of a public health crisis, mandated lockdowns and changes in consumer behavior likely make the cash flow constraint (3.4) binding.

Nominal dividends for the wholesale firm are:

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

or, in real terms:

$$d_{w,t} = p_t^w A_t K_t^\alpha L_{d,t}^{1-\alpha} - w_t L_t - p_t^k \widehat{I}_t - \frac{F_{w,t-1}}{P_t} + \frac{Q_t(F_{w,t} - \kappa F_{w,t-1})}{P_t}, \tag{3.6}$$

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. The firm's objective is to maximize the present discounted value of real dividends, 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:

$$w_t = (1-\alpha)p_t^w A_t K_t^\alpha L_{d,t}^{-\alpha} \tag{3.7}$$

$$\lambda_{1,t} = p_t^k(1 + \psi\lambda_{2,t}) \tag{3.8}$$

$$\lambda_{1,t} = \mathbb{E}_t \Lambda_{t,t+1} \left[(1 + \varphi\lambda_{3,t+1})\alpha p_{t+1}^w A_{t+1} K_{t+1}^{\alpha-1} L_{d,t+1}^{1-\alpha} + \lambda_{1,t+1}(1 - \delta) \right] \tag{3.9}$$

$$(1 + \lambda_{2,t} - \lambda_{3,t})Q_t = \mathbb{E}_t \Lambda_{t,t+1}\Pi_{t+1}^{-1} \left[1 + \kappa Q_{t+1}(1 + \lambda_{2,t+1} - \lambda_{3,t+1}) \right] \tag{3.10}$$

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

9

cash flow constraint. Π_{t+1} is the gross inflation rate. (3.7) is the labor demand expression; this condition looks entirely standard. (3.8) 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. (3.9) 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. (3.10) 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.

3.2   Financial Intermediaries

Financial intermediaries are structured as in Gertler and Karadi (2013) and Sims and Wu (2020b). Here, we sketch out the principal ingredients.

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

10

central bank RE_t. The balance sheet condition is:

$$Q_t f_t + Q_{B,t} b_t + re_t = d_t + n_t, \tag{3.11}$$

where lower cases represent real terms: $f_t = F_t/P_t$, $b_t = B_t/P_t$, $re_t = RE_t/P_t$, $d_t = D_t/P_t$, $n_t = N_t/P_t$.

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

$$n_t \Pi_t = \left(R_t^F - R_{t-1}^d\right) Q_{t-1} f_{t-1} + \left(R_t^B - R_{t-1}^d\right) Q_{B,t-1} b_{t-1} + \left(R_{t-1}^{re} - R_{t-1}^d\right) + R_{t-1}^d n_{t-1}, \tag{3.12}$$

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 central bank. The holding period returns satisfy:

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

$$R_t^B = \frac{1 + \kappa Q_{B,t}}{Q_{B,t-1}}. \tag{3.14}$$

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 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:

$$V_t = \max_{f_t, b_t, re_t} (1 - \sigma) \mathbb{E}_t \Lambda_{t,t+1} n_{t+1} + \sigma \mathbb{E}_t \Lambda_{t,t+1} V_{t+1}. \tag{3.15}$$

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:

$$V_t \geq \theta_t \left(Q_t f_t + \Delta Q_{B,t} b_t \right). \tag{3.16}$$

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:

$$\mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} \left(R_t^{re} - R_t^d \right) = 0, \tag{3.17}$$

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

$$\mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} \left(R_{t+1}^B - R_t^d \right) = \frac{\lambda_t}{1 + \lambda_t} \Delta \theta_t, \tag{3.19}$$

where Ω_t satisfies:

$$\Omega_t = 1 - \sigma + \sigma \theta_t \phi_t, \tag{3.20}$$

and ϕ_t is a modified leverage ratio and satisfies:

$$\phi_t = \frac{\mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} R_t^d}{\theta_t - \mathbb{E}_t \Lambda_{t+1} \Pi_{t+1}^{-1} \Omega_{t+1} (R_{t+1}^F - R_t^d)} \tag{3.21}$$

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

$$\phi_t = \frac{Q_t f_t + \Delta Q_{B,t} b_t}{n_t}. \tag{3.22}$$

(3.17) 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.

3.3 Fiscal Policy

The government consumes an exogenous and constant level of output each period, G. It finances this spending through a combination of lump sum taxes, debt issuance, and a remittance from the central bank, $T_{cb,t}$. In nominal terms, its flow budget constraint is:

$$P_t G + B_{G,t-1} = P_t T_t + P_t T_{cb,t} + Q_{B,t}(B_{G,t} - \kappa B_{G,t-1}). \tag{3.23}$$

Government bonds are perpetuities with decaying coupon payments and are structured identically to the bonds issued by the wholesale firm. They trade at price $Q_{B,t}$. $T_{cb,t}$ is a transfer from the central bank, discussed below. We assume that the real amount of government bonds outstanding is fixed at $\bar{b}_G$, so $b_{G,t} = B_{G,t}/P_t = \bar{b}_{G,t}$. Assuming constant (real) government debt is a simplification that avoids complications arising because of a breakdown of Ricardian Equivalence due to balance sheet constraints facing intermediaries. Lump sum taxes automatically adjust, given the level of G, the price of debt $Q_{B,t}$, and the fixed real outstanding debt $\bar{b}_G$, to ensure that (3.23) always holds.

3.4 Central Bank

The central bank sets the interest rate on reserves according to a traditional Taylor-type rule. For now, we ignore constraints imposed by the ZLB.

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

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

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

$$Q_t f_{cb,t} + Q_{B,t} b_{cb,t} = re_t. \tag{3.25}$$

We allow the amount of central bank private bond holdings, $f_{cb,t}$ to be split into two components. We will refer to these as "Wall Street QE" (or traditional QE), qe_t for short, and "Main Street QE," or qe_t^M:

$$f_{cb,t} = qe_t + qe_t^M. \tag{3.26}$$

qe_t^M involves *direct* purchases of long-term bonds from firms, whereas qe_t involves purchases of long-term bonds from intermediaries. We will discuss why these different kinds of purchases might matter in Subsection 3.5.

We simply assume that qe_t and qe_t^M obey exogenous AR(1) processes:

$$qe_t = (1 - \rho_{qe})qe + \rho_{qe}qe_{t-1} + s_{qe}\varepsilon_{qe,t}, \tag{3.27}$$

$$qe_t^M = (1 - \rho_{qe})qe^M + \rho_{qe}qe_{t-1}^M + s_{qe}\varepsilon_{qe,t}^M, \tag{3.28}$$

In (3.27)-(3.28), we assume that the AR(1) parameters and shock standard deviations are the same. This is not necessary, but makes our subsequent analysis more transparent. We also assume that the central bank holds a constant quantity of real government bonds, $\bar{b}_{cb}$. This is again not central to our analysis; government bond purchases have identical (albeit smaller, to the extent that $\Delta < 1$) effects as private bond purchases from intermediaries; for further discussion, see Sims and Wu (2020b).

14

The central bank potentially earns an operating profit from its holdings of long-term bonds relative to its cost of issuing reserves. This operating profit is remitted to the government each period and satisfies:

$$T_{cb,t} = R_t^F \Pi_t^{-1} Q_{t-1} f_{cb,t-1} + R_t^B \Pi_t^{-1} Q_{B,t-1} \bar{b}_{cb} - R_{t-1}^{re} \Pi_t^{-1} re_{t-1} \qquad (3.29)$$

3.5 Wall Street vs. Main Street QE

We refer to purchases of bonds – either private or government – from intermediaries as "Wall Street QE" since it involves an interaction only with the financial sector. We refer to direct asset purchases from the wholesale firm as "Main Street QE." This section highlights mechanisms through which each of them works and contrasts the two policy tools.

Main Street QE works through the wholesale firm's cash flow constraint. In particular, to allow for direct lending, we modify (3.4) as follows:

$$Q_t(f_{w,t} - \kappa \Pi_t^{-1} f_{w,t-1}) - Q_t(qe_t^M - \kappa \Pi_t^{-1} qe_{t-1}^m) \leq \varphi \left(p_t^w A_t K_t^\alpha L_{d,t}^{1-\alpha} - w_t L_{d,t} \right). \qquad (3.30)$$

The new cash flow constraint says that *net bond issuance to be absorbed by intermediaries cannot exceed some multiple of current cash flows*. Though the wholesale firm takes qe_t^M as given and hence it does not affect the first order conditions presented above, the distinction between (3.4) and (3.30) is important when contrasting between Wall Street and Main Street QE. Direct bond purchases, qe_t^M, loosen the cash flow constraint because fewer of the wholesale firm's bonds need to be absorbed by intermediaries. This allows the firm to issue more debt and increases its investment even when its cash flows are low. This situation seems especially relevant in the midst of the COVID-19 crisis.

Wall Street QE works the same as in Sims and Wu (2020b) by loosening the enforcement constraint facing intermediaries when the cash flow constraint, (3.30), does not bind. Purchases of private bonds are more effective than government bonds to the extent to which

15

$\Delta < 1$, but this difference is not important for thinking about the intuition for how such purchases can stimulate the economy. Asset purchases by the central bank from intermediaries involves a *swap* of assets where a constraint applies (corporate or government 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 and government 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 encourages the issuance of higher-valued debt and hence more investment. This works to stimulate overall aggregate demand.

If there is no cash flow constraint facing the wholesale firm (i.e. if (3.30) does not bind), the distinction between purchases of bonds from intermediaries and direct purchases from firms, or what we label as qe_t and qe_t^M, is irrelevant – both would have the same effects and would work through intermediary balance sheets.

However, when the cash flow constraint binds, Wall Street QE without Main Street QE becomes ineffective. To see this, combine (3.4) with (3.3):

$$\psi p_t^k \widehat{I}_t \leq \varphi \left(p_t^w A_t K_t^\alpha L_{d,t}^{1-\alpha} - w_t L_{d,t} \right) \tag{3.31}$$

Private investment is simply restricted by current cash flows and does not directly depend on the bond price Q_t. 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.

Main Street QE, in contrast, is highly effective because it directly loosens the constraint facing the wholesale firm and permits higher investment and more aggregate demand. To see this, combine (3.30) with (3.3) – in other words, allow for Main Street QE:

16

$$\psi p_t^k \widehat{I}_t \leq \varphi \left(p_t^w A_t K_t^\alpha L_{d,t}^{1-\alpha} - w_t L_{d,t} \right) + Q_t (qe_t^M - \kappa \Pi_t^{-1} qe_{t-1}^m) \tag{3.32}$$

Increases in qe_t^M here directly loosen the constraints facing the firm, resulting in more investment and aggregate demand.

4   COVID-19 vs. the Great Recession

In this section, we quantitatively analyze the effects of Wall Street and Main Street QE in the two environments: the most recent COVID-19 crisis and the previous Great Recession.

4.1   Calibration

We begin by assigning values to the different parameters in the model in Table 1. Many of them are chosen based on consensus values from the extant literature.

Parameters governing preferences and technology are fairly standard. The unit of time in the model is a quarter. We follow Sims and Wu (2020b) 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 as well as SMCCF. We set the AR(1) parameter for both Main Street and Wall Street QE to $\rho_{qe} = 0.97$. The size of the QE shocks we consider amount to about a one-third expansion in the size of the central bank's pre-Great Recession balance sheet, which is roughly in-line with the sizes of recent Fed interventions.[2] For the situation in which the cash flow constraint on production firms is binding, we set $\varphi = 0.30$.

---

[2]Because the model is solved via a linear approximation, we do not need to specify parameter values for other exogenous processes, and impulse responses are just proportional to the size of the QE shocks we consider.

Table 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	0.33	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
$\bar{b}_G$	$\frac{B_G Q_B}{4Y} = 0.41$	Steady state 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
b_{cb}	$\frac{b_{cb} Q_B}{4Y} = 0.06$	Steady state central bank Treasury holdings
f_{cb}	0	Steady state central private bond holdings
ρ_{qe}	0.97	AR QE
φ	0.30	Cash flow constraint

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

4.2 Great Recession

We begin by using our model to think about the experience of the US during the Great Recession of 2007-2009. 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 (3.30) is not binding, and accordingly solve the model dropping that equation as well as the Lagrange multiplier $\lambda_{3,t}$.

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 (2020b), is a sequence of adverse credit shocks, captured by the exogenous

18

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.

Figure 1 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; responses of a shock to government bond-holdings would be similar but smaller in magnitude. For the responses shown, we do not impose a ZLB constraint on the short-term interest rate. Doing so would amplify the effects of the QE shock. Responses of inflation and the policy rate are expressed in annualized percentage points. Responses of central bank bond holdings, as well as the multiplier on the balance sheet constraint, are expressed in absolute deviations from steady state. All other responses are expressed in percentage deviations from steady state.

The Wall Street QE 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 three 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 central bank 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, denoted in the model by λ_t. Less constrained, intermediaries purchase more bonds. This pushes 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 and Wall Street QE are equivalent to one another. As discussed in

Figure 1: Great Recession: Wall Street QE
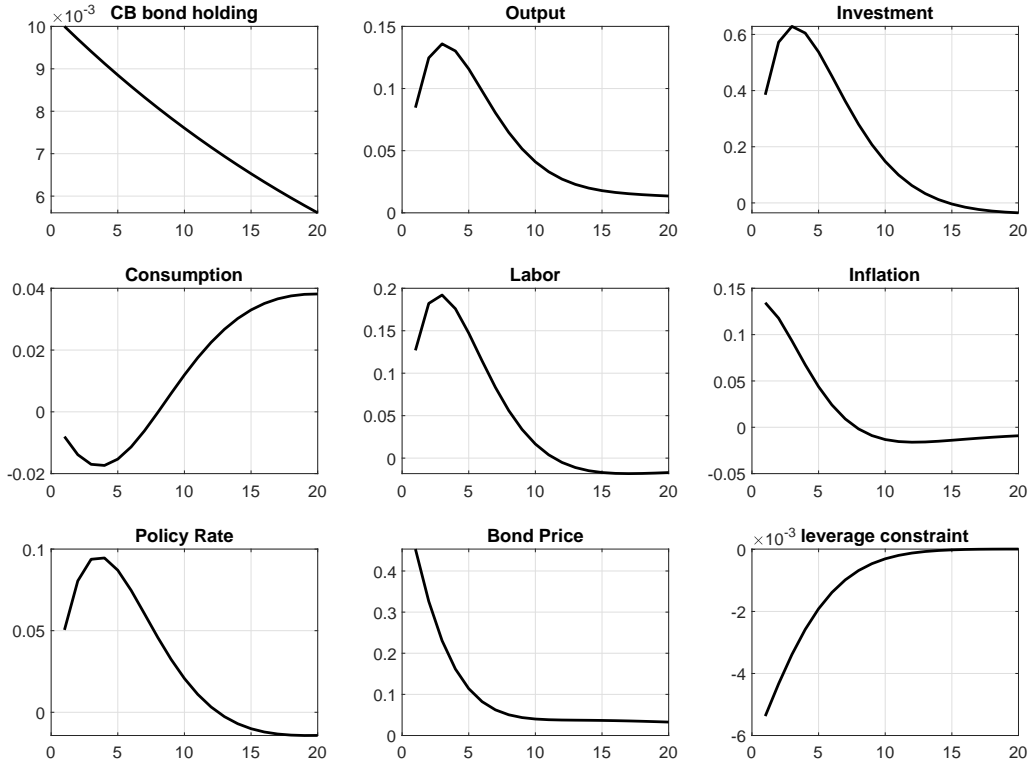
Notes: The shock is a 0.01 shock to central bank private bonding holdings, $f_{cb,t}$, when the cash-flow constraint on the wholesale firm is not binding. Units of variables: CB bond holding and the multiplier on the leverage constraint are in absolute deviations. Inflation and the policy rate are changes in annualized percentage points. All other variables are in percentage deviation from the steady state.

Subsection 3.5, it does not matter whether a central bank issues credit directly to firms or indirectly through easing balance sheet constraints on intermediaries.

4.3 COVID-19

We next use our model to discuss different kinds of QE during the COVID-19 pandemic, a situation in which the cash flow constraint on non-financial firms is binding. We do not formally model why this constraint is binding, but nevertheless think this captures in a convenient way the situation facing firms in the present crisis. A combination of government-mandated lockdowns, unwillingness of households to go to work, and changes in consumption

20

Figure 2: COVID: Wall Street QE
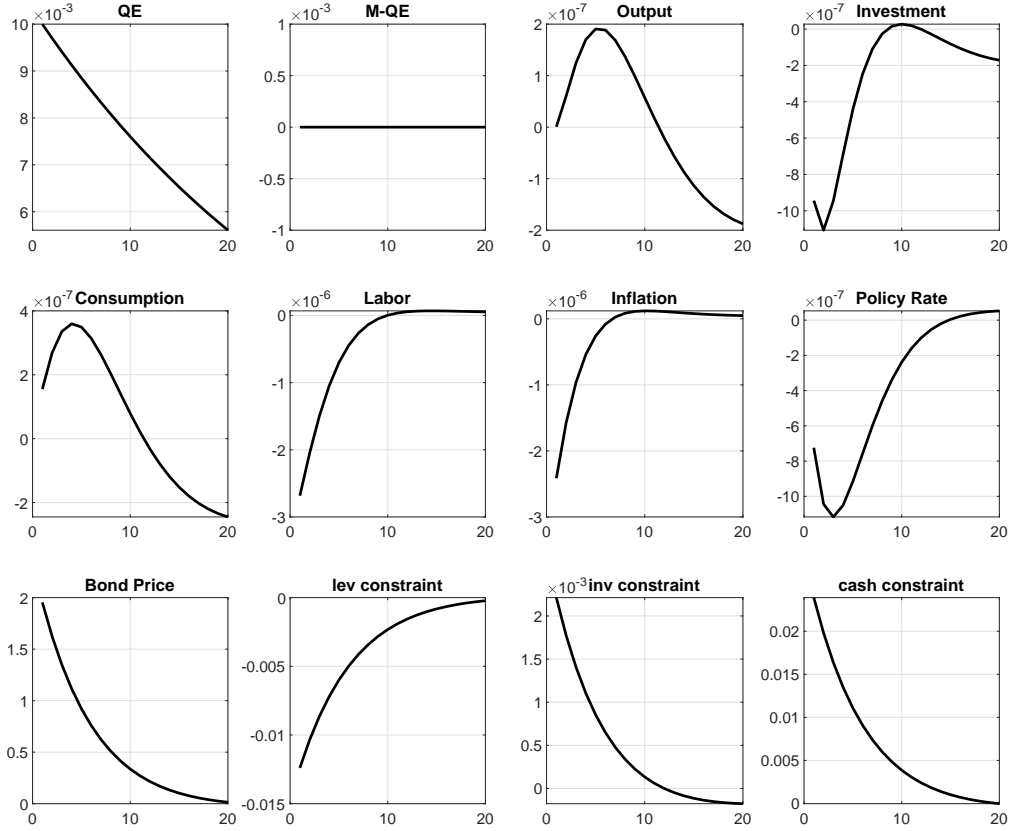
Notes: The shock is a 0.01 shock to central bank bond purchases from intermediaries, qe_t, when the cash-flow constraint on the wholesale firm is binding. Units of variables: CB bond holding and the multipliers on the three constraints are in absolute deviations. Inflation and the policy rate are changes in annualized percentage points. All other variables are in percentage deviation from the steady state.

patterns have resulted in a near evaporation of cash flows for many firms. One could think of this is as a massive reduction in $Y_t - w_t L_{d,t}$ in response to some combination of shocks. Alternatively, given serious concerns about the profitability of these firms, one could also think of this constraint as being binding due to a reduction in φ – i.e. an unwillingness of banks to extend credit.

Figure 2 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. 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 QE shock in a situation in which firms are cash flow constrained. These responses are depicted in Figure 3. We consider a shock to Main Street QE of exactly the same magnitude as the Wall Street QE shock in Figure 2. Here one observes that Main Street QE is even *more* stimulative than in Figure 1. 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, consumption, 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 QE.

In comparing the impulse responses in Figure 3 to Figure 1, one notices that in the COVID-19 scenario output and investment respond maximally on impact and then revert rather quickly.[3] This is because Main Street QE works through a *flow* channel: in the cash flow constraint (3.30), the new bond issuances are constrained by the firm's cash flows. To relax this constraint, the central bank needs to absorb *new* debt. In contrast, Wall Street QE works through a *stock* channel, because the leverage constraint facing intermediaries applies to their stock of assets and not to the flow. In this paper, we have assumed the same exogenous processes for both types of QE to facilitate comparison. In practice, QE is implemented more in the flow sense. Hence, if one were to modify our exercises to apply to

---

[3]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.

Figure 3: COVID: Main Street QE
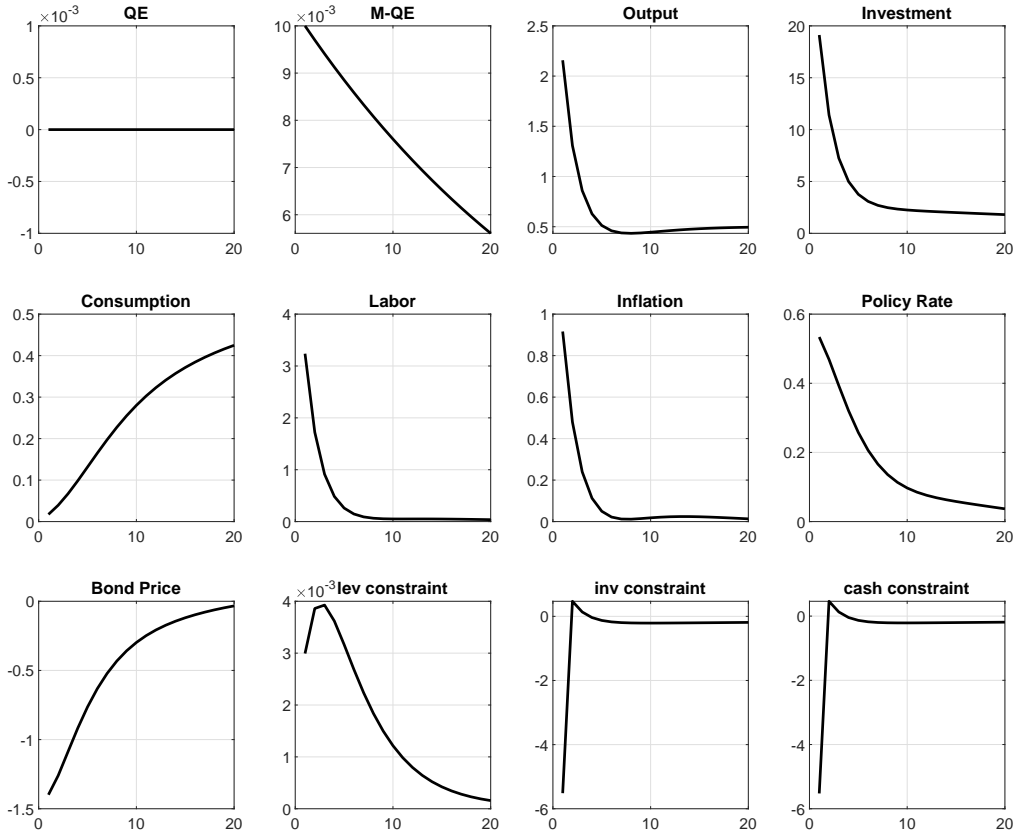
Notes: The shock is a 0.01 shock to central bank direct bond purchases, qe_t^M, when the cash-flow constraint on the wholesale firm is binding. Units of variables: CB bond holding and the multipliers on the three constraints are in absolute deviations. Inflation and the policy rate are changes in annualized percentage points. All other variables are in percentage deviation from the steady state.

the flow and not the stock of central bank bond purchases, one would expect to see a more prolonged effect on variables like output and investment from Main Street QE.

The take-home message from these exercises is that, to simulate economic activity, it is not simply important for the Fed to purchase assets and lend freely, it is important that they allocate 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

23

of the current state of affairs, direct lending to firms can be a powerful stimulative tool.

5   Conclusion

This paper represents a first attempt at formally modeling direct lending by the Federal Reserve to non-financial firms as an emergency measure to combat the COVID-19 crisis. Direct lending, both through the Primary Market Corporate Credit Facility and the various facilities associated with the Main Street Lending Program, amounts to more than $1 trillion of credit that the Fed has or is planning to funnel into the economy. Lending to non-financial firms represents an important departure from past Fed policies, all of which only targeted banks and other financial firms. We refer to direct lending to non-financial firms as "Main Street QE," while we call lending and asset purchases involving financial firms as "Wall Street QE."

We construct a macro model with two key frictions relevant for central bank balance sheet 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 and Main Street QE are 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 intermediaries is also binding (which we think of as a defining characteristic of the COVID-19 crisis), Wall Street QE becomes ineffective. Main Street QE, however, becomes even more effective. By directly lending to firms, the Fed can loosen the constraint facing them and trigger an increase in investment and aggregate demand.

Overall, we conclude that Wall Street QE is an appropriate policy response to a "balance sheet" recession such as the Great Recession. COVID-19 is much more of a "cash flow" recession that is directly impacting non-financial firms, rather than financial intermediaries.

It is not sufficient for the Fed to simply lend freely to counteract the crisis. Rather, the central bank ought to lend freely, but more importantly its lending should be targeted at segments of the economy where constraints are most binding. For the particular circumstances surrounding the COVID-19 crisis, lending directly to non-financial firms can be a highly effective way to raise aggregate demand.

In closing, we wish to highlight that we do *not* aim to address a variety of issues related to independence and accountability that arise from the Fed directly interacting with non-financial firms. Many commentators (e.g. Cecchetti and Schoenholtz 2020) have argued that the assumption of credit risk and "picking winners and losers" through direct extension of credit to non-financial firms poses a significant threat to hard-won central bank independence. The resultant blurring of lines between monetary and fiscal intervention will likely need to be addressed once the current crisis has passed.

References

Bagehot, Walter, *Lombard Street: A Description of the Money Market*, New York: Scribner, Armstrong & Co., 1873.

Brainard, Lael, "Federal Reserve Review of Monetary Policy Strategy, Tools, and Communications: Some Preliminary Views," 2019. Remarks by Governor Lael Brainard at the 2019 Will F. Butler Award New York Associate for Business Economics, New York, New York.

Carlstrom, Charles T., Timothy S. Fuerst, and Matthias Paustian, "Targeting Long Rates in a Model with Segmented Markets," *American Economic Journal: Macroeconomics*, January 2017, *9* (1), 205–42.

Cecchetti, Stephen G. and Kermit L. Schoenholtz, "The Fed Goes to War: Part 2," 2020. Blog Post from *Money, Banking, and Financial Markets*,.

Drechsel, Thomas, "Earnings-Based Borrowing Constraints and Macroeconomic Fluctuations," 2019. working paper.

Gertler, Mark and Peter Karadi, "QE 1 vs. 2 vs. 3 . . .: A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool," *International Journal of Central Banking*, 2013, *9(S1)*, 5–53.

Sims, Eric and Jing Cynthia Wu, "The Four Equation New Keynesian Model," 2019. NBER Working Paper No. 26067.

_ **and** _ , "Are QE and Conventional Monetary Policy Substitutable?," *International Journal of Central Banking*, 2020, *16* (1).

_ **and** _ , "Evaluating Central Banks' Tool Kit: Past, Present, and Future," *Journal of Monetary Economics*, 2020. Forthcoming.

Swanson, Eric T., "The Federal Reserve is Not Very Constrained by the Lower Bound on Nominal Interest Rates," 2018. Working Paper.

Woodford, Michael, "Fiscal Requirements for Price Stability," *Journal of Money, Credit and Banking*, August 2001, *33* (3), 669–728.

Wu, Jing Cynthia and Fan Dora Xia, "Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound," *Journal of Money, Credit, and Banking*, 2016, *48* (2-3), 253–291.

A Full Model and Derivations

This appendix lays out the more standard parts of the model presented in Section 3.

A.1 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:

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

$PROF_t$ 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 interemdiaries. 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.

A.2 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:

28

$$L_{d,t} = \left(\int_0^1 L_{d,t}(h)^{\frac{\epsilon_w - 1}{\epsilon_w}} dh \right)^{\frac{\epsilon_w}{\epsilon_w - 1}}, \tag{A.6}$$

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

$$L_{d,t}(h) = \left(\frac{W_t(h)}{W_t} \right)^{-\epsilon_w} L_{d,t} \tag{A.7}$$

$$W_t^{1-\epsilon_w} = \int_0^1 W_t(h)^{1-\epsilon_w} dh \tag{A.8}$$

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:

$$w_t^{\#} = \frac{\epsilon_w}{\epsilon_w - 1} \frac{f_{1,t}}{f_{2,t}}, \tag{A.9}$$

$$f_{1,t} = w_t^H w_t^{\epsilon_w} L_{d,t} + \phi_w \, \mathbb{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_w} f_{1,t+1}, \tag{A.10}$$

$$f_{2,t} = w_t^{\epsilon_w} L_{d,t} + \phi_w \, \mathbb{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_w - 1} f_{2,t+1}. \tag{A.11}$$

A.3 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:

$$Y_t = \left(\int_0^1 Y_t(f)^{\frac{\epsilon_p - 1}{\epsilon_p}} df \right)^{\frac{\epsilon_p}{\epsilon_p - 1}}, \tag{A.12}$$

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

$$Y_t(f) = \left(\frac{P_t(f)}{P_t} \right)^{-\epsilon_p} Y_t, \tag{A.13}$$

$$P_t^{1-\epsilon_p} = \int_0^1 P_t(f)^{1-\epsilon_p} df. \tag{A.14}$$

Retailers simply repackage wholesale output, earning dividend $DIV_{Y,t}(f) = (P_t(f) - P_t^w) Y_t(f)$. If they could freely adjust price, then given (A.13), 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:

$$\Pi_t^\# = \frac{\epsilon_p}{\epsilon_p - 1} \frac{x_{1,t}}{x_{2,t}}, \tag{A.15}$$

$$x_{1,t} = p_t^w Y_t + \phi_p \, \mathbb{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_p} x_{1,t+1}, \tag{A.16}$$

$$x_{2,t} = Y_t + \phi_p \, \mathbb{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_p - 1} x_{2,t+1}. \tag{A.17}$$

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

$$\widehat{I}_t = \left[1 - S\left(\frac{I_t}{I_{t-1}} \right) \right] I_t, \tag{A.18}$$

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 $P_t^k \widehat{I}_t - P_t I_t$. 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:

$$1 = p_t^k \left[1 - S\left(\frac{I_t}{I_{t-1}} \right) - S'\left(\frac{I_t}{I_{t-1}} \right) \frac{I_t}{I_{t-1}} \right] + \mathbb{E}_t \Lambda_{t,t+1} p_{t+1}^k S'\left(\frac{I_{t+1}}{I_t} \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \tag{A.19}$$

A.4   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:

$$\ln A_t = \rho_A \ln A_{t-1} + s_A \varepsilon_{A,t}. \tag{A.20}$$

$$\ln \theta_t = (1 - \rho_\theta) \ln \theta + \rho_\theta \ln \theta_{t-1} + s_\theta \varepsilon_{\theta,t}. \tag{A.21}$$

The aggregate inflation rate evolves according to:

$$1 = (1 - \phi_p) \left(\Pi_t^\# \right)^{1 - \epsilon_p} + \phi_p \Pi_t^{\epsilon_p - 1}. \tag{A.22}$$

Similarly, the aggregate real wage evolves according to:

$$w_t^{1 - \epsilon_w} = (1 - \phi_w) \left(w_t^\# \right)^{1 - \epsilon_w} + \phi_w \Pi_t^{\epsilon_w - 1} w_{t-1}^{1 - \epsilon_w}. \tag{A.23}$$

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

$$v_t^p Y_t = Y_{w,t}, \tag{A.24}$$

where v_t^p is a measure of price dispersion:

$$v_t^p = (1 - \phi_p) \left(\Pi_t^\#\right)^{-\epsilon_p} + \phi_p \Pi_t^{\epsilon_p} v_{t-1}^p. \tag{A.25}$$

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

$$L_t = L_{d,t} v_t^w, \tag{A.26}$$

where v_t^w is a measure of wage dispersion:

$$v_t^w = (1 - \phi_w) \left(\frac{w_t^\#}{w_t}\right)^{-\epsilon_w} + \phi_w \left(\frac{w_t}{w_{t-1}}\right)^{\epsilon_w} \Pi_t^{\epsilon_w} v_{t-1}^w. \tag{A.27}$$

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

$$f_{w,t} = f_t + f_{cb,t} \tag{A.28}$$

Similar, debt issued by the government must be held by either intermediaries or the central bank:

$$\bar{b}_G = b_t + \bar{b}_{cb} \tag{A.29}$$

Aggregating the balance sheet conditions across intermediaries, and imposing that total reserves issued by intermediaries are held in the banking system, yields:

$$Q_t f_t + Q_{B,t} b_t + re_t = d_t + n_t \tag{A.30}$$

Each period, the fraction $1 - \sigma$ of intermediaries exists 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:

$$n_t = \sigma \Pi_t^{-1} \left[\left(R_t^F - R_{t-1}^d\right) Q_{t-1} f_{t-1} + \left(R_t^B - R_{t-1}^d\right) Q_{B,t-1} b_{t-1} + \left(R_{t-1}^{re} - R_{t-1}^d\right) re_{t-1} + R_{t-1}^d n_{t-1} \right] + X \tag{A.31}$$

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:

$$Y_t = C_t + I_t + G \tag{A.32}$$

A.5 Full Set of Equilibrium Conditions

For completeness, below we list the full set of equilibrium conditions in our model:

- Household

$$\mu_t = \frac{1}{C_t - bC_{t-1}} - b\beta \, \mathbb{E}_t \frac{1}{C_{t+1} - bC_t} \tag{A.33}$$

$$\Lambda_{t-1,t} = \beta \frac{\mu_t}{\mu_{t-1}} \tag{A.34}$$

$$\chi L_t^\eta = \mu_t w_t^H \tag{A.35}$$

$$1 = \mathbb{E}_t \, \Lambda_{t,t+1} R_t^d \Pi_{t+1}^{-1} \tag{A.36}$$

- Labor unions:

$$w_t^\# = \frac{\epsilon_w}{\epsilon_w - 1} \frac{f_{1,t}}{f_{2,t}}, \tag{A.37}$$

$$f_{1,t} = w_t^H w_t^{\epsilon_w} L_{d,t} + \phi_w \, \mathbb{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_w} f_{1,t+1}, \tag{A.38}$$

$$f_{2,t} = w_t^{\epsilon_w} L_{d,t} + \phi_w \, \mathbb{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_w - 1} f_{2,t+1}. \tag{A.39}$$

- Wholesale firm:

$$w_t = (1 - \alpha) p_t^w A_t K_t^\alpha L_{d,t}^{-\alpha} \tag{A.40}$$

$$\lambda_{1,t} = p_t^k (1 + \psi \lambda_{2,t}) \tag{A.41}$$

$$\lambda_{1,t} = \mathbb{E}_t \, \Lambda_{t,t+1} \left[(1 + \varphi \lambda_{3,t+1}) \alpha p_{t+1}^w A_{t+1} K_{t+1}^{\alpha-1} L_{d,t+1}^{1-\alpha} + \lambda_{1,t+1} (1 - \delta) \right] \tag{A.42}$$

$$(1 + \lambda_{2,t} - \lambda_{3,t}) Q_t = \mathbb{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{-1} \left[1 + \kappa Q_{t+1} (1 + \lambda_{2,t+1} - \lambda_{3,t+1}) \right] \tag{A.43}$$

$$K_{t+1} = \widehat{I}_t + (1 - \delta) K_t \tag{A.44}$$

$$Q_t \left(f_{w,t} - \kappa \Pi_t^{-1} f_{w,t-1} \right) \geq \psi p_t^k \widehat{I}_t \tag{A.45}$$

$$\varphi \left(p_t^w A_t K_t^\alpha L_{d,t}^{1-\alpha} - w_t L_{d,t} \right) \geq Q_t \left(f_{w,t} - \kappa \Pi_t^{-1} f_{w,t-1} \right) Q_t \left(q e_t^M - \kappa \Pi_t^{-1} q e_{t-1}^M \right) \tag{A.46}$$

$$Y_{w,t} = A_t K_t^\alpha L_{d,t}^{1-\alpha} \tag{A.47}$$

- Retail firm:

$$\Pi_t^\# = \frac{\epsilon_p}{\epsilon_p - 1} \frac{x_{1,t}}{x_{2,t}}, \tag{A.48}$$

$$x_{1,t} = p_t^w Y_t + \phi_p \, \mathbb{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_p} x_{1,t+1}, \tag{A.49}$$

$$x_{2,t} = Y_t + \phi_p \, \mathbb{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{\epsilon_p - 1} x_{2,t+1}. \tag{A.50}$$

- New capital producer:

$$\widehat{I}_t = \left[1 - S \left(\frac{I_t}{I_{t-1}} \right) \right] I_t, \tag{A.51}$$

$$1 = p_t^k \left[1 - S \left(\frac{I_t}{I_{t-1}} \right) - S' \left(\frac{I_t}{I_{t-1}} \right) \frac{I_t}{I_{t-1}} \right] + \mathbb{E}_t \, \Lambda_{t,t+1} p_{t+1}^k S' \left(\frac{I_{t+1}}{I_t} \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \tag{A.52}$$

- Financial intermediaries:

$$\mathbb{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} \left(R_t^{re} - R_t^d \right) = 0, \tag{A.53}$$

$$\mathbb{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} \left(R_{t+1}^F - R_t^d \right) = \frac{\lambda_t}{1 + \lambda_t} \theta_t, \tag{A.54}$$

$$\mathbb{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} \left(R_{t+1}^B - R_t^d \right) = \frac{\lambda_t}{1 + \lambda_t} \Delta \theta_t, \tag{A.55}$$

$$\Omega_t = 1 - \sigma + \sigma \theta_t \phi_t, \tag{A.56}$$

$$\phi_t = \frac{\mathbb{E}_t \, \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{t+1} R_t^d}{\theta_t - \mathbb{E}_t \, \Lambda_{t+1} \Pi_{t+1}^{-1} \Omega_{t+1} (R_{t+1}^F - R_t^d)} \tag{A.57}$$

$$\phi_t = \frac{Q_t f_t + \Delta Q_{B,t} b_t}{n_t} \tag{A.58}$$

$$R_t^F = \frac{1 + \kappa Q_t}{Q_{t-1}} \tag{A.59}$$

$$R_t^B = \frac{1 + \kappa Q_{B,t}}{Q_{B,t-1}} \tag{A.60}$$

- Fiscal policy:

$$G + \Pi_t^{-1} \bar{b}_G = T_t + T_{cb,t} + Q_{B,t} (\bar{b}_G - \kappa \Pi_t^{-1} \bar{b}_G) \tag{A.61}$$

- Monetary policy:

$$\ln R_t^{re} = (1 - \rho_R) \ln R^{re} + \rho_R \ln R_{t-1}^{re} +$$
$$(1 - \rho_R) \left[\phi_\pi (\ln \Pi_t - \ln \Pi) + \phi_y (\ln Y_t - \ln Y_{t-1}) \right] + s_R \varepsilon_{R,t} \tag{A.62}$$

$$Q_t f_{cb,t} + Q_{B,t} \bar{b}_{cb} = re_t \tag{A.63}$$

$$f_{cb,t} = qe_t + qe_t^M \tag{A.64}$$

$$qe_t = (1 - \rho_{qe}) qe + \rho_{qe} qe_{t-1} + s_{qe} \varepsilon_{qe,t} \tag{A.65}$$

$$qe_t^M = (1 - \rho_{qe}) qe^M + \rho_{qe} qe_{t-1}^M + s_{qe} \varepsilon_{qe,t}^M \tag{A.66}$$

$$T_{cb,t} = R_t^F \Pi_t^{-1} Q_{t-1} f_{cb,t-1} + R_t^B \Pi_t^{-1} Q_{B,t-1} \bar{b}_{cb} - R_{t-1}^{re} \Pi_t^{-1} re_{t-1} \tag{A.67}$$

- Exogenous processes:

$$\ln A_t = \rho_A \ln A_{t-1} + s_A \varepsilon_{A,t} \tag{A.68}$$

$$\ln \theta_t = (1 - \rho_\theta) \ln \theta + \rho_\theta \ln \theta_{t-1} + s_\theta \varepsilon_{\theta,t} \tag{A.69}$$

- Aggregate conditions

$$1 = (1 - \phi_p) \left(\Pi_t^{\#} \right)^{1-\epsilon_p} + \phi_p \Pi_t^{\epsilon_p - 1} \tag{A.70}$$

$$w_t^{1-\epsilon_w} = (1 - \phi_w) \left(w_t^{\#} \right)^{1-\epsilon_w} + \phi_w \Pi_t^{\epsilon_w - 1} w_{t-1}^{1-\epsilon_w} \tag{A.71}$$

$$v_t^p Y_t = Y_{w,t} \tag{A.72}$$

$$v_t^p = (1 - \phi_p) \left(\Pi_t^{\#} \right)^{-\epsilon_p} + \phi_p \Pi_t^{\epsilon_p} v_{t-1}^p \tag{A.73}$$

$$L_t = L_{d,t} v_t^w \tag{A.74}$$

$$v_t^w = (1 - \phi_w) \left(\frac{w_t^\#}{w_t} \right)^{-\epsilon_w} + \phi_w \left(\frac{w_t}{w_{t-1}} \right)^{\epsilon_w} \Pi_t^{\epsilon_w} v_{t-1}^w \tag{A.75}$$

$$f_{w,t} = f_t + f_{cb,t} \tag{A.76}$$

$$\bar{b}_G = b_t + \bar{b}_{cb} \tag{A.77}$$

$$Q_t f_t + Q_{B,t} b_t + re_t = d_t + n_t \tag{A.78}$$

$$n_t = \sigma \Pi_t^{-1} \left[\left(R_t^F - R_{t-1}^d \right) Q_{t-1} f_{t-1} + \left(R_t^B - R_{t-1}^d \right) Q_{B,t} b_t + \left(R_{t-1}^{re} - R_{t-1}^d \right) re_{t-1} + R_{t-1}^d n_{t-1} \right] + X \tag{A.79}$$

$$Y_t = C_t + I_t + G \tag{A.80}$$

Equations (A.33)-(A.80) constitute 48 equations and 48 variables: $\Big\{ \mu_t, C_t, \Lambda_{t-1,t}, L_t, w_t^H,$ $R_t^d, \Pi_t, w_t^\#, f_{1,t}, f_{2,t}, w_t, L_{d,t}, p_t^w, A_t, K_t, \lambda_{1,t}, \lambda_{2,t}, \lambda_{3,t}, p_t^k, Q_t, \widehat{I}_t, f_{w,t}, Y_{w,t}, \Pi_t^\#, x_{1,t}, x_{2,t}, Y_t, I_t,$ $\Omega_t, R_t^{re}, R_t^F, R_t^B, \lambda_t, \theta_t, \phi_t, T_t, T_{cb,t}, Q_{B,t}, f_{cb,t}, re_t, qe_t, qe_t^M, v_t^p, v_t^w, f_t, b_t, d_t, n_t \Big\}$. When solving the model without the cash-flow constraint, we set $\lambda_{3,t} = 0$ and drop (A.46).