Quantitative Easing and Direct Lending in Response to the COVID-19 Crisis

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When the COVID-19 crisis hit the economy in 2020, the Federal Reserve responded with numerous programs designed to prevent a collapse in bank credit and firms' available funds. I develop a dynamic general equilibrium model to study how these programs work and to evaluate their effectiveness. In the model, quantitative easing works through three channels: the expansion of bank reserves lowers a liquidity premium, the purchase of assets lowers a volatility risk premium, and the economic stimulus lowers a credit risk premium. Since bank reserves are currently larger than in the past, the liquidity premium channel is weaker, and quantitative easing is less effective. Direct lending to firms at a market rate is also less effective. Direct lending to firms at a subsidized rate can be more stimulative than quantitative easing, provided that it lowers firms' marginal borrowing rate and user cost of capital.

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1 Introduction

The COVID-19 crisis cut off businesses' cash flow and available funds, threatening the survival of many firms. The Federal Reserve responded with numerous programs designed to prevent a collapse in bank credit and firms' available funds. I develop a dynamic general equilibrium model to study how these programs work and to evaluate their effectiveness.

The paper shows that quantitative easing is much less effective now than it was in 2008, when it was first introduced. The reason has to do with the level of bank reserves. Quantitative easing refers to the Federal Reserve's large-scale purchases of Treasury bonds and other securities, financed by an increase in bank reserves. It works by decreasing the market availability of Treasury bonds and by expanding bank reserves. Quantitatively, the most important channel through which it works is by expanding bank reserves and lowering the associated liquidity premium, which, in turn, decreases the loan-deposit spread and stimulates bank lending, investment, and output. The strength of this channel depends on the level of bank reserves. In 2008, the level of bank reserves was relatively low, so an increase in bank reserves had a large effect on the liquidity premium. Currently, the level of bank reserves is higher, so an increase in bank reserves has a smaller effect. I find that Treasury bond purchases worth 4 percent of GDP would currently raise real GDP by 0.55 percent only, while they would have raised real GDP by 1.95 percent in 2008.

One program that could be more stimulative than quantitative easing is direct lending to firms at a subsidized rate. Subsidized direct lending works through an additional channel. By directly lowering the marginal borrowing rate faced by firms and their user cost of capital, it further stimulates investment and output. This channel is as strong now as it was in 2008. Subsidized lending, then, can be more stimulative than quantitative easing, to the extent that it manages to lower firms' marginal borrowing rate and user cost of capital. I find that if subsidized lending managed to lower firms' marginal borrowing rate by 1 percentage point, it would currently raise output by 0.95 percent, 0.4 percentage points more than quantitative easing.

The model features households, banks, firms, a government, and the central bank. Financial frictions create a spread between the rate that banks charge firms for loans and the

rate that banks offer households for deposits. The loan-deposit spread is the sum of three premiums: a liquidity premium, a volatility risk premium, and a credit risk premium. The liquidity premium increases with the ratio of bank deposits to bank reserves. The volatility risk premium increases with the ratio of banks' volatile assets to bank equity. The credit risk premium decreases with aggregate output.

Federal Reserve programs work by reducing all three of these premiums: the expansion of bank reserves lowers the liquidity premium; bond purchases and direct lending lower the volatility risk premium (this channel is akin to the portfolio balance channel); and the economic stimulus lowers the credit risk premium. As the premiums decrease, the spread between firms' borrowing rate and households' deposit rate decreases, stimulating bank lending and investment. In addition, if direct loans to firms are extended at a subsidized rate, they directly lower firms' borrowing rate and user cost of capital, further stimulating bank lending and investment.

This paper contributes to the literature that studies the macroeconomic effects of quantitative easing using DSGE models with financial frictions and segmented asset markets, such as Gertler and Karadi (2011, 2013), Chen, Cúrdia, and Ferrero (2012), Carlstrom, Fuerst, and Paustian (2017), and Sims and Wu (2020a, 2020b). In particular, my paper complements the work of Sims and Wu (2020b) along various dimensions. They point out that, during the Great Recession, the amount of loans extended by financial intermediaries to firms was constrained by financial constraints faced by the financial intermediaries. In such a situation, both the central bank's purchases of Treasury bonds and direct lending to firms manage to stimulate the economy, as both programs can relax these constraints. In contrast, during the COVID-19 crisis, the amount of loans extended by financial intermediaries to firms was limited by financial constraints faced by the firms. In such a situation, the central bank's purchases of Treasury bonds are ineffective, while direct lending to firms can relax these firm-level constraints and stimulate the economy. The channels through which Federal Reserve programs work are different in my model, so I reach different conclusions. I find that all programs are less effective now than at the time of the Great Recession, because bank reserves are already large and the liquidity premium channel is weak. However, subsidized direct lending can be more stimulative than other programs to the extent that it manages

to lower firms' marginal borrowing rate and user cost of capital.

More generally, this paper contributes to the literature that, using various methodologies, estimates the effects of quantitative easing. Some papers use a Bayesian VAR methodology to estimate the effect on real GDP. For instance, Weale and Wieladek (2016) find that central bank purchases of government bonds worth 1 percent of GDP raise real GDP by about 0.62 percent, while Baumeister and Benati (2013) find that the first round of quantitative easing raised real GDP by about 3.5 percent in the first quarter of 2019. Other papers, such as Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), D'Amico et al. (2012), D'Amico and King (2012), Hamilton and Wu (2012), and Neely (2015), focus on the effects on interest rates. Krishnamurthy and Vissing-Jorgensen (2011), in particular, study separately several channels through which quantitative easing affects interest rates, including some related to the ones I model in this paper: a liquidity channel, a duration risk channel, and a default risk channel. While all of these papers estimate the effects of past rounds of quantitative easing, my paper focuses on why the effects of quantitative easing and other Federal Reserve programs are weaker now than they were at the time of the Great Recession.

In the rest of the paper, Section 2 describes the model; Section 3 details the calibration; Section 4 contains the results on the effectiveness of various Federal Reserve programs now and in 2008; and Section 5 concludes.

2   Model

In the model, there are households, banks, firms, the central bank, and the government. Households supply labor to firms and hold deposits at banks. Banks hold reserves at the central bank, invest in short-term and long-term government debt, and lend to firms. Firms invest and produce. The government uses lump-sum transfers to the households to balance its intertemporal budget constraint.

Three financial frictions discourage lending and investment. Banks face a liquidity friction that decreases with their reserves at the central bank relative to their deposits. Banks also face a volatility risk friction that decreases with their equity relative to their holdings of

volatile assets. Firms face a credit risk friction that decreases with aggregate output. These three frictions generate, respectively, a liquidity premium, a volatility risk premium, and a credit risk premium, which, in turn, create a spread between the firms' borrowing rate and the households' deposit rate, and discourage lending and investment.

2.1 Households

Households consume c_t^H, supply labor, n_t, and receive wages, $w_t n_t$. They deposit D_{t+1}^H at banks, receive gross-of-interest deposit repayments from banks, $(1 + r_t^D)D_t^H$, and lump-sum transfers from the government, T_t. The households' budget constraint is:

$$c_t^H + D_{t+1}^H = w_t n_t + (1 + r_t^D)D_t^H + T_t. \tag{1}$$

The households' optimization problem is:

$$\max_{\{c_t^H, n_t, D_{t+1}^H\}_{t=0}^\infty} E_0 \sum_{t=0}^\infty (\beta^H)^t [u(c_t^H) - v(n_t)] \tag{2}$$

$$\text{subject to (1),}$$

where $\beta^H \in (0,1)$ is the households' discount factor, $u(c)$ is such that $u'(c) \equiv c^{-\gamma}$, $\gamma > 0$ is the relative risk aversion, $v(n) \equiv \Phi n^{1+1/\varphi}$, $\Phi > 0$, $\varphi > 0$ is the Frisch elasticity of labor supply, and E_0 is the expectation operator.

The first-order conditions are:

$$\frac{v'(n_t)}{u'(c_t^H)} = w_t$$

$$1 = E_t \left\{ \frac{\beta^H u'(c_{t+1}^H)}{u'(c_t^H)} \left(1 + r_{t+1}^D\right) \right\}.$$

2.2 Banks

Banks receive household deposits, D_{t+1}, hold reserves at the central bank, R_{t+1}, purchase short-term Treasury bills, M_{t+1}, and long-term Treasury bonds, N_{t+1}, and extend loans to firms, L_{t+1}. Treasury bonds are modeled as perpetuities with decaying coupon payments, as

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in Sims and Wu (2020b). Let $\kappa \in [0, 1]$ denote the decay parameter for coupon payments—for instance, $\kappa = 0$ for one-period bonds, $\kappa = 1$ for consols that promise a unitary coupon forever. Equivalently, one can think of a bond as a promise to repay next period a unitary coupon plus a fraction κ of a new bond. Let q_t be the price of a bond.

Banks face two financial frictions. The first captures how assets differ in terms of liquidity. Deposits are on-demand assets. To manage any larger-than-expected demand by households to withdraw their deposits, banks need to maintain reserves at the central bank. I model the banks' need for reserves using a penalty function that increases with the ratio of deposits to reserves:

$$g_{t+1} = A_g \left(\frac{D_{t+1}}{R_{t+1}} \frac{R}{D} \right)^2, \tag{3}$$

where D and R are steady-state values, and $A_g > 0$. The penalty encourages banks to hold a fraction of household deposits in the form of reserves at the central bank, and creates a liquidity premium that drives down the return of liquid assets, such as deposits and reserves, relative to illiquid ones, such as Treasuries and bank loans.

The second financial friction captures how assets differ in terms of volatility risk. The price of long-term Treasury bonds can change because of changes in the duration risk, while the price of bank loans can change because of changes in the duration risk or in the credit risk. To protect against any larger-than-expected drop in asset values, banks need to maintain a capital cushion. Let volatile assets be the sum of long-term Treasury and bank loans,

$$Z_{t+1} \equiv L_{t+1} + q_t N_{t+1}, \tag{4}$$

and let bank equity be the difference between bank assets and liabilities,

$$S_{t+1} \equiv R_{t+1} + M_{t+1} + q_t N_{t+1} + L_{t+1} - D_{t+1}. \tag{5}$$

I model the banks' need for equity using a penalty function that increases with the ratio of

volatile assets to bank equity:

$$h_{t+1} = A_h \left(\frac{Z_{t+1}}{S_{t+1}} \frac{S}{Z} \right)^2, \tag{6}$$

where Z and S are steady-state values, and $A_h > 0$. The penalty encourages banks to hold an amount of equity equal to a fraction of their volatile assets, and creates a volatility risk premium that drives up the return of volatile assets, such as long-term Treasury bonds and bank loans, relative to risk-free ones, such as deposits, reserves, and Treasury bills.

Banks make their portfolio choices taking into account how the penalties, g_{t+1} and h_{t+1}, depend on their portfolio choices. Then, the equilibrium values of the penalties, denoted by $\overline{g_{t+1}}$ and $\overline{h_{t+1}}$, are rebated in a lump-sum way to the banks, so banks take these two equilibrium values as given while choosing their portfolio.

The bank's constraint is:

$$c_t^B + R_{t+1} + M_{t+1} + q_t N_{t+1} + L_{t+1} - D_{t+1} + g_t - \overline{g_t} + h_t - \overline{h_t} =$$
$$(1 + r_t^R)R_t + (1 + r_t^M)M_t + (1 + \kappa q_t)N_t + (1 + r_t^L)L_t - (1 + r_t^D)D_t. \tag{7}$$

On the left-hand side, the first term represents consumption expenditures. The next four terms represent the bank purchases of assets (reserves, Treasury bills, Treasury bonds and loans). The sixth term is the funds received from depositors. The final four terms are the penalties associated with the frictions minus their equilibrium values. On the right-hand side, the first four terms are the gross-of-interest payoffs from the bank asset investment in the previous period, net of the gross-of-interest payoff paid to depositors.

The optimization problem solved by the owner of a bank is:

$$\max_{\left\{ c_t^B, D_{t+1}, R_{t+1}, M_{t+1}, N_{t+1}, L_{t+1}, g_{t+1}, h_{t+1} \right\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} (\beta^B)^t u(c_t^B) \tag{8}$$

subject to (3), (6), and (7),

where $\beta^B \in (0,1)$ is the banks' discount factor, and $u(c^B)$ is the same function as the one for households.

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The first-order conditions are:

$$1 = E_t \left\{ \frac{\beta^B u'(c_{t+1}^B)}{u'(c_t^B)} \left(1 + r_{t+1}^M + 2h_{t+1}/S_{t+1}\right) \right\} \tag{9}$$

$$1 = E_t \left\{ \frac{\beta^B u'(c_{t+1}^B)}{u'(c_t^B)} \left(1 + r_{t+1}^N + 2h_{t+1}/S_{t+1} - 2h_{t+1}/Z_{t+1}\right) \right\} \tag{10}$$

$$1 = E_t \left\{ \frac{\beta^B u'(c_{t+1}^B)}{u'(c_t^B)} \left(1 + r_{t+1}^L + 2h_{t+1}/S_{t+1} - 2h_{t+1}/Z_{t+1}\right) \right\} \tag{11}$$

$$1 = E_t \left\{ \frac{\beta^B u'(c_{t+1}^B)}{u'(c_t^B)} \left(1 + r_{t+1}^R + 2h_{t+1}/S_{t+1} + 2g_{t+1}/R_{t+1}\right) \right\} \tag{12}$$

$$1 = E_t \left\{ \frac{\beta^B u'(c_{t+1}^B)}{u'(c_t^B)} \left(1 + r_{t+1}^D + 2h_{t+1}/S_{t+1} + 2g_{t+1}/D_{t+1}\right) \right\}, \tag{13}$$

where

$$1 + r_{t+1}^N \equiv \frac{1 + \kappa q_{t+1}}{q_t} \tag{14}$$

is the stochastic gross rate of return on Treasury bonds. From the first-order conditions, one can derive the following equilibrium expressions for the spreads:

$$r_{t+1}^L - r_{t+1}^M = 2h_{t+1}/Z_{t+1} = 2A_h \frac{Z_{t+1}}{S_{t+1}^2} \frac{S^2}{Z^2} \tag{15}$$

$$r_{t+1}^M - r_{t+1}^D = 2g_{t+1}/D_{t+1} = 2A_g \frac{D_{t+1}}{R_{t+1}^2} \frac{R^2}{D^2}. \tag{16}$$

The first equation shows that, as volatile assets increase or bank equity decreases, the rate of return on bank loans increases relative to the Treasury bills rate. The second equation shows that, as deposits increase or reserves decrease, the deposit rate decreases relative to the Treasury bills rate.

2.3 Firms

Firms begin period t with capital, k_t, and loans, L_t^F. Each firm hires labor, l_t, at the wage rate, w_t. It produces and sells output:

$$y_t \equiv \theta_t A f(k_t, l_t), \tag{17}$$

where $A > 0$, θ is a productivity shock, $f(k, l) \equiv k^\alpha l^{1-\alpha}$, and $\alpha \in (0, 1)$.

The firm invests x_t, so capital evolves according to:

$$k_{t+1} = (1 - \delta)k_t + x_t - \frac{\psi}{2}\left(\frac{k_{t+1} - k_t}{k}\right)^2 k, \tag{18}$$

where $\delta \in (0, 1)$ is the economic depreciation rate, the last term is an investment adjustment cost, with $\psi > 0$, and $k > 0$ is the steady-state level of capital.

Firms face a financial friction that captures how the cost of their external funds increases with their credit risk. I assume that the interest rate paid by a firm on bank loans, $\tilde{r}^L_{t+1}$, is higher than the interest rate received by banks on the same loans, r^L_{t+1}. The wedge between the two rates, z_{t+1}, is a decreasing function of aggregate output:

$$\tilde{r}^L_{t+1} - r^L_{t+1} \equiv z_{t+1} = A_z - \eta \log(y_t/y), \tag{19}$$

where $A_z > 0$ and $\eta > 0$ are positive constants, and $y > 0$ indicates the steady-state level of aggregate output. This wedge creates a credit risk premium that drives up the firm's cost of external funds and user cost of capital relative to the return of assets with no credit risk. The equilibrium value of the difference between the return paid by firms and the return received by banks is equal to $z_{t+1}\overline{L^F_{t+1}}$, where $\overline{L^F_{t+1}}$ denotes the equilibrium value of loans. The equilibrium value of the difference is rebated in a lump-sum way to the firms, so firms take it as given while choosing their loans.

The firm's budget constraint is:

$$c^F_t + (1 + \tilde{r}^L_t)L^F_t - z_t\overline{L^F_t} = y_t - w_t l_t - x_t + L^F_{t+1}. \tag{20}$$

The left-hand side lists the firm's consumption expenditure, the gross-of-interest loans repaid to banks, and the lump-sum rebate. The right-hand side lists the firm's revenue, net of wages and investment expenditures, and the new funds borrowed from banks.

It is helpful to define the firm's total available funds, Q_t, which include all funds available

to finance consumption and investment:

$$Q_t \equiv y_t - w_t l_t + L_{t+1}^F - (1 + \tilde{r}_t^L)L_t^F + z_t \overline{L_t^F} = c_t^F + x_t. \tag{21}$$

I will show the effect of various programs on this variable, since one of the primary objectives of the Federal Reserve's programs in 2020 was to prevent a collapse in business funds.

The optimization problem solved by the owner of a firm is:

$$\max_{\left\{c_t^F, L_{t+1}^F, y_t, l_t, x_t, k_{t+1}\right\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} (\beta^F)^t u(c_t^F) \tag{22}$$

$$\text{subject to (17), (18), and (20),}$$

where $\beta^F \in (0, 1)$ is the firms' discount factor, and $u(c)$ is the same function as the one for households and banks.

The first-order conditions are:

$$\theta_t A f_l(k_t, l_t) = w_t$$

$$1 + \psi \frac{k_{t+1} - k_t}{k} = E_t \left\{ \frac{\beta^F u'(c_{t+1}^F)}{u'(c_t^F)} \left[1 - \delta + \psi \frac{k_{t+2} - k_{t+1}}{k} + \theta_{t+1} A f_k(k_{t+1}, l_{t+1}) \right] \right\}$$

$$1 = E_t \left\{ \frac{\beta^F u'(c_{t+1}^F)}{u'(c_t^F)} (1 + \tilde{r}_{t+1}^L) \right\}.$$

2.4 Central bank

The central bank accepts bank reserves and purchases Treasury bills and bonds:

$$R_{t+1} = \tilde{M}_{t+1} + q_t \tilde{N}_{t+1}. \tag{23}$$

The central bank returns to the government its seigniorage, S_t, composed of the difference between the returns of its assets and liabilities:

$$S_t = (1 + r_t^M)\tilde{M}_t + (1 + \kappa q_t)\tilde{N}_t - (1 + r_t^R)R_t. \tag{24}$$

2.5 Government

The government sells and redeems Treasury bills and bonds, spends a constant $G > 0$, receives seigniorage from the central bank, S_t, and distributes lump-sum transfers to households, T_t:

$$\hat{M}_{t+1} + q_t \hat{N}_{t+1} = (1 + r_t^M)\hat{M}_t + (1 + \kappa q_t)\hat{N}_t + G - S_t + T_t. \tag{25}$$

I assume that the lump-sum transfers to households respond to changes in government debt enough to insure that government debt is stationary and an equilibrium exists:

$$T_t = A_T - \tau\, r^M (\hat{M}_{t+1} + q_t \hat{N}_{t+1}), \tag{26}$$

where A_T is a constant, r^M is the steady-state Treasury bill rate, and $\tau > 0$.

2.6 Equilibrium conditions

The equilibrium condition for the goods market equates the demand for private consumption, government consumption, and investment to production:

$$c_t^H + c_t^B + c_t^F + G + x_t = y_t. \tag{27}$$

The remaining equilibrium conditions equate demand and supply in the markets for labor, deposits, Treasury bills, Treasury bonds, and loans:

$$l_t = n_t \tag{28}$$

$$D_{t+1} = D_{t+1}^H \tag{29}$$

$$M_{t+1} + \tilde{M}_{t+1} = \hat{M}_{t+1} \tag{30}$$

$$N_{t+1} + \tilde{N}_{t+1} = \hat{N}_{t+1} \tag{31}$$

$$L_{t+1}^F = L_{t+1}. \tag{32}$$

One variable that plays a crucial role is the loan-deposit spread, the spread between the

rate paid by firms, $\tilde{r}^L_{t+1}$, and the rate received by depositors, r^D_{t+1}. A large spread discourages bank lending and investment. Using equations (15), (16), and (19), one can decompose the spread into the sum of three premiums:

$$
\begin{aligned}
\tilde{r}^L_{t+1} - r^D_{t+1} &= (\tilde{r}^L_{t+1} - r^L_{t+1}) + (r^L_{t+1} - r^M_{t+1}) + (r^M_{t+1} - r^D_{t+1}) \\
&= [A_z - \eta \log(y_t/y)] + 2A_h \frac{Z_{t+1}}{S^2_{t+1}} \frac{S^2}{Z^2} + 2A_g \frac{D_{t+1}}{R^2_{t+1}} \frac{R^2}{D^2}.
\end{aligned}
\tag{33}
$$

The term in square brackets on the right-hand side is the credit risk premium, which decreases with aggregate output. The next term is the volatility risk premium, which increases with volatile assets (long-term Treasury bonds and loans) and decreases with bank equity. The final term is the liquidity premium, which increases with bank deposits and decreases with reserves. By changing the supply of assets with different liquidity and risk characteristics, Federal Reserve programs can reduce these premiums and expand businesses' available funds.

3   Calibration

This paper compares the effects of Federal Reserve programs in 2008, when quantitative easing was first introduced, and 2020, at the time of the COVID-19 crisis. For this comparison, I change a few parameters to target the values of banks' assets and liabilities in 2008 and 2020. Next, I describe the parameter setting for the 2020 case. After that, I indicate the parameters that I change for the 2008 case. The parameter values for the two cases are listed in Table 1.

The length of one period is equal to one quarter. Some parameters are set equal to standard values in the literature: the exponent of the production function is $\alpha = 0.35$; the capital depreciation rate is $\delta = 0.025$; and the relative risk aversion is $\gamma = 2$. The value of the investment adjustment cost parameter, $\psi = 1$, is also within the range of standard values. The Frisch elasticity of labor supply, $\varphi = 0.5$, is close to common econometric estimates. The scale parameters A and Φ are set so that $y = 1$ and $n = 1/3$, respectively.

The preference discount factors (β^H, β^B, and β^F) and the friction parameters (A_g and A_h) are set to target steady-state values of interest rates and values of banks' assets and

liabilities before the COVID-19 crisis. The steady-state values of interest rates are set to match the corresponding average interest rates in the period 2005-2019. Specifically, the quarterly interest rates of deposits, Treasury bills and Treasury bonds are set to $r^D = 0.0005$, $r^M = 0.0033$, $r^N = 0.0075$ to match the average savings rate (RateWatch/Haver Analytics), 3-month Treasury bill rate, and 10-year Treasury note rate. The values of banks' assets and liabilities (relative to y) are set to match the corresponding values for all commercial banks in 2019:Q4 (relative to quarterly GDP). Specifically, bank reserves, $R = 0.32$, match the cash assets of all commercial banks; banks' holdings of government debt, $M + qN = 0.55$, match holdings of Treasury and agency securities; bank loans, $L = 1.99$, match bank credit net of Treasury and agency securities; and deposits, $D = 2.42$, match the deposits of all commercial banks (Federal Reserve statistical release, Table H.8, Haver Analytics). These values for interest rates and banks' assets and liabilities, together with the agents' first-order conditions and the friction definitions (3) and (6), pin down the preference discount factors (β^H, β^B, and β^F) and the friction parameters (A_g and A_h).

Combining the banks' first-order conditions and equation (19), one can derive that, in the steady state, the spread between the firms' borrowing rate and the Treasury bond rate is equal to the credit risk wedge: $\tilde{r}^L - r^N = z$. Then, I set the steady-state credit risk wedge, $z = 0.0041$, to match the average quarterly spread between the 10-year investment-grade bond yield (High Quality Market Corporate Bond Spot Yield, U.S. Treasury/Haver Analytics) and the 10-year Treasury yield (Treasury Note Yield at Constant Maturity, US Treasury/Haver Analytics) in the period 2005-2019. The semi-elasticity of the credit risk wedge with respect to output, $\eta = 0.25$, is set to replicate the increase in the quarterly spread (1 percentage point) relative to the drop in GDP (4 percent) during the Great Recession.

The decay parameter for the Treasury bond coupon payments is set equal to $\kappa = 1 - 1/40$, so the Treasury bond duration is 10 years. The duration of a Treasury bill is one quarter. I assume that 50 percent of the value of government debt is made up of Treasury bills and the remaining 50 percent is made up of Treasury bonds, so the average duration of government debt in the model, 5.125 years, matches, approximately, the weighted average maturity in the data (US Treasury Office of Debt Management). I also assume that, in the model, both the central bank and the banks hold 50 percent of their government debt holdings in Treasury

bills, and the remaining 50 percent in Treasury bonds.

Government spending is set to $G = 0.15$, to match the fact that government spending is, approximately, equal to 14 percent of GDP. The constant A_T is set to balance the government's budget constraint. The fiscal rule policy coefficient is equal to $\tau = 1$, so the response of government transfers to government debt is small but sufficient to ensure the existence of an equilibrium.

The parameter values for the 2008 case are the same as for the 2020 case, except for the following. The values of banks' assets and liabilities are set to match the corresponding data in 2008:Q3, before the announcement of the first round of quantitative easing, rather than 2019:Q4. Specifically, bank reserves are set to $R = 0.09$; banks' holdings of government debt are set to $M + qN = 0.31$; bank loans are set to $L = 2.04$; and deposits are set to $D = 1.86$ (Federal Reserve statistical release, Table H.8, Haver Analytics). These different target values for banks' assets and liabilities imply different values for the following parameters: the utility function scale parameter, Φ; the banks' preferences discount factor, β^B; the friction parameters, A_g and A_h; and the government budget constraint constant, A_T.

4 Results

In this section, first, I will study the effect of quantitative easing, comparing the effect in 2008 with the effect in 2020. Then, I will study the effect of direct lending at market rates and subsidized rates.

4.1 Quantitative easing

In the model, quantitative easing refers to the purchase of Treasury bonds by the central bank from private banks, financed by an increase in bank reserves. The direct effect of quantitative easing is to change the portfolio of private banks, increasing bank reserves, R_{t+1}, and decreasing banks' holdings of Treasury bonds, $q_t N_{t+1}$ by the same amount.

Since bank reserves increase, while deposits remain constant, the liquidity premium (the last term in equation (33)) decreases. Also, since banks' holdings of Treasury bonds decrease, banks' volatile assets, Z_{t+1}, decrease, while bank equity, S_{t+1}, remains constant, so the

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volatility risk premium (the next-to-last term in equation (33)) decreases. Both effects lead to a decrease in the loan-deposit spread, the spread between the rate paid by firms, $\tilde{r}_{t+1}^L$, and the rate received by depositors, r_{t+1}^D. The decrease in the spread stimulates bank lending, investment, and output. In turn, the increase in output decreases the credit risk premium (the term in square brackets in equation (33)), which further decreases the loan-deposit spread, and amplifies the initial direct effect of quantitative easing.

The overall effect of quantitative easing can be seen in Figure 1. The figure shows the effect of central bank purchases of Treasury bonds worth 4 percent of annual GDP, similar to the size of the first round of quantitative easing announced in November 2008 (asset purchases of \$600 billion). The dashed and solid lines refer, respectively, to the 2008 and 2020 cases, as described in the calibration section.

Starting with the 2008 case, the figure shows the increase in bank reserves accompanied by the increase in government debt held by the central bank. As a result, government debt held by banks decreases. As explained earlier, both the liquidity premium and the volatility risk premium decrease. Notice that, with our calibration setting, the decrease in the liquidity premium is more than 10 times larger than the decrease in the volatility risk premium, so, quantitatively, the increase in bank reserves and the resulting decrease in the liquidity premium are the main drivers of the effects.

The decreases in the two premiums translate into a decrease in the loan-deposit spread, which stimulates bank lending, investment, and output. The output increase, in turn, lowers the credit risk premium and further decreases the loan-deposit spread, amplifying the initial direct effect of quantitative easing. Notice the increase in the firms' funds available for consumption and investment, which was a primary objective of the Federal Reserve's programs in 2020. Banks expand their demand for deposits, to fund the increase in bank loans.

Turning to the 2020 case, the effects of quantitative easing are, qualitatively, the same as in the 2008 case. Quantitatively, however, the percent increase in bank reserves is about 3 times smaller, and the decrease in the liquidity premium is similarly smaller. Since the changes in bank reserves and in the liquidity premium are the main drivers of the effects, the effects of quantitative easing in 2020 are about 3 times smaller than in 2008. In particular, the decrease in the credit risk premium is about 3 times smaller, so the amplification mechanism

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is similarly smaller. And the increase in bank lending, firms' available funds, investment, and output is similarly smaller.

The result that quantitative easing is much less effective in 2020 than in 2008 is similar to the one obtained by Sims and Wu (2020b), but the reasons behind the result are different. Their argument is that what constrains bank lending in 2020 is different from what constrained it in 2008. In 2008, bank lending was limited by financial constraints at the bank level, and quantitative easing was effective in relaxing these constraints. In 2020, bank lending is limited by financial constraints at the firm level: firms are not able to obtain bank loans because their cash flow has collapsed. In this situation, quantitative easing is ineffective because it can relax the financial constraints at the bank level, but not at the firm level. My argument is that the main driver of the effects of quantitative easing in 2008 was the increase in bank reserves and the decrease in the liquidity premium, while the decrease in the volatility risk premium played a much smaller role. Bank reserves are larger in 2020, so the direct effect of an increase in bank reserves on the liquidity premium is smaller, and the overall effect of quantitative easing is smaller.

The previous results about the effects of quantitative easing in 2008 and 2020 apply to other Federal Reserve programs as well. For example, notice that the volatility risk premium depends in the same way on banks' holdings of Treasury bonds and bank loans. This means that if the central bank purchases bank loans (or corporate bonds) from banks, financing the purchase with an increase in bank reserves, the effects on the economy are the same as those of quantitative easing.

Also, we have seen that, quantitatively, the main driver of the effects of quantitative easing is the decrease in the liquidity premium, while the decrease in the volatility risk premium plays a much smaller role. This means that the previous results apply not only to quantitative easing, but also to other Federal Reserve programs that involve an increase in bank reserves. For instance, if the central bank lends directly to banks, financing the loans with an increase in bank reserves, the direct effect consists of a decrease in the liquidity premium, without any direct effect on the volatility risk premium. Since the main driver of the effects of quantitative easing is the decrease in the liquidity premium, the overall effects of direct lending to banks are very similar to those of quantitative easing. Similarly, if the

central bank purchases a mix of Treasury bills and bonds, financing the purchase with an increase in bank reserves, the effect on the volatility risk premium is different from that of quantitative easing, but the overall effects on the economy are, quantitatively, very similar.

4.2 Direct lending to firms

The effects of direct lending to firms depend on whether loans are unsubsidized, that is, extended at the market rate, or subsidized, that is, extended at a subsidized rate. In turn, the effects of subsidized loans are larger if they manage to lower firms' marginal borrowing rate and user cost of capital. Similar conclusions apply to central bank purchases of corporate bonds directly from firms, depending on whether the central bank purchases the bonds at market prices or higher prices. Let's look at all these effects.

If the central bank lends directly to firms at market rate, financing the loans with an increase in bank reserves, the effects on the economy are the same as those of quantitative easing. This can be seen by comparing Figure 2, which shows the effects of unsubsidized direct loans to firms, with Figure 1, which shows the effects of quantitative easing. All of the subplots are the same, except for the ones that refer to loans and holdings of government debt. The reason the effects on the economy are the same is that Treasury bonds and bank loans enter in the same way in the banks' optimization problem, so banks are indifferent between holding Treasury bonds or bank loans. If the central bank lends directly to firms rather than purchasing Treasury bonds from banks, banks offset this policy change by extending fewer bank loans and holding more Treasury bonds in such a way that the sum of bank loans and direct loans extended by the central bank is constant.

Things are different if the central bank extends the loans at a subsidized rate. In this case, there are two additional effects. First, the loans provide a lump-sum subsidy to firms. Second, the loans can lower the marginal borrowing cost of firms and their user cost of capital. Let's look at these two effects.

The first additional effect of a subsidized loan is a lump-sum subsidy equal to the size of the loan times the difference between the market rate and the subsidized rate. Quantitatively, this effect is tiny, as shown in Figure 3. The figure plots the additional effect of a subsidized loan relative to an unsubsidized loan, assuming that the subsidized loan does not affect firms'

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marginal borrowing rate, that is, assuming that firms' marginal borrowing rate remains equal to the market rate. The size of the additional effect on firms' available funds, investment, and output is 2 orders of magnitude smaller than the size of unsubsidized loans.

The second additional effect of a subsidized loan is a decrease in the marginal borrowing cost of firms and their user cost of capital. The extent to which a subsidized loan manages to decrease firms' marginal borrowing rate likely depends on the difference between the market rate and the subsidized rate, and the amount of subsidized loans relative to total loans. Firms' marginal borrowing rate is likely to drop more if the difference between the market rate and the subsidized rate is larger, and/or if the size of the subsidized loan relative to total loans is larger. However, the simple introduction of a lending facility can lower firms' marginal borrowing rate by serving as a backstop even if the facility is not actually used, as shown by the easing of financial conditions that followed the announcement of the Federal Reserve's Corporate Credit Facilities in March 2020 (Boyarchenko, Kovner, and Shachar 2020). If firms' marginal borrowing rate drops, the effects on the economy are large. Figure 4 plots the additional effect of a 1 percentage point decrease in firms' marginal borrowing rate relative to the market rate. The effects on firms' available funds, investment, and output are large, more than two-thirds the size of the effects of quantitative easing in 2020. The size of the effects increases proportionally with the decrease in firms' marginal borrowing rate—for instance, the effect of a 2 percentage point decrease in firms' marginal borrowing rate is twice as large as the effect of a 1 percentage point decrease. The size of the effects is similar in 2020 and 2008.

The overall effect of a subsidized loan is the sum of the previous three effects: the effect of an unsubsidized loan, the effect of the lump-sum subsidy, and the effect of the drop in firms' marginal borrowing rate. The overall effect on the economy is large, larger than the effect of quantitative easing. Figure 5 shows the overall effect in the case where the loan manages to decrease firms' marginal borrowing rate by 1 percentage point. The overall effect on output is 70 percent larger than the effect of quantitative easing. Obviously, the overall effect would be even larger if firms' marginal borrowing rate dropped more—the case of a rate drop by x percentage points can be computed by multiplying the effects shown in Figure 4 by $x - 1$, and adding the result to the effects shown in Figure 5. Although the size of the effects of

subsidized lending on the economy decreases from the 2008 case to the 2020 case, it does not decrease as much as the size of the effects of quantitative easing. For instance, while the size of the effect of quantitative easing on output in 2020 is about 28 percent the size in 2008, the size of the effect of subsidized lending on output in 2020 is about 39 percent the size in 2008. The reason subsidized lending is relatively more effective than quantitative easing in 2020 is that the effect of the drop in firms' marginal borrowing rate is similar in 2008 and 2020.

5 Conclusion

In the model I have presented, Federal Reserve programs, including quantitative easing and direct lending to firms, work through three channels. By expanding bank reserves, these programs decrease the liquidity premium, the premium that assets earn above the return of on-demand deposits. By decreasing the supply of assets with volatile returns, such as Treasury bonds and loans demanded by firms, these programs decrease the volatility risk premium. By stimulating the economy, they decrease the credit risk premium. All these channels decrease the loan-deposit spread, and stimulate bank lending, firms' available funds, investment, and output. The model indicates that the liquidity premium channel is, quantitatively, the most important. Since bank reserves are larger now than in 2008, the liquidity premium channel is weaker, and Federal Reserve programs are less effective.

While unsubsidized direct lending to firms has, in the model, similar effects to quantitative easing, subsidized direct lending has two additional effects: the effect of a lump-sum subsidy to firms, which is tiny, and the effect of a decrease in firms' marginal borrowing rate, which can be large. The latter effect is similar in size in 2008 and 2020, so the overall effect of subsidized direct lending can be sizeable in 2020 as well. The model's implication is that, even in the current situation of ample bank reserves, subsidized direct lending can be quite stimulative, provided that it manages to decrease firms' marginal borrowing rate and user cost of capital.

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|	Description	2008 Case	2020 case	Targeted moments and notes
	length of one period	1 quarter	1 quarter	
A	scale of production function	0.9267	0.9267	$y = 1$
α	exponent of production function	0.35	0.35	
δ	capital depreciation rate	0.025	0.025	
ψ	investment adjustment cost	1	1	
γ	relative risk aversion	2	2	
φ	Frisch elasticity of labor supply	0.5	0.5	
Φ	labor disutility scale parameter	23.01	23.03	$n = 1/3$
β^H	households' pref. discount factor	0.9995	0.9995	r^D
β^B	banks' pref. discount factor	0.9809	0.9754	
β^F	firms' pref. discount factor	0.9885	0.9885	$\tilde{r}^L$
A_g	liquidity friction scale parameter	0.0026	0.0033	r^D, r^M, and D/R
A_h	risk friction scale parameter	0.0045	0.0046	r^M, r^N, and Z/S
A_z	steady-state credit risk wedge	0.0041	0.0041	
η	semielasticity of z to y	0.25	0.25	
κ	bond coupon decay parameter	0.975	0.975	10-year bond duration
qN/M	ratio of Treasury bonds to bills	1	1	5-year govt debt duration
G	government spending	0.15	0.15	
τ	response of govt transfers to debt	1	1	
A_T	steady-state govt transfers	-0.147	-0.147	balances govt budget
R	bank reserves	0.09	0.32	matches data
$M + qN$	bank holdings of govt debt	0.31	0.55	matches data
L	bank loans	2.04	1.99	matches data
D	bank deposits	1.87	2.42	matches data

Table 1: Parameters and steady-state values.
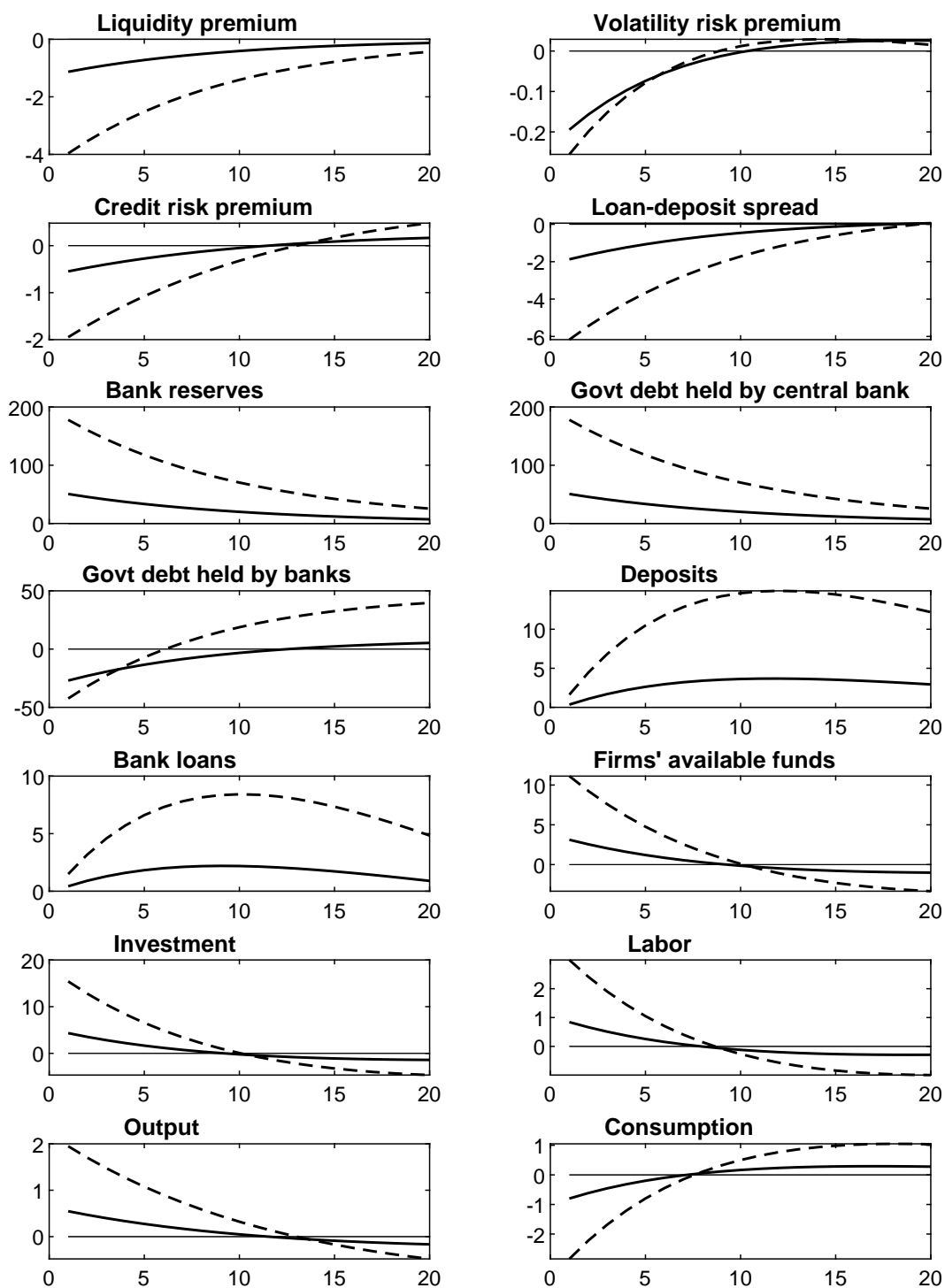
Figure 1: Effect of purchases of Treasury bonds worth 4 percent of annual GDP, with a 0.9 first-order autocorrelation. *Note: The dashed and solid lines refer to the 2008 economy and the 2020 economy, respectively. The first four subplots are expressed in annualized percentage rates; the other ones are expressed in percent.*
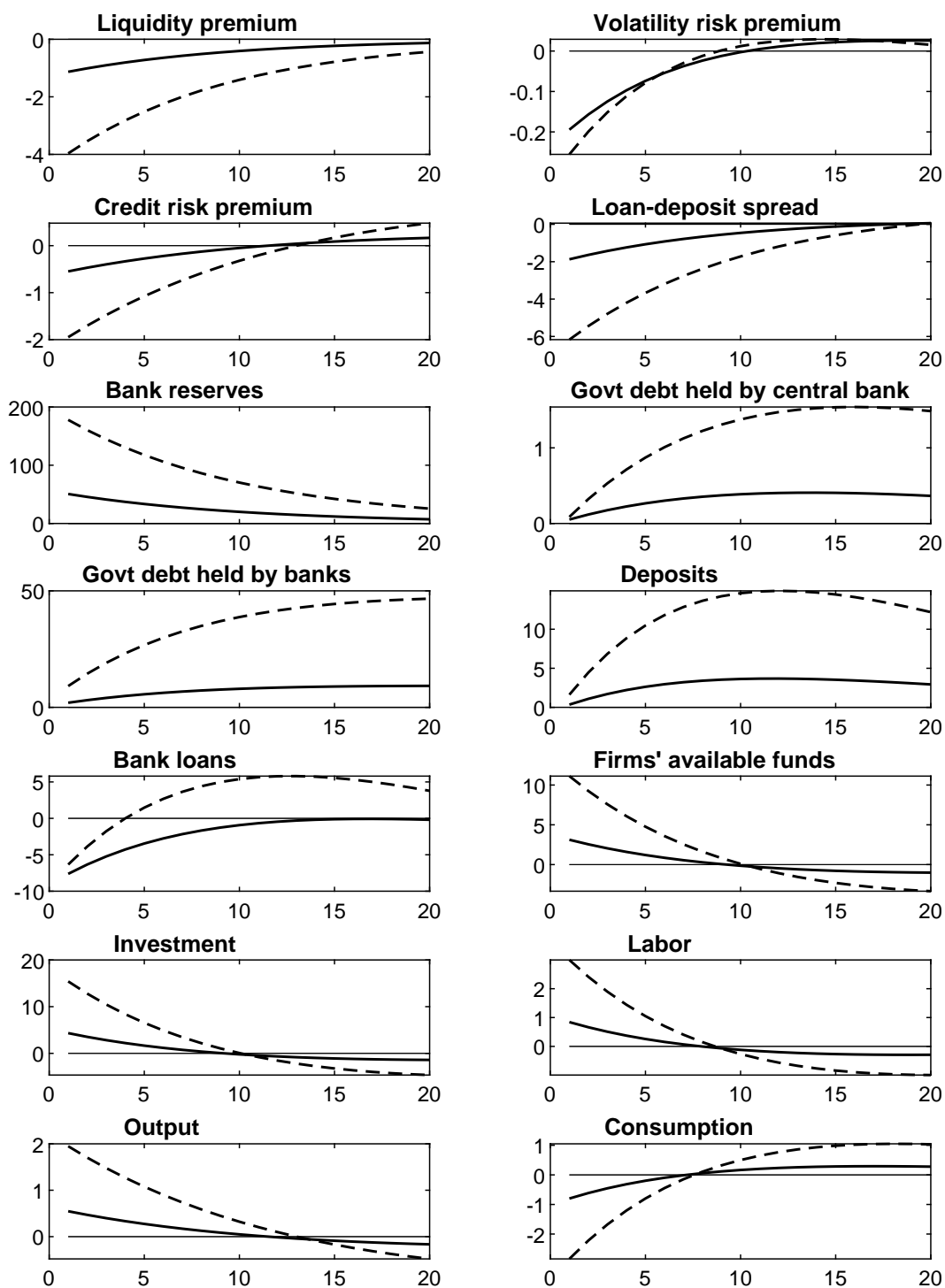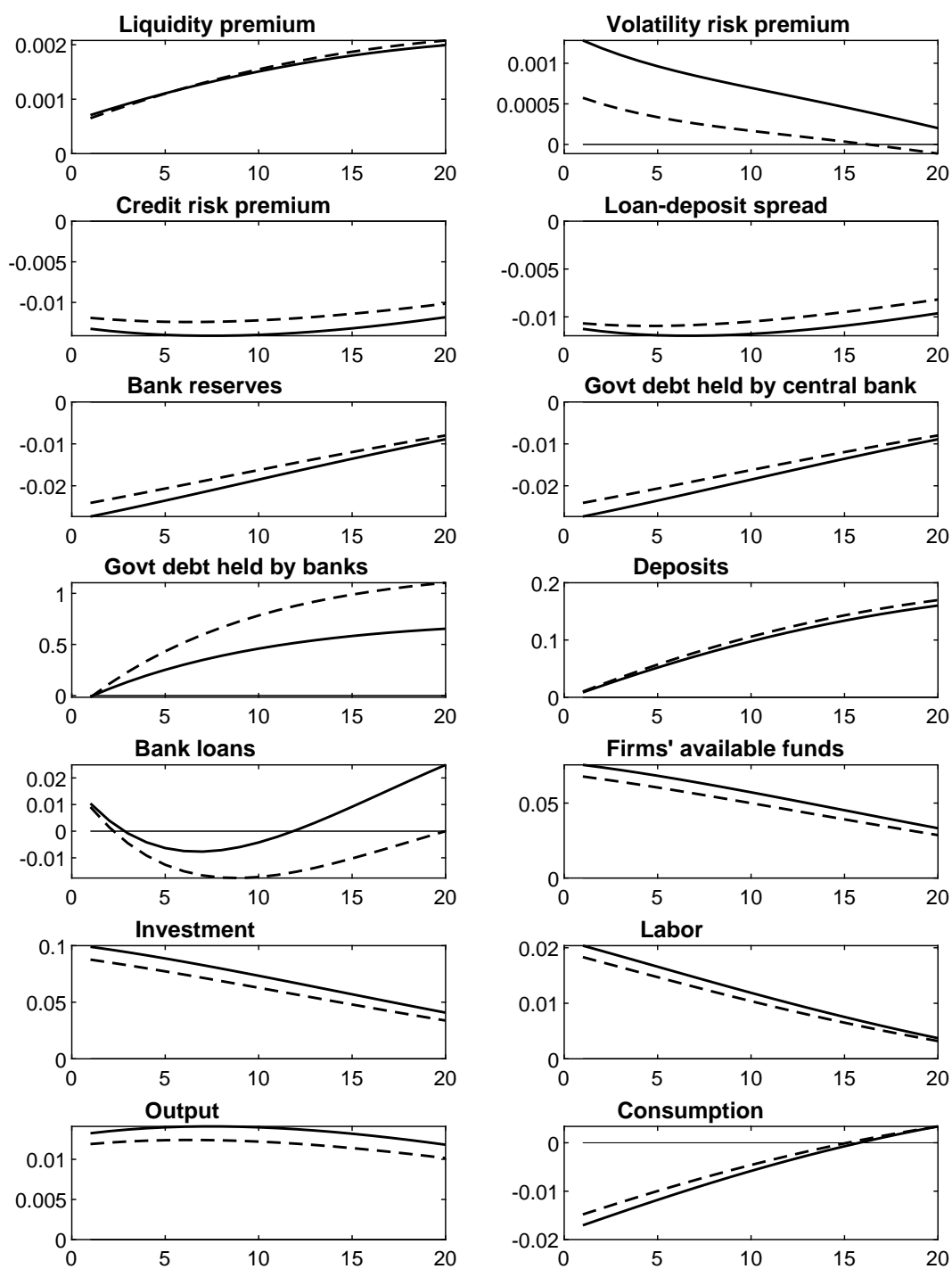
Figure 2: Effect of unsubsidized direct loans to firms. The loans are worth 4 percent of annual GDP, with a 0.9 first-order autocorrelation. *Note: The dashed and solid lines refer to the 2008 economy and the 2020 economy, respectively. The first four subplots are expressed in annualized percentage rates; the other ones are expressed in percent.*

Figure 3: Effect of lump-sum subsidy generated by subsidized direct loans to firms. The subsidized rate is 1 percentage point below the market rate, and the loans are worth 4 percent of GDP, with a 0.9 first-order autocorrelation. *Note: The dashed and solid lines refer to the 2008 economy and the 2020 economy, respectively. The first four subplots are expressed in annualized percentage rates; the other ones are expressed in percent.*
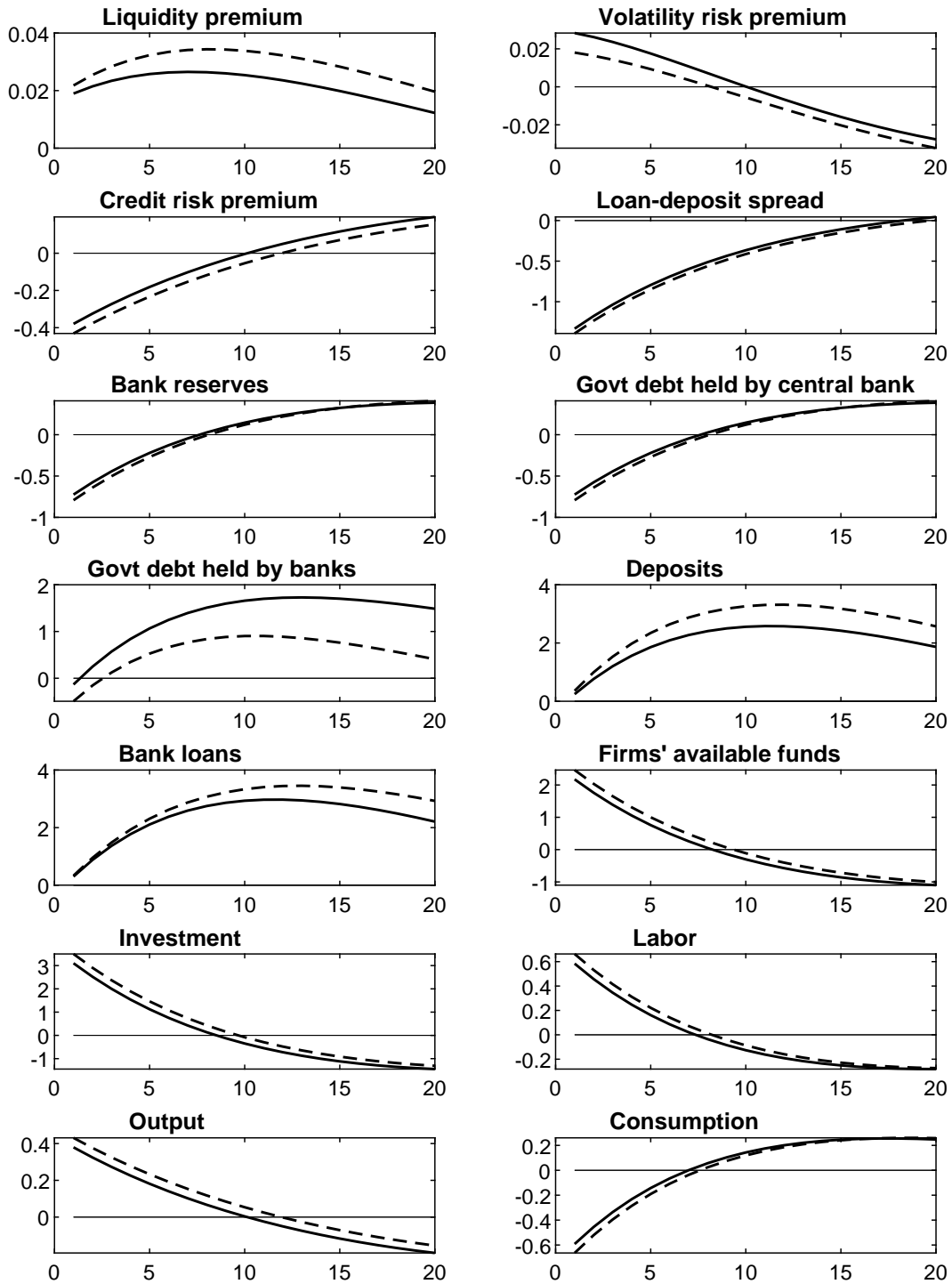
Figure 4: Effect of a decrease in firms' marginal borrowing rate. Firms' marginal borrowing rate drops 1 percentage point below the market rate. *Note: The dashed and solid lines refer to the 2008 economy and the 2020 economy, respectively. The first four subplots are expressed in annualized percentage rates; the other ones are expressed in percent.*
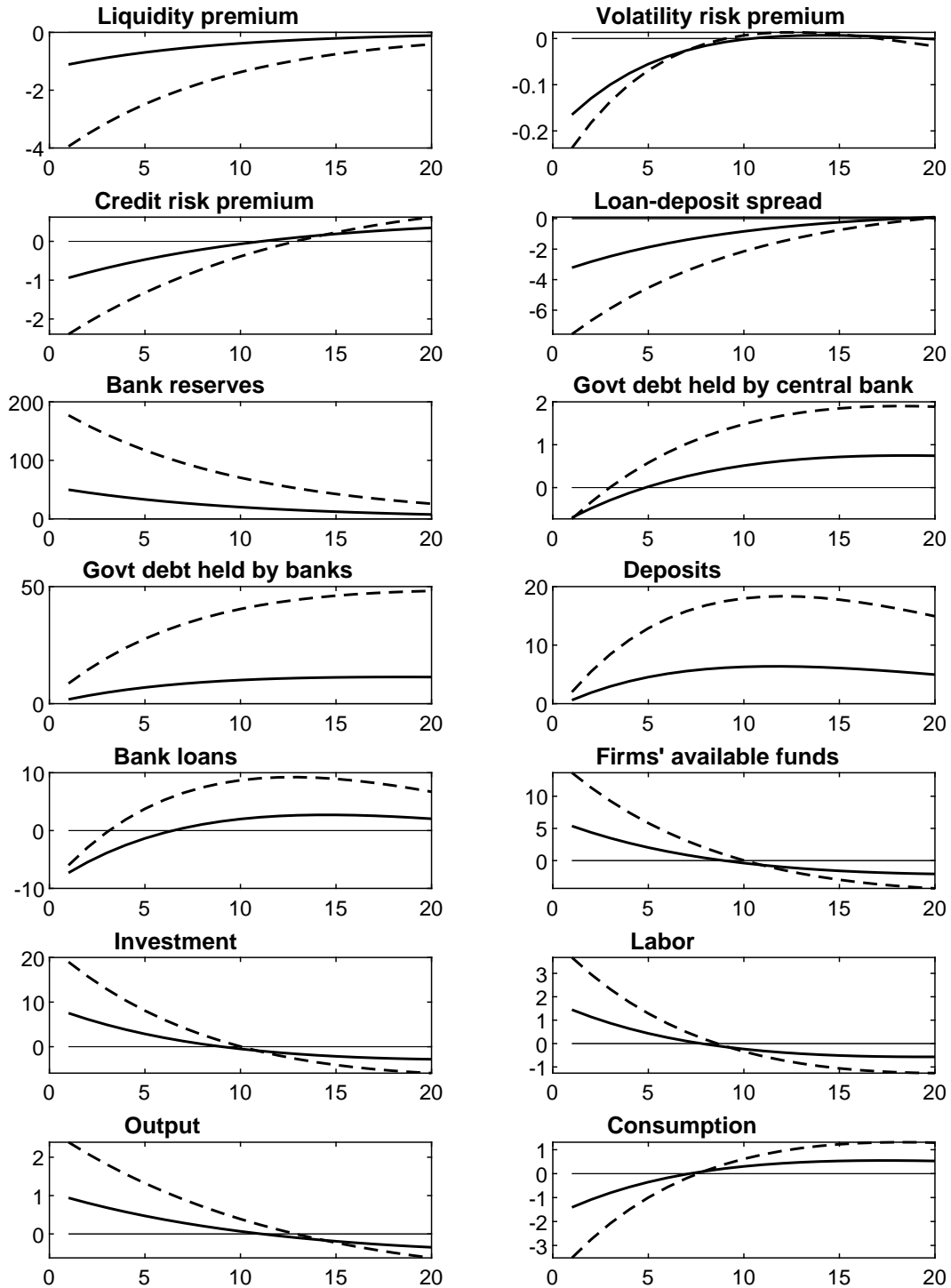
Figure 5: Effect of subsidized direct loans to firms. The subsidized rate is 1 percentage point below the market rate. Firms' marginal borrowing rate becomes equal to the subsidized rate. The loans are worth 4 percent of annual GDP, with a 0.9 first-order autocorrelation. *Note: The dashed and solid lines refer to the 2008 economy and the 2020 economy, respectively. The first four subplots are expressed in annualized percentage rates; the other ones are expressed in percent.*