Macroeconomic Dynamics (2024), **29**, e52, pp. 1–27
doi:10.1017/S1365100524000373

ARTICLE

Conventional vs. unconventional monetary policy under credit regulation

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Abstract

We provide empirical evidence that the impact of quantitative easing (QE) programs on investment is weaker for countries with high-credit market regulations. We then extend a simple DSGE model with segmented financial markets to include credit regulation and examine its impact on the transmission of conventional and unconventional monetary policies. In our model, the government requires banks to hold a fraction of their assets in government debt. We show that the presence of such regulation can invert monetary transmission under QE policy: An expansionary QE program raises term premiums on corporate bonds and causes a contraction instead of an expansion in the economy. Such a perversion is absent under conventional policy. Further, in contrast to Carlstrom et al. (2017), we show that a simple Taylor rule welfare dominates a term premium peg under financial shocks, while the peg does better in the case of non-financial shocks.

Keywords: Credit regulations; Segmented asset markets; Quantitative easing; Term premium targeting

JEL classifications: E22; E31; E43; E44; E52; E58

1. Introduction

This paper aims to examine the efficacy of quantitative easing programs vis-à-vis conventional monetary policy in the presence of credit market regulations. Post-2008, quantitative easing (QE)—the large-scale purchases of assets by central banks—has become an essential weapon in central banks' arsenal worldwide. Indeed, in the aftermath of the pandemic, many emerging markets emulated their developed peers with bond-buying programs to mitigate the fallout to the financial sector from the crisis. Much of the literature has found QE policies effective, particularly when the interest rate is constrained by the zero lower bound Bernanke (2020). However, the literature is silent on the effectiveness of these programs in the presence of credit market regulations.

These regulations are generally divided into a number of categories, including reserve requirements, capital requirements, and restrictions on the types of investments banks are permitted to make. In addition, it may include a variety of government policies that divert resources from the rest of the economy to the government. Literature classifies such policies as "financial repression" as in Reinhart and Sbrancia (2015). In this paper, we focus on a particular form of regulation imposed by the government, which requires banks to hold a certain fraction of their assets as government debt. Our objective is to illustrate the consequences of such distortions on the monetary transmission mechanism under QE and contrast it with conventional policy.

We begin by carrying out an empirical investigation on the impact of the bond-buying program on private investment. To this end, we consider a set of economies where central banks implemented quantitative easing during the COVID-19 pandemic. We demonstrate that while the impact of the bond-buying program is significant and positive in economies with low credit market regulations, its impact on economies with stringent credit market regulations is not significant.

Next, we develop a model to explain this muted response of private investment to quantitative easing in high-credit regulation economies. In our model, as in Carlstrom et al. (2017) and Sims and Wu (2021), asset markets are segmented in the sense that only financial intermediaries can purchase long-term debt issued by the government and the firms. Firms issue long-term debt to finance part of their investment expenditure. Households can access long-term debt only indirectly by depositing their funds with financial intermediaries. As in Sims and Wu (2021), a simple agency problem results in an endogenous leverage constraint that limits the financial intermediary's ability to arbitrage the yield gap between the short-term deposit rate and long-term lending rate, resulting in a time-varying term premium.

Following Chari et al. (2020) and Kriwolutzy et al. (2018), banks in our setup also face a "regulatory constraint" that requires them to hold a certain fraction of their assets as government debt. The motivation for our modeling strategy stems from the fact that there has been a surge in the domestic sovereign debt holding of banks in the aftermath of the 2007-2008 global financial crisis, the European debt crisis, and the COVID-19 pandemic in both advanced and emerging economies. Becker and Ivashina (2018), for instance, show that local banks largely absorbed sovereign debt in Europe during the sovereign debt crisis. They document that banks' share of government debt more than doubled in the Eurozone countries between 2007 and 2013. In the context of the United States, Mullin (2021) points out one of the unintended consequences that followed the 2014 implementation of the Liquidity Coverage Ratio, which required banks to hold certain levels of high-quality liquid assets was a dramatic increase in bank holdings of government debt obligations.[1]

In the case of emerging economies, the global financial stability report by the International Monetary Fund (IMF, 2022) documents that the holdings by banks of domestic sovereign debt have increased during the COVID-19 pandemic, on average accounting for about one-fifth of banking sector assets and 200% of their regulatory capital. Furthermore, using BankFocus data, Figure 1 shows that in terms of the maturity structure, the share of long-term debt has been steadily increasing in the banks' portfolio.[2] This feature motivates our choice of formulating the regulatory constraint in terms of long-term government debt.

Such credit regulation reduces the yield on long-term government bonds and offsets their term premiums. We study the impact on conventional and unconventional (QE) monetary policies in the milieu. Our model's conventional monetary policy involves the central bank setting short-term interest rates according to the Taylor rule. Unconventional or QE policy, on the other hand, involves the central bank buying or selling long-term government bonds.

We begin by comparing exogenous shocks to unconventional and conventional policies. Consider, first, the case of an expansionary QE shock, which involves increasing government bond-buying by the central bank. We show that credit regulation can completely invert the monetary transmission mechanism: the expansion in the central bank's balance sheet can raise the term premiums on private bonds and cause a contraction instead of an economic expansion. The intuition is best understood by noting that such a program has opposing effects on the leverage and the regulatory constraints.

While the bank's increased holding of reserves eases the agency problem and relaxes the leverage constraint, its reduced holdings of government bonds tightens the regulatory constraint. Effectively, the binding regulatory constraint implies limited substitutability between government and private bonds. Banks are forced to keep loans to the private sector and the government in

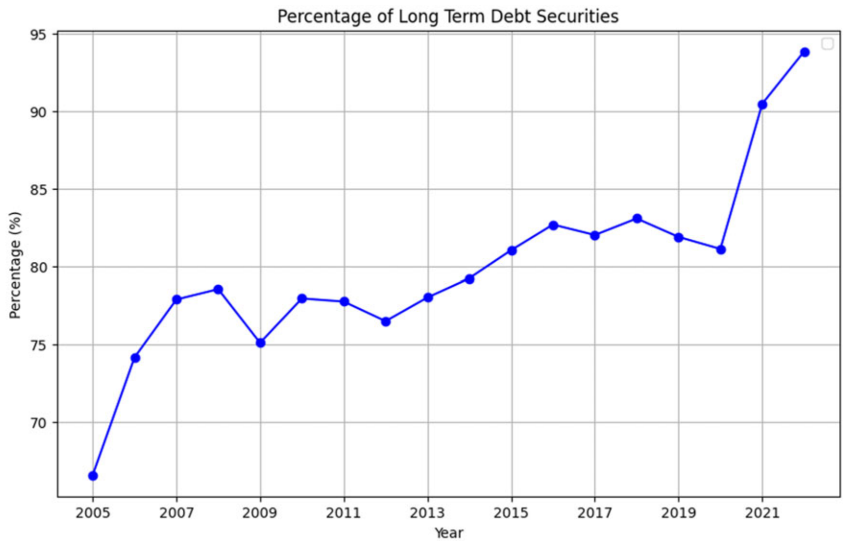

Figure 1. The percentage of long-term debt securities held by banks in 202 countries, as reported in the BankFocus database, relative to their total debt securities.

fixed proportions. As the regulatory constraint tightens on the banks due to the central bank's bond-buying program, banks respond by rebalancing their portfolio. They reduce their loans to the private sector, which causes the term premiums to rise on private bonds.

By contrast, a cut in the policy rate (conventional monetary policy shock) causes an expansion in the economy. By increasing the net worth, the lower policy rate relaxes the leverage constraint and increases investment demand. However, the consequent rise in demand for private bonds tightens the regulatory constraint, putting upward pressure on the term premiums. Ultimately, the absence of a strong portfolio rebalancing effect results in the net worth effect dominating, causing a lowering of the term premiums on private bonds and an expansion in the economy.

We next study the monetary transmission mechanism under credit and productivity shocks in two policy scenarios: (1) simple Taylor rule and (2) term premium peg in which the central bank endogenously adjusts its bond portfolio to hold the term premium on government bonds fixed. Further, we go on to welfare rank these rules under the two shocks. Our objective is to see how well the endogenous QE policy (term premium peg) performs relative to the Taylor rule.[3]

An adverse financial or credit shock tightens the leverage constraints on financial intermediaries, causing term premiums to rise. The central bank responds under a term premium peg by purchasing government bonds to mitigate this rise. Lower government bond holdings, in turn, cause the regulatory constraint to tighten, and the financial intermediary re-balances its portfolio by lowering its holding of private bonds. Consequently, term premiums on corporate bonds rise, and investment and output in the economy drop. On the other hand, the absence of the strong portfolio rebalancing effect in the simple Taylor rule causes it to welfare dominate the term premium peg.

Next, consider the case of a positive productivity shock. The increase in the demand for investment tightens the regulatory constraint. Under a term premium peg, the central bank responds by selling government bonds to the intermediary, which relaxes the regulatory constraint. This causes a significant rise in investment and output. Unlike the term premium peg, the absence of the central bank selling bonds in the case of the Taylor rule tightens the regulatory constraint, thereby limiting investment, output, and welfare. Consequently, the pegging rule ends up being welfare superior.

The work in this paper straddles several strands of literature. A significant body of literature has tried to understand the differences in the transmission of conventional versus unconventional monetary policy. Conventional policy involves the use of short-term interest to influence aggregate demand through its impact on the long-term interest rate, exchange rates, asset prices, bank lending (Kashyap et al., 1994) and the credit channel (Bernanke and Gertler, 1995). Quantitative easing, on the other hand, involves changing the size and composition of central bank balance sheets to alter the yield curve. Theoretically, medium- to long-term expected interest rates are a function of the investors' expectations of short-term rates. If assets are perfect substitutes, arbitrage will mean that all assets have equal expected returns. Essentially, a bond-buying QE program that attempts to lower the long rate without changing investors' expectations about the short rates would leave the yield curve unchanged, as investors would arbitrage away the difference in yields.

Theoretically, financial segmentation resulting in imperfect substitutability between assets has been used by the literature to resolve this issue and explain the impact of QE on the real economy.[4] One way to introduce this imperfect substitutability is through employing the "preferred habitat" framework, where segmentation occurs due to investors' preferences for specific types of asset. Ray et al. (2019) incorporates the preferred habitat framework of Vayanos and Vila (2009) into a New Keynesian model to study QE. Alternatively, papers (Gertler and Karadi, 2011, 2013; Carlstrom et al. 2017; Darracq Pariès and Kühl, 2017; Harrison, 2017; Sims and Wu, 2019, 2021) incorporate segmented asset markets arising due to financial frictions in DSGE models to analyze the real effects of unconventional monetary policy.

As noted earlier, much of this literature has argued that unconventional policy has been quite effective in easing financial conditions, especially when interest rates have been constrained by the lower bound. In particular, compared to conventional policy, QE is an effective tool to offset the negative impact of financial shocks. For example, Carlstrom et al.(2017)show that an endogenous QE policy that directly targets the term premium completely sterilizes the real economy from shocks originating in the financial sector. Karadi and Nakov (2021) show, in a model of occasionally binding constraints, that the nature of the shock matters for the effectiveness of QE: These policies, while effective in the case of financial shocks, are ineffective when the economy faces non-financial shocks. Our work complements this literature and examines the effectiveness of QE policy when an economy under credit regulation experiences financial and non-financial shocks. In contrast to the literature, we show that QE exacerbates the effects of financial shocks on the economy compared to a simple Taylor rule. At the same time, it mitigates the impact of non-financial shocks.

In relational lines, Lahiri and Patel (2016), in a simple model, show that the presence of credit regulations can invert the transmission of the monetary policy under conventional policy. The result essentially arises due to their model's absence of net worth effects. By contrast, we show that their result is overturned with a leverage constraint and its consequent net worth effects.

Finally, this paper is related to the literature that examines the impact of regulations on the economy. Recent work on this line includes Chari et al. (2020), which shows that regulations generating financial repression can be optimal if governments cannot credibly commit to paying back their debt. Kriwolutzy et al. (2018) use a framework similar to ours to quantify the extent of financial repression in the US during the post-WWII period. Our work adds to this literature and examines how these regulations differentially impact the transmission of monetary policy under conventional and unconventional monetary policy.

The rest of the paper is structured as follows: Section 2 provides empirical motivation for our paper, Section 3 outlines the model, Section 4 examines the impulse responses to conventional and unconventional monetary policy shocks, Section 5 performs a sensitivity analysis of our results with regard to some key model parameters, Section 6 contrasts welfare under the Taylor rule and a term premium peg and Section 7 concludes the paper. Detailed derivations of the model and steady state are provided in the appendix.

2. Empirical analysis

In this section, we present empirical evidence regarding the impact of a central bank's public QE program on private investment in an economy. In particular, we wish to investigate whether the impact varies across a set of economies based on their degree of credit market regulation. We use the panel vector autoregression (PVAR) approach to estimate the impact of QE on these two sets of economies.

2.1 Data

Our sample comprises countries listed by Cantú et al. (2021), who provide detailed information on quantitative easing programs implemented by central banks during the COVID-19 pandemic.

The variables considered for the study are equity return, asset purchases, investment growth, and consumer price index (CPI) inflation. "Asset purchases" is measured as the ratio of the central bank's net claims on the central government to the total assets of the central bank. "Investment growth" is the annual change in real gross fixed capital formation. "Equity return" is the year-on-year percentage change of the stock market index of the economy. All these data are collected from the IMF's International Financial Statistics database. We use quarterly data because our key variable—private gross fixed capital formation—is at a quarterly frequency.

We wish to classify economies based on their overall credit market regulations. To this end, we use the *credit market regulation index* from the economic freedom index provided by the Fraser Institute. We classify countries as high- and low-credit-regulated based on the median credit regulation of the entire sample between 2013 (post-GFC) and 2021. We classify a country as highly regulated if the mean credit regulation index (over time) for the country is greater than the sample median value. The empirical analysis is carried out for these two categories of economies from 2019Q1 to 2022Q3.

Tables 1 and 2 in online appendix present the various characteristics of the public QE announcements made in both low- and high-credit regulation countries based on data provided by Cantú et al. (2021). While data on the end date of the QE exercise is not always available, all countries in our sample commenced their QE programs in 2020. It is also clear from the tables that the QE exercise mainly involved purchasing long-term bonds.

To address any apprehensions about the results being impacted by the varying levels of quantitative easing in different economies, we define "Asset Purchase" in our VAR model as the ratio of the central bank's net claims on the central government to the total assets of the central bank. For robustness, we also demonstrate that the findings remain consistent when we define "Asset purchases" in line with Weale and Wieladek (2016), that is, as the ratio of the central bank's net claims on central government to nominal GDP.

2.2 Methodology

We use the PVAR method to estimate the impact of QE. It combines the conventional VAR method which considers all system variables endogenous, with the panel data method that allows for unobserved individual heterogeneity. This enables us to utilize cross-sectional dimensions to control for heterogeneity and to increase the number of observations for small sample sizes.

A k-variate panel VAR of order p is specified as follows:

$$Y_{it} = A_1 Y_{it-1} + A_2 Y_{it-2} + \ldots + A_p Y_{it-p} + u_i + \eta_{it} \tag{1}$$

where i denotes an economy and $t = 1, 2, \ldots, T$ is the time period. Y_{it} represents the (1 x k) vector of variables used for estimation, A_l represents the (k x k) matrix of reduced form coefficients, and u_i and η_{it} represent the (1 x k) vector of fixed effect and residuals, respectively. The orthogonal impulse response is obtained using the Cholesky decomposition. It requires all variables to be arranged in such a way that the variable that comes first has both a contemporaneous and a lagging

 https://doi.org/10.1017/S1365100524000373

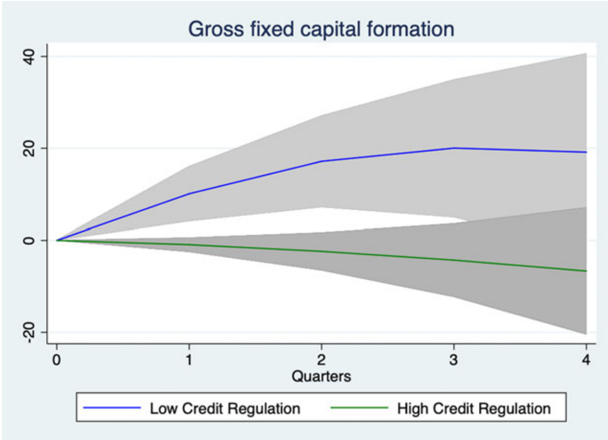

Figure 2. Impact of hundred basis point increase in central bank's claim on central government as a percentage of central bank assets on fixed capital formation in the economy.
Note: The impulse response is generated using 1000 Monte Carlo simulation of system-GMM estimation of Equation (1).

effect on the variable that comes next. Specifically, we follow an approach similar to Weale and Wieladek (2016) and arrange variables in the following order - equity return, asset purchases, investment growth, and CPI inflation - with the equity return being the most endogenous. In Appendix A, we show that the result remains robust to an alternate identification scheme with investment growth being the most exogenous variable.

To avoid any endogeneity concerns and to obtain consistent and efficient estimates, we estimate our PVAR model using the system-generalized method of moment (system-GMM) developed by Blundell and Bond (1998). This methodology employs the lagged differences of the dependent variable as instruments for level equations and the lagged levels of the dependent variable as instruments for first difference equations. The system is identified using the same number of instruments as the endogenous variables. Furthermore, the GMM style estimator is advantageous in situations where the sample size is large and the time period is short, as it avoids the Nickell bias described in Nickell (1981). We have chosen the VAR model with lag one based on the moment model selection criteria (MMSC) proposed by Andrews and Lu (2001). These criteria include the MMSC-Bayesian information criterion, MMSC-Akaike information criterion, MMSC-Hannan and Quinn information criterion and coefficient of determination (CD). Additionally, the first-order panel VAR models do not reject Hansen's over-identification restriction, indicating that there is no possible misspecification in the model. The results of the Hansen J statistics along with moment model selection criteria for both the PVAR models can be found in Online Appendix A.

2.3 Results

Figure 2 illustrates the estimated impulse response for the two sets of economies derived from the two PVARs. Confidence bands are calculated by approximating a Gaussian distribution, which is based on 1000 Monte Carlo simulations from the fitted panel VAR model. We find that, in economies with low credit market regulation, an asset purchase equal to 1% of the size of the central bank's balance sheet leads to a statistically significant cumulative increase of 20 basis (0.20%) points in private investment. However, in economies with high-credit market regulation, the impact of a similar asset purchase is negligible and insignificant on private investment.

For robustness, we use an alternative definition of the variable "Asset Purchase" in line with Weale and Wieladek (2016). The estimated impulse response function for both groups of economies is shown in Figure 2 of Appendix A. We find that the results remain robust as a 1%

increase in asset purchase relative to GDP leads to a statistically significant cumulative increase of 0.20% in private investment only in those economies that have low credit market regulations. The results also remain robust to the alternative identification scheme where the investment growth is the most exogenous (see Figure 3 of Appendix A.)

The literature on the impact of QE policies on the real economy has largely been centered around the US and Europe (see Fabo et al. (2021) for a survey). The results of this survey are mixed. Weale and Wieladek (2016) for instance, finds that an announcement of a purchase of 1% of GDP leads to a statistically significant increase of 0.58% in GDP in the US. These results are broadly in the ballpark of our findings.

To address the concern that our results are not driven by the short data series, we identify eight central banks from Tables 1 and 2 of Appendix A (five in the low-regulation economies and three in the high-regulation economies) that had an active asset purchase program even before the pandemic. We now run PVARs only for these eight economies from 2014 to 2022. The results are shown in Figure 4 of Appendix A. Even with longer time period data series, the results show that the public QE program or "Asset Purchase" has a much higher and significant impact on private investment in economies with low credit regulation compared to economies with higher credit regulation.

3. Model

The model we use is a variant of Sims and Wu (2021) and Kriwolutzy et al. (2018) to highlight the effect of credit regulations on the monetary transmission process under both conventional and unconventional policy. The economy consists of households, various production firms, financial intermediaries, fiscal authority, and a central bank. Households consume a composite final good, supply labor, and save in the form of one-period deposits. Asset markets are segmented in the sense that households cannot hold long-term debt[5] A representative wholesale firm purchases labor from households and new capital from a capital goods firm. It must issue long-term debt to finance a part of its investment. The wholesale producer sells its output to a continuum of monopolistically competitive retailers who repackage it and sell it to the final goods firms.

Financial intermediaries use their net worth and deposits to purchase long-term debt issued by firms and the government. These intermediaries are faced with two types of constraints. The first is an endogenous leverage constraint that arises due to a simple holdup problem that constrains the amount of deposits that a given level of net worth can support. To the extent that intermediaries are leverage constrained, they cannot arbitrage the yield gap between short-term and long-term rates. The second constraint captures credit regulation, termed as regulatory constraint, which forces banks to hold a fraction of their assets in the form of government debt. The presence of this constraint drives a wedge between the return on private and government bonds.

Finally, there is a central bank that, in addition to setting the short-term interest rate, can also influence liquidity conditions by buying or selling long-term debt to financial intermediaries.

3.1 Households

There is a representative household that consumes the final good, supplies labor to wholesale firm, and makes deposits with financial intermediaries. Its lifetime discounted utility takes the following form:

$$U_t = \mathbb{E}_t \sum_{i=0}^{\infty} \beta^i \left\{ ln(C_{t+i} - hC_{t+i-1}) - \frac{L_{t+i}^{1+\eta}}{1+\eta} \right\}$$

where $0 < \beta < 1$ is the household's utility discounting factor, $0 < h < 1$ is the habit persistence parameter, and $\eta > 0$ is inverse of Frisch elasticity of labor supply. The deposits are made in the form of one-period nominal debt D_t so that the household has the option of deciding whether to roll over the deposits or not. These bonds earn a gross return of R_t^D in the next period $(t+1)$.

The household earns labor income W_t, dividends DIV_t from their ownership in production firms and intermediaries, and pays a lump-sum tax T_t to the government. Formally, the budget constraint of the household can be written as:

$$P_t C_t + D_t = W_t L_t + R_{t-1}^D D_{t-1} + DIV_t - P_t X - P_t T_t$$

Here, P_t is the price of the final output good and X is the amount of fixed real equity (in terms of consumption units) infused by household to start up new intermediaries each period.

The first-order conditions with respect to C_t, L_t, and D_t, respectively, are:

$$\mu_t = \frac{1}{C_t - hC_{t-1}} - \beta h \mathbb{E}_t \frac{1}{C_{t+1} - hC_t} \tag{2}$$

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

$$1 = R_t^D \mathbb{E}_t \left[\Lambda_{t,t+1} \Pi_{t+1}^{-1} \right] \tag{4}$$

Here, $\mu_t = U'(C_t)$ is the marginal utility of consumption, w_t is the real wage, $\Lambda_{t,t+1} = \beta \frac{\mu_{t+1}}{\mu_t}$ is the real stochastic discount factor of the household, and $\Pi_{t+1} = \frac{P_{t+1}}{P_t}$ is the gross inflation rate. Together, Equations (2) and (3) give us the households labor supply curve while Equation (4) is the familiar Fisher equation.

3.2 Financial Intermediaries

There is a unit mass of intermediaries (indexed by i) in the economy. Each period, a fraction $1-\sigma$ of total intermediaries stochastically exit and return their net worth to their owner household. They are replaced by an equal number of new intermediaries with a startup equity of X given to them by the household.

On its asset side, each intermediary holds perpetual government debt $(B_{i,t})$ and wholesale firm's debt $(F_{i,t})$ along with the reserves $RE_{i,t}$ (issued by the Central Bank).[6] It finances them using one-period deposits $(D_{i,t})$ from households and its own net worth $(N_{i,t})$. The balance-sheet equation of an intermediary i is therefore given by:

$$Q_t F_{i,t} + Q_{B,t} B_{i,t} + RE_{i,t} = D_{i,t} + N_{i,t} \tag{5}$$

Until an intermediary stochastically exits, it accumulates its net worth instead of paying it out as dividends to the households. Therefore, its net worth evolves according to:

$$N_{i,t} = \left(R_t^F\right) Q_{t-1} F_{i,t-1} + \left(R_t^B\right) Q_{B,t-1} B_{i,t-1} + \left(R_{t-1}^{re}\right) RE_{i,t-1} - R_{t-1}^D D_{i,t-1}$$

where $R_t^F = \frac{1+\kappa Q_t}{Q_{t-1}}$, $R_t^B = \frac{1+\kappa Q_{B,t}}{Q_{B,t-1}}$ are the realized holding period returns on private and government debt, respectively, and (R_{t-1}^{re}) is the gross interest rate on reserves set by the central bank which is known at time $t-1$. Combining the above equation with (5), we get:

$$N_{i,t} = \left(R_t^F - R_{t-1}^D\right) Q_{t-1} F_{i,t-1} + \left(R_t^B - R_{t-1}^D\right) Q_{B,t-1} B_{i,t-1} + \left(R_{t-1}^{re} - R_{t-1}^D\right) RE_{i,t-1} + R_{t-1}^D N_{i,t-1} \tag{6}$$

The interpretation of the above equation is standard. The first three terms represent the excess returns over the deposit rate of holding private debt, government debt, and reserves. The last term reflects the savings made from financing assets using net worth as opposed to deposits. The stochastic exit assumption prevents an intermediary from accumulating enough net worth to make the limited enforcement constraint, that we describe below, redundant.

It is important to note that the net worth of a bank can change in two ways: (i) through its balance-sheet Equation (5), and (ii) through the net worth accumulation Equation (6). The unconventional policy works through the balance-sheet equation as the bank's reserves holdings change, while the conventional policy works through the net worth accumulation equation as the excess returns earned by the bank change.

3.2.1 Intermediary's problem

The presence of excess returns implies that the objective of a financial intermediary is to maximize the expected terminal value of its net worth. The expected continuation value of remaining an intermediary at the end of period t is given by:

$$V_{i,t} = (1-\sigma)\mathbb{E}_t[\Lambda_{t,t+1} n_{i,t+1}] + \sigma \mathbb{E}_t[V_{i,t+1}\Lambda_{t,t+1}] \tag{7}$$

where $V_{i,t}$ is the maximized expected value of the intermediary's terminal net worth, $n_{i,t+j} = \frac{N_{i,t+j}}{P_{t+j}}$ is the real net worth at $t+j$, and $\Lambda_{t,t+j}$ is the real stochastic discount factor of households.

3.2.2 Leverage constraint

The financial intermediary faces two constraints. The first, as modeled in Gertler and Karadi (2011), arises due to an agency problem under which an intermediary can divert a fraction θ_t of the total value of private debt and $\Delta\theta_t$ fraction of the government debt, where $\theta_t \geq 0$ and $\Delta \leq 1$. This implies that it is easier for the intermediary to divert private debt than government debt. Creditors can recover the rest of the intermediary's assets including reserves which are held with the central bank. As a consequence of this agency problem, the following endogenous leverage constraint must be satisfied for depositors to be willing to lend to intermediaries:

$$V_{it} \geq \theta_t (Q_t f_{i,t} + \Delta Q_{B,t} b_{i,t}) \tag{8}$$

where $f_{i,t}$ and $b_{i,t}$ are the real values of private and government debt, respectively. Here, the left-hand side denotes the expected value of continuing as an intermediary after time t, and the right-hand side denotes the gain if it decides to divert assets. The constraint ensures that it is never optimal for the intermediary to abscond with assets in equilibrium. It also implies that net worth limits the intermediary's ability to attract deposits.

3.2.3 Regulatory constraint

The second constraint faced by the intermediaries is a regulatory constraint. Following Chari et al. (2020) and Kriwolutzy et al. (2018), financial intermediaries face an additional constraint wherein they have to hold a certain minimum fraction (Γ) of their bond assets in the form of government bonds. Formally, the constraint is given by[7]

$$Q_{B,t} b_{i,t} \geq \Gamma \left(Q_{B,t} b_{i,t} + Q_t f_{i,t}\right)$$

which can be rewritten as

$$Q_{B,t} b_{i,t} \geq \gamma Q_t f_{i,t} \tag{9}$$

where $\gamma = \frac{\Gamma}{1-\Gamma}$.

3.2.4 Discussion

The objective of an intermediary is to maximize Equation (7) subject to Equations (6), (8), and (9). The Lagrangian optimization yields the following first-order conditions:

$$\mathbb{E}_t \left[\Lambda_{t,t+1} \Pi_{t+1}^{-1} \Omega_{i,t+1} \left(R_t^{re} - R_t^D \right) \right] = 0 \tag{10}$$

$$\mathbb{E}_t\left[\Lambda_{t,t+1}\Pi_{t+1}^{-1}\Omega_{i,t+1}\left(R_{t+1}^F - R_t^D\right)\right] = \frac{\lambda_{it}}{1+\lambda_{it}}\theta_t + \frac{\zeta_{it}}{1+\lambda_{it}}\gamma \tag{11}$$

$$\mathbb{E}_t\left[\Lambda_{t,t+1}\Pi_{t+1}^{-1}\Omega_{i,t+1}\left(R_{t+1}^B - R_t^D\right)\right] = \frac{\lambda_{it}}{1+\lambda_{it}}\theta_t\Delta - \frac{\zeta_{it}}{1+\lambda_{it}} \tag{12}$$

where $\left(\Omega_{i,t+1} = 1-\sigma+\sigma\frac{\partial V_{it+1}}{\partial n_{i,t+1}}\right)$. The Lagrange multipliers λ_{it} and ζ_{it} represent the tightness of leverage and regulatory constraints, respectively. Equation (10) implies intermediaries do not earn any excess returns on the reserves, i.e., $R_t^{re} = R_t^D$. Equations (11) and (12) imply that if the leverage constraint is binding ($\lambda_{it} > 0$), then excess returns earned on both private and government debt persist in equilibrium. We note that the presence of the regulatory constraint drives a wedge between the expected returns on private and government bonds. Intuitively, such a constraint raises the demand for government bonds and depresses their yield. To see this, consider the case when there are no regulations. Under this scenario, the regulatory constraint is slack i.e. $Q_{B,t}b_{i,t} > \gamma Q_t f_{i,t}$ and $\zeta_{it} = 0$. Following Kriwolutzy et al. (2018), Equation (12) can therefore be rewritten as

$$\mathbb{E}_t\left[\Lambda_{t,t+1}\Pi_{t+1}^{-1}\Omega_{i,t+1}\left(\tilde{R}_{t+1}^B - R_t^D\right)\right] = \frac{\lambda_{it}}{1+\lambda_{it}}\theta_t\Delta \tag{13}$$

where, Kriwolutzy et al. (2018) term $\tilde{R}_{t+1}^B$ as the laissez-faire return on government debt. To see the impact of credit regulation, we combine Equations (12) and (13) to get

$$\mathbb{E}_t\left[\Lambda_{t,t+1}\Pi_{t+1}^{-1}\Omega_{i,t+1}\left(R_{t+1}^B - \tilde{R}_{t+1}^B\right)\right] = -\frac{\zeta_{it}}{1+\lambda_{it}}$$

It follows from the above equation that whenever the regulatory constraint binds ($\zeta_{it} > 0$), the return on government debt is lesser than the laissez-faire case, i.e., $R_{t+1}^B < \tilde{R}_{t+1}^B$. Throughout the paper, we assume that the regulatory constraint binds. Although the extent of credit regulation does not change over time, the tightness of regulatory constraints does change as a result of changing economic conditions that impact term premiums.

We also assume that the leverage constraint always binds. Following Sims and Wu (2021), we assume that the value function is linear in net worth, i.e., $V_{it} = a_t n_{it}$. Defining $\phi_{it} = \frac{Q_t f_{it} + \Delta Q_{B,t} b_{it}}{n_{it}}$ as the modified leverage ratio for an intermediary and solving for ϕ_t (see Appendix D for derivation), we get

$$\phi_t = \frac{(1+\Delta\gamma)\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}R_t^D\right]}{\theta_t + \theta_t\Delta\gamma - \mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}\left\{\left(R_{t+1}^F - R_t^D\right) + \gamma\left(R_{t+1}^B - R_t^D\right)\right\}\right]} \tag{14}$$

where $\tilde{\Lambda}_{t,t+1} = \Lambda_{t,t+1}\Pi_{t+1}^{-1}\Omega_{t+1}$. Note that the leverage ratio decreases with increasing θ_t. Intuitively, a higher θ_t means the intermediary can divert a larger fraction of the assets and hence the depositor will require the intermediary to put in more equity. On the other hand, higher expected excess returns $\left(R_{t+1}^F - R_t^D\right)$ or $\left(R_{t+1}^B - R_t^D\right)$ results in a higher leverage ratio. Intuitively, higher expected excess returns on assets increase the expected net worth of the intermediary and reduce the risk of default. Similarly, the discounted deposit rate $\mathbb{E}_t\left[\tilde{\Lambda}_{t,t+1}R_t^D\right]$ increases the net worth and hence raises the continuation value of staying a banker. Thus, it also impacts the leverage ratio positively.

Lastly, the leverage ratio decreases with an increase in the credit regulation parameter Γ. Essentially, higher regulation reduces the excess returns on corporate and government bonds received by the intermediary. The consequent lower expected net worth increases the risk of default and results in a lower leverage ratio. This is displayed in Figure 3.

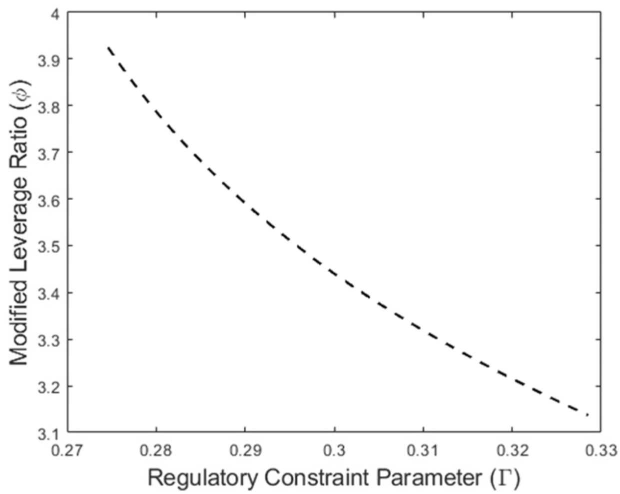

Figure 3. Steady-state leverage ratio (ϕ) as a function of regulatory constraint parameter (Γ).
Note: The range of regulatory constraint parameter Γ, as shown in the above Figure, is the only possible set of its values given our model parameters. The lower and upper bounds for Γ correspond to the limiting cases of Δ and θ approaching unity in the steady state, respectively.

3.2.5 Term premium

The presence of both leverage and regulatory constraints results in a term premium in the model. Following Carlstrom et al. (2017), we define (log) term premium as the difference between the observed (log) yield on a long-term bond[8] and the implied (log) yield on a short-term bond. This implied yield is obtained by applying the expectation hypothesis (EH) of the term structure to the series of short rates. The price of such a hypothetical (EH) bond satisfies

$$R_t^D = \frac{1 + \kappa Q_{t+1}^{EH}}{Q_t^{EH}}$$

and its yield is given by

$$R_t^{EH} = \frac{1}{Q_t^{EH}} + \kappa$$

The yield of a long bond is given by

$$RL_t^i = \frac{1}{Q_{i,t}} + \kappa \ ; i \in \{B, F\}$$

We define term-premium as the ratio of these two yields, i.e,

$$TP_{i,t} = \frac{RL_t^i}{R_t^{EH}} \ ; i \in \{B, F\} \tag{15}$$

It follows from Equations (11), (12), and (15) that the term premium on private and government bonds is a function of asset market segmentation (λ_{it}), credit regulation (ζ_{it}) and credit shocks (shock to θ_t). This insight turns out to be crucial during the analysis of monetary policy transmission.

 https://doi.org/10.1017/S1365100524000373

3.3 Production

Our production section is similar to Sims and Wu (2021) which consists of four different types of production firms: a competitive final good producer, monopolistic retailers, wholesale firm, and investment good firm. A representative investment good firm produces new physical capital from final output subject to a convex adjustment cost. The key departure from a standard framework is that the wholesale firm produces output using its own capital, which is accumulated via the purchase of new capital from the investment goods firm and labor hired competitively from the households. A continuum of retail firms then repackages this wholesale output and sells to the final good firm. These retail firms behave as monopolistic competitors and are subject to price stickiness. In the text, we focus on the wholesale firm, while the rest of the production section is described in the Appendix B.

The wholesale firm produces output using labor input $L_{d,t}$ and the capital that it accumulates using a Cobb-Douglas technology:

$$Y_{w,t} = A_t(u_tK_t)^{\alpha} L_{d,t}^{1-\alpha}$$

where A_t is an exogenous productivity variable that obeys an exogenous stochastic process, K_t is the stock of physical capital that the firm owns and u_t is the capital utilization factor. In addition, $\alpha \in (0, 1)$ is the exponent on capital services in production.

Physical capital accumulates according to the following law of motion, which generates faster depreciation as a cost of utilization:

$$K_{t+1} = \hat{I}_t + (1 - \delta(u_t))K_t \tag{16}$$

Here, $\delta(u_t) = \delta_0 + \delta_1(u_t - 1) + \frac{\delta_2}{2}(u_t - 1)^2$ is the utilization adjustment cost, which maps utilization into depreciation.

We assume that the wholesale firm purchases at least a constant fraction ψ of its new physical capital $\hat{I}_t$ using fresh issues of perpetual debt or bonds. This results in a "loan in advance" constraint of the form:

$$\psi P_t^K \hat{I}_t \leq Q_t CF_{w,t} = Q_t(F_{w,t} - \kappa F_{w,t-1}) \tag{17}$$

where P_t^K is the price of the new physical capital. $CF_{w,t}$ is the number of new bonds issued (see Appendix B for details), while Q_t is the nominal price of a bond. The labor is hired in a competitive market at the nominal wage W_t. The firm maximizes the present discounted value of the real dividend. The nominal dividend of the firm is given by:

$$DIV_{w,t} = P_{w,t}A_t(u_tK_t)^{\alpha} L_{d,t}^{1-\alpha} - W_tL_{d,t} - P_t^K\hat{I}_t - F_{w,t-1} + Q_t(F_{w,t} - \kappa F_{w,t-1})$$

The first-order conditions are:

$$w_t = (1 - \alpha)p_{w,t}A_t(u_tK_t)^{\alpha} L_{d,t}^{-\alpha} \tag{18}$$

$$\nu_{1,t}\delta^{'}(u_t) = \alpha p_{w,t}A_t(u_tK_t)^{\alpha-1} L_{d,t}^{1-\alpha} \tag{19}$$

$$\nu_{1,t} = (1 + \psi\nu_{2,t})p_t^k \tag{20}$$

$$p_t^kM_{1,t} = \mathbb{E}_t\Lambda_{t,t+1}\left[\alpha p_{w,t+1}A_{t+1}(u_{t+1}K_{t+1})^{\alpha-1}u_{t+1}L_{d,t+1}^{1-\alpha} + (1 - \delta(u_{t+1}))p_{t+1}^kM_{1,t+1}\right] \tag{21}$$

$$Q_tM_{2,t} = \mathbb{E}_t\Lambda_{t,t+1}\Pi_{t+1}^{-1}[1 + \kappa Q_{t+1}M_{2,t+1}] \tag{22}$$

Here, $\nu_{1,t}$ and $\nu_{2,t}$ are the Lagrange multipliers for (16) and (17) respectively, and $M_{1,t} = 1 + \psi\nu_{2,t}$ and $M_{2,t} = 1 + \nu_{2,t}$ are two auxiliary variables. Variables w_t, $p_{m,t}$, and p_t^k are real wages, the relative price of wholesale product, and the relative price of new capital, respectively.

Equation (18) is the standard labor demand equation. As discussed in Sims and Wu (2021), the uniqueness lies with $M_{1,t}$ and $M_{2,t}$ which serve as endogenous "investment wedge" and "financial wedge," respectively. The fluctuations in these wedges are key channels through which any monetary action, either conventional or unconventional, has an impact on the real economy.

3.4 Fiscal authority

There is a government that consumes a constant $\overline{G}$ amount of real output of final goods and makes the interest payments on its outstanding debt with the help of lump-sum tax raised from households, transfers from the central bank, and fresh issue of perpetual government bonds. The budget constraint is given by:

$$P_t\overline{G} + B_{G,t-1} = P_tT_t + P_tT_{cb,t} + Q_{B,t}\left(B_{G,t} - \kappa B_{G,t-1}\right) \tag{23}$$

where $B_{G,t-1}$ is the total liability (payable at t) on outstanding bonds issued till $t-1$, $T_{cb,t}$ is the transfer from the central bank, and the last term denotes the value of bonds freshly issued at t.

3.5 Central bank

The central bank sets the interest rate on reserves according to the following Taylor Rule:

$$lnR_t^{re} = (1-\rho_r)lnR^{re} + \rho_r lnR_{t-1}^{re} + (1-\rho_r)[\phi_\pi(ln\Pi_t - ln\Pi) + \phi_y(lnY_t - lnY_{t-1})] + s_r\epsilon_{r,t}$$

where R^{re} and Π denote the steady state values of the policy rate and inflation respectively, with $0 < \rho_r < 1$, $\phi_\pi > 1$ and $\phi_y > 0$. Since $R_t^{re} = R_t^D$, setting the rate on reserves would be equivalent to the central bank setting the deposit rate.

The asset market segmentation (or presence of a leverage constraint) implies that a central bank can also conduct monetary policy on the long end of the debt-maturity structure. That is, it can influence long rates in the economy without necessarily changing the short-term rates. The sale or purchases of government long-term debt, which we term unconventional or QE policies are financed using its reserves. Formally, the balance-sheet equation for the central bank is given by:

$$Q_{B,t}B_{cb,t} = RE_t$$

where $Q_{B,t}B_{cb,t}$ denotes the total value of all government bonds acquired by the central bank till period t, and RE_t denotes the nominal value of period t reserves issued by the central bank. We consider both exogenous and endogenous unconventional policies. For exogenous policy, we assume that the central bank's government bond holdings follow an exogenous AR(1) process:

$$b_{cb,t} = (1-\rho_b)b_{cb} + \rho_b b_{cb,t-1} + s_b\epsilon_{b,t} \tag{24}$$

where b_{cb} denotes the steady state of government bond holdings and $\epsilon_{b,t}$ is an i.i.d shock. Endogenous unconventional policy considered in Section 6 involves the central bank pegging the government bond term premium to its steady state level, thus making the level of debt endogenous.

Finally, the monetary authority remits any net revenue it makes to the government in the form of lump-sum transfers $T_{cb,t}$. This can be expressed in real terms as

$$T_{cb,t} = \left(R_t^B - R_{t-1}^{re}\right)\Pi_t^{-1}Q_{B,t-1}b_{cb,t-1}$$

where the right-hand side reflects the net revenue earned by the central bank on its asset holdings.

3.6 Aggregate and market clearing conditions

Since the labor market is competitive, labor supplied by households should equal the labor demanded by the wholesale firm, i.e.

$$L_t = L_{d,t}$$

The market for long-term bonds of both the wholesale firm and the government should clear as follows:

$$f_{w,t} = f_t$$

$$b_{G,t} = b_t + b_{cb,t}$$

where f_t and b_t are the real aggregate values of all long bonds acquired by intermediaries from the wholesale firms and government, respectively.

Following (6), the aggregate real net worth of intermediaries (both surviving and new ones) at the start of date t is given by:

$$n_t = \sigma \Pi_t^{-1} \left[\left(R_t^F - R_{t-1}^d \right) Q_{t-1} f_{t-1} + \left(R_t^B - R_{t-1}^d \right) Q_{B,t-1} b_{t-1} + \left(R_{t-1}^{re} - R_{t-1}^d \right) re_{t-1} + R_{t-1}^d n_{t-1} \right] + X \tag{25}$$

Since households own both financial and non-financial firms, we plug back the aggregate real dividends from these firms and X from Equation (25) into the budget constraint of households to get the usual aggregate resource constraint given by:

$$Y_t = C_t + I_t + G_t$$

4. Numerical experiments

In this section, we perform simple numerical exercises to investigate the impact of credit regulation on the transmission of monetary policy under both conventional and unconventional policies. Our baseline calibration corresponds to the Indian economy. India provides a textbook case for analyzing the modeled in the article. Consistent with the modeling assumptions in this paper, banks in India are subject to a Statutory Liquidity Ratio (SLR), which requires them to hold a fraction of their liabilities in the form of government securities Lahiri and Patel (2016). SLR, which used to be 30% in the 1990s, currently varies between 18 and 21%. The objective of the SLR, as pointed out by Lahiri and Patel (2016), where dated securities or long-term government bonds are favored, is to facilitate government borrowing at cheap rates and neatly capture the financial repression modeled in our framework.

The standard parameters for India are taken from previous studies on India, particularly Banerjee and Basu (2019); Banerjee et al. (2020); Ghate (2012). The unit of time is one quarter. Below, we explain the calibration of nonstandard parameters related to financial intermediaries and firms.

We target a steady-state excess return of the private bond over the deposit rates ($R_t^F - R_t^D$) of 526 basis points annually and a steady-state excess return of the government bond over the deposit rates ($R_t^B - R_t^D$) of 374 basis points annually. The spreads are chosen, respectively, to match the observed spreads on ten-year AA corporate bond yields and ten-year government bond yields over the average deposit rate of five major banks in India provided by the RBI. Together with other parameters, as shown in Appendix E, these targets imply a steady-state value of $\Delta = 0.71$, $\theta = 0.50$ and $\Gamma = 0.29$.

The fraction of investment that the wholesale firm must finance by issuing debt, that is, the loan-in-advance parameter, is calibrated as $\psi = 0.9$. This selection is made to align the parameter with the observed ratio of the total value of corporate debt and total private investment. The

Table 1. Parameters

Parameter	Description	Value or Target	Source
Households			
β	Utility discount rate	0.9901	Average annual deposit rate of 4 percent
h	Habit parameter	0.659	Banerjee and Basu (2019)
η	Inverse Frisch elasticity of labor supply	0.33	Aoki et al. (2016)
Financial Intermediaries			
σ	Survival rate	0.9	Aoki et al. (2016)
Δ	Relative moral hazard towards govt. bonds	0.7144	Model calibrated
Γ	Minimum fraction of govt. bonds in portfolio	0.2897	Model calibrated
ρ_θ	Persistence in variable θ_t	0.98	Sims and Wu (2021)
s_θ	Standard deviation of shocks to θ_t	0.04	Sims and Wu (2021)
Wholesale Firm			
α	Effective capital share	0.3	Banerjee and Basu (2019)
U	Steady state capital utilization rate	1	Normalization assumption
δ_0, δ_2	Utilization adjustment-cost constants	0.025,0.01	Banerjee and Basu (2019); Sims and Wu (2021)
ψ	Loan-in-advance parameter	0.9	Fraction of investment by non-financial
			corporate sector financed using debt
κ	Coupon decay parameter	$1 - 40^{-1}$	Carlstrom et al. (2017)
ρ_A	Persistence in productivity process	0.765	Banerjee and Basu (2019)
s_A	Standard deviation of shocks to A_t	0.0865	Banerjee and Basu (2019)
Retail Firms			
ϵ_p	Elasticity of substitution	5.645	Banerjee and Basu (2019)
ϕ_p	Probability of keeping prices fixed	0.67	Ghate (2012)
Investment Goods Producer			
κ_I	Cost of adjusting investment goods production	1.993	Banerjee and Basu (2019)
Fiscal Authority			
$\frac{\overline{G}}{Y}$	Steady state proportion of government expenditures	0.27	Average government expenditure to GDP
$\frac{bG}{Y}$	Steady state proportion of government debt	0.5184	Average government debt to GDP

Table 1. Continued

Parameter	Description	Value or Target	Source
Central Bank			
ρ_r	Smoothing parameter of Taylor rule	0.66	Banerjee et al. (2020)
ϕ_π	Inflation gap coefficient of Taylor rule	1.20	Banerjee et al. (2020)
ϕ_y	Output gap coefficient of Taylor rule	0.5	Banerjee et al. (2020)
s_r	Standard deviation of shocks to short rates	0.04	Banerjee and Basu (2019)
ρ_b	Smoothing parameter of exogenous debt policy	0.8	Sims and Wu (2021)
s_b	Standard deviation of shocks to $b_{cb,t}$	0.04	Matched to s_r

Note: Most parameters correspond to the Indian economy as they are either taken from Banerjee and Basu (2019); Banerjee et al. (2020); Ghate (2012) or calibrated using Indian data. Some parameters are chosen from Aoki et al. (2016) corresponding to emerging economies.

steady-state values of government spending and government debt are chosen to match a government spending share of output at 27. 09 % and an average debt-to-GDP ratio of 51.84 %. The steady-state holding of government bonds by the central bank, denoted by B_{cb}, is aligned with the proportion of RBI assets relative to GDP, which was 13.5%. The data on corporate bond yields are sourced from Bloomberg, whereas all other data is obtained through the CEIC database. All parameters are listed in Table 1 and steady-state calculations are shown in Appendix E.

4.1 Unconventional monetary policy shock

We begin by considering impulse responses under an exogenous positive QE shock. The central bank bond-buying program is described by Equation (24). Figure 4 shows that such a shock has opposing effects on leverage and regulatory constraints. Here, the vertical axes indicate deviations of the variables from the steady state, and the horizontal axes indicate time in quarters. The bond-buying program by the central bank decreases the banks' government debt holdings, which tightens the regulatory constraint. The shortage of government debt increases its demand, which raises its price and reduces its expected return or yield.

Under a binding regulatory constraint, the financial intermediary must hold government and private bonds in a fixed proportion. The intermediary, therefore, responds to this shock by rebalancing its portfolio and reducing its holding of private bonds. In the spirit of Chari et al. (2020) and Kriwolutzy et al. (2018), this portfolio effect causes the yields of private bonds to increase and investment to fall. On the other hand, QE increases the reserves that intermediaries hold. Higher reserves, in turn, increase their net worth *through the balance-sheet equation*[9] and relax the leverage constraint. The positive net worth effect increases deposits and stimulates investment. For our baseline parameters, the portfolio effect seems to dominate, resulting in reduced investment and output.

Next, we perform the counterfactual, where we examine the impact of a QE shock on an economy without regulatory constraints. As we can see in Figure 5, in such an environment, a positive shock to QE, by increasing banks' net worth, results in an expansion of production and investment in the economy. In other words, in the absence of the regulatory constraint, a QE shock is expansionary.

To summarize, the regulatory constraint can completely invert the monetary transmission mechanism under QE: an increase in bond buying by the central bank raises the yield on private bonds and causes a contraction instead of an expansion in the economy.

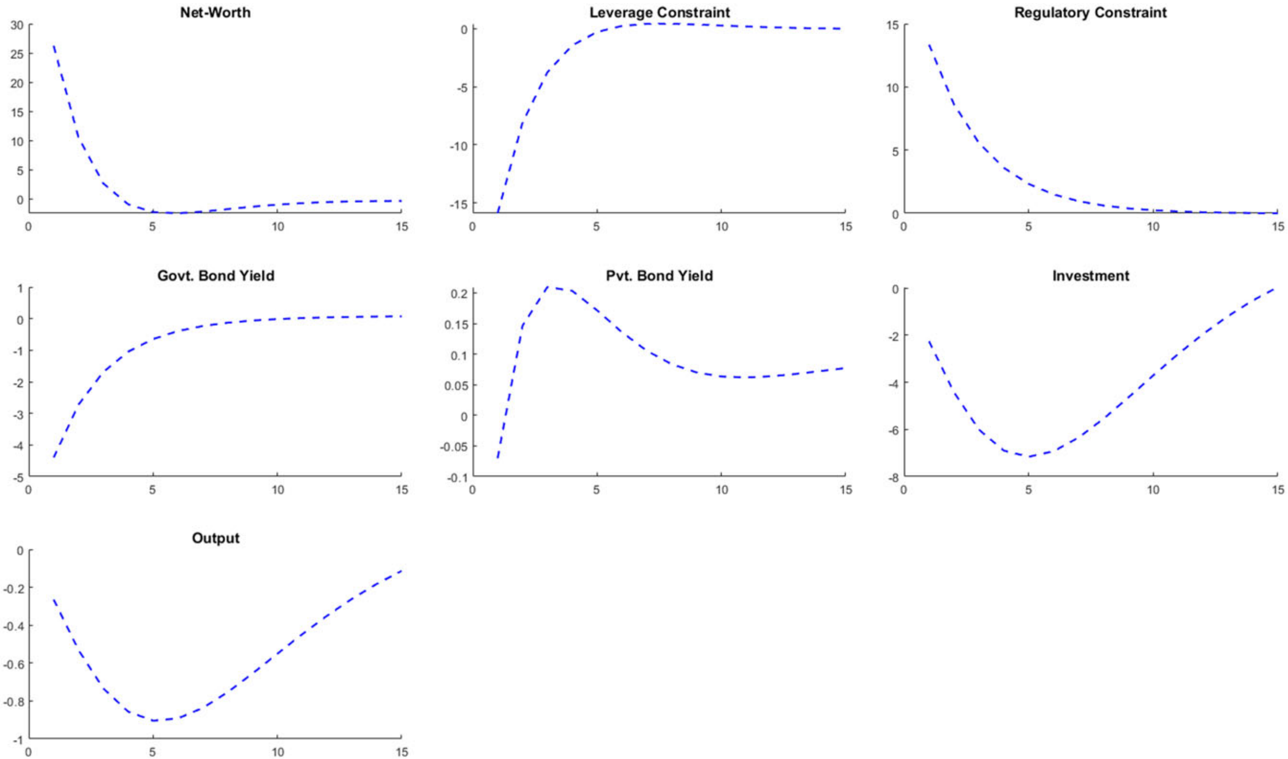

Figure 4. Impulse responses to a positive quantitative easing shock in the presence of credit regulations.
Note: All variables are in percentage points and all rates are annualized.

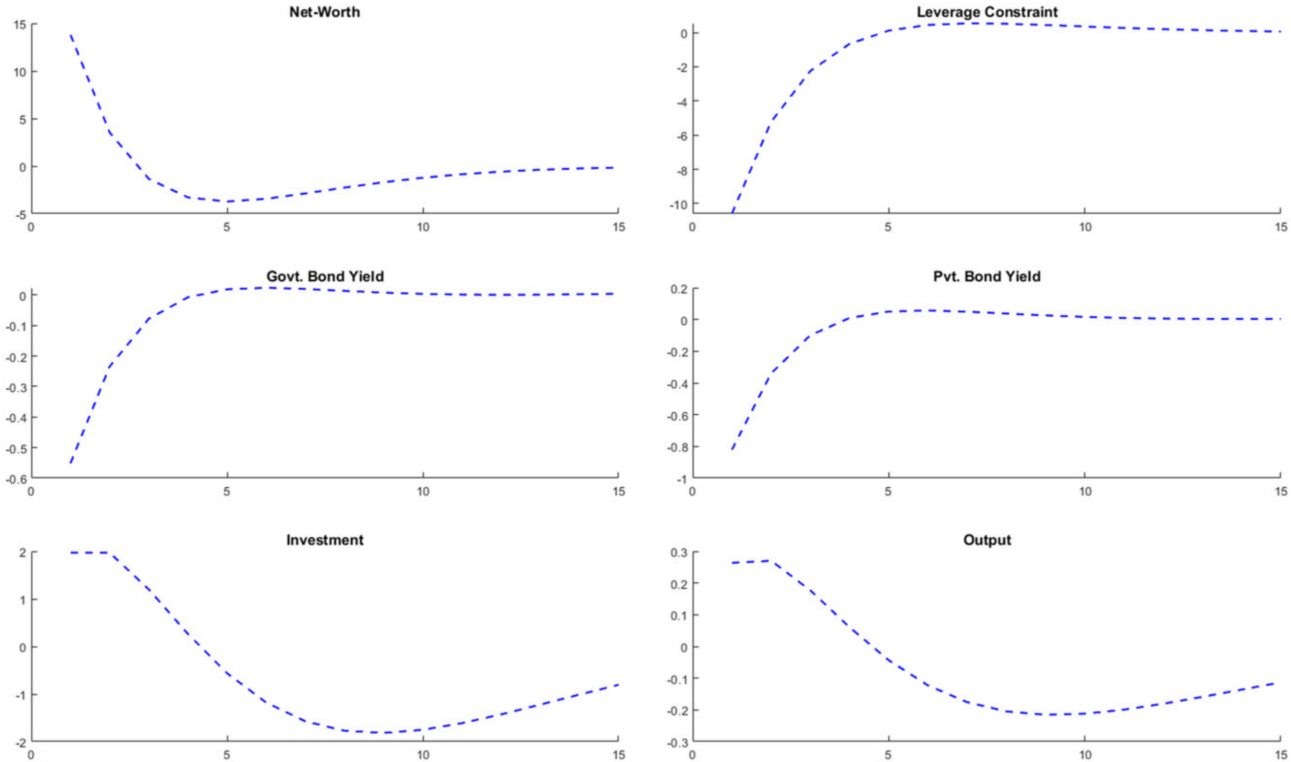

Figure 5. Impulse responses to a positive quantitative easing shock under no credit regulations.
Note: All variables are in percentage points and all rates are annualized.

4.2 Conventional monetary policy shock

Figure 6 shows the impulse responses to a negative policy rate shock. Again, this conventional expansionary policy shock has opposing effects on leverage and regulatory constraints. The reduction in the deposit rate raises excess returns earned by the intermediary on their assets, causing their net worth to increase *through the net worth accumulation Equation* (6). The positive net worth effect relaxes the leverage constraint, increasing deposits, and raising the demand for private bonds. The rise in demand for private bonds reduces their yield and stimulates investment.

However, it also tightens the regulatory constraint, as the intermediaries cannot increase their holdings of private bonds without proportionately raising their holdings of government bonds. Ultimately, it is the net worth effect that triumphs, causing investment and output to rise. In the counterfactual exercise where the regulatory constraint is absent, as shown in Figure 7, the results are qualitatively similar.

Our result here is in contrast to Lahiri and Patel (2016), who, in a simple model without leverage constraints, show that the presence of regulatory constraints can invert monetary policy transmission under conventional policy. On the contrary, we show that their result is overturned with a leverage constraint.

5. Sensitivity analysis

In this section, we look at the sensitivity of the above transmission of both monetary policies to some key parameters of interest in our model.

First, we analyze the sensitivity of monetary transmission to a change in the price stickiness parameter ϕ_p. The impulse responses corresponding to both positive QE and negative policy rate shocks remain qualitatively similar to our baseline case. However, quantitatively, a lower price stickiness ($\phi_p = 0.2$) dampens the positive jump in investment and output in the case of a rate shock (see Figure 5 of Appendix F), while the responses remain unchanged under the QE shock (see Figure 6 of Appendix F). On the other hand, a higher price-stickiness ($\phi_p = 0.9$) amplifies the responses. The above results align well with our theoretical expectations because monetary policy shocks, being a demand-side shock, get amplified by an increase in the nominal rigidity in an economy (see Figures 7 and 8 of Appendix F).

Secondly, we look at the sensitivity towards changing the loan-in-advance constraint parameter ψ. Again, the results are qualitatively robust. Since the calibrated value of ψ is already high at 0.9, therefore, we do not find any meaningful differences in impulse responses when it is increased to $\psi = 1$. However, the responses change quantitatively when we reduce the value to $\psi = 0.1$ (see Figure 9 and 10 in Appendix F). In the case of QE shock (Figure 11 of Appendix F), with a lower loan-in-advance constraint, the investment does not fall significantly as the yield increases. Therefore, the overall impact of the regulatory constraint is less than that of the baseline calibration. Similarly, in the case of rate shock (Figure 12 of Appendix F), we observe that investment does not increase significantly as the yield on private bonds decreases. These results are expected because it is the loan-in-advance constraint that transmits any changes on the financial side of the model to its real side via the investment. As the constraint becomes less stringent with a decrease in the value of ψ, the connection between the financial and real sectors of the economy is correspondingly diminished.

6. Simple rules

In the spirit of Carlstrom et al. (2017), we illustrate in this section the mechanism of monetary transmission under credit and productivity shocks in two different policy scenarios: (1) under the simple Taylor rule and (2) under term premium pegging, in which the central bank endogenously adjusts its portfolio of bonds to maintain the term premium of the government bond at the steady-state level.

Further, we go on to rank these rules based on welfare under the two shocks. For welfare-based evaluation of alternative policy regimes, we compute the lifetime utility of the household in the

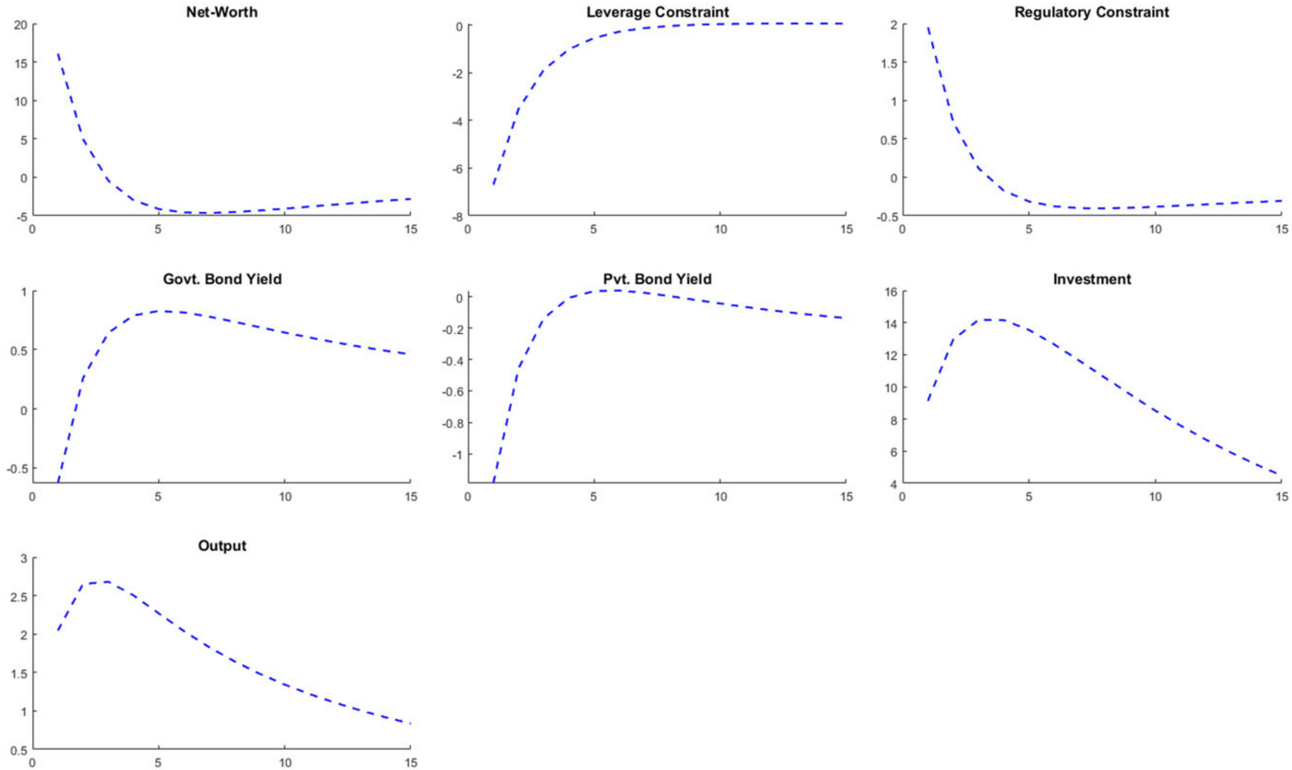

Figure 6. Impulse responses to a negative policy rate shock in the presence of credit regulations.
Note: All variables are in percentage points and all rates are annualized.

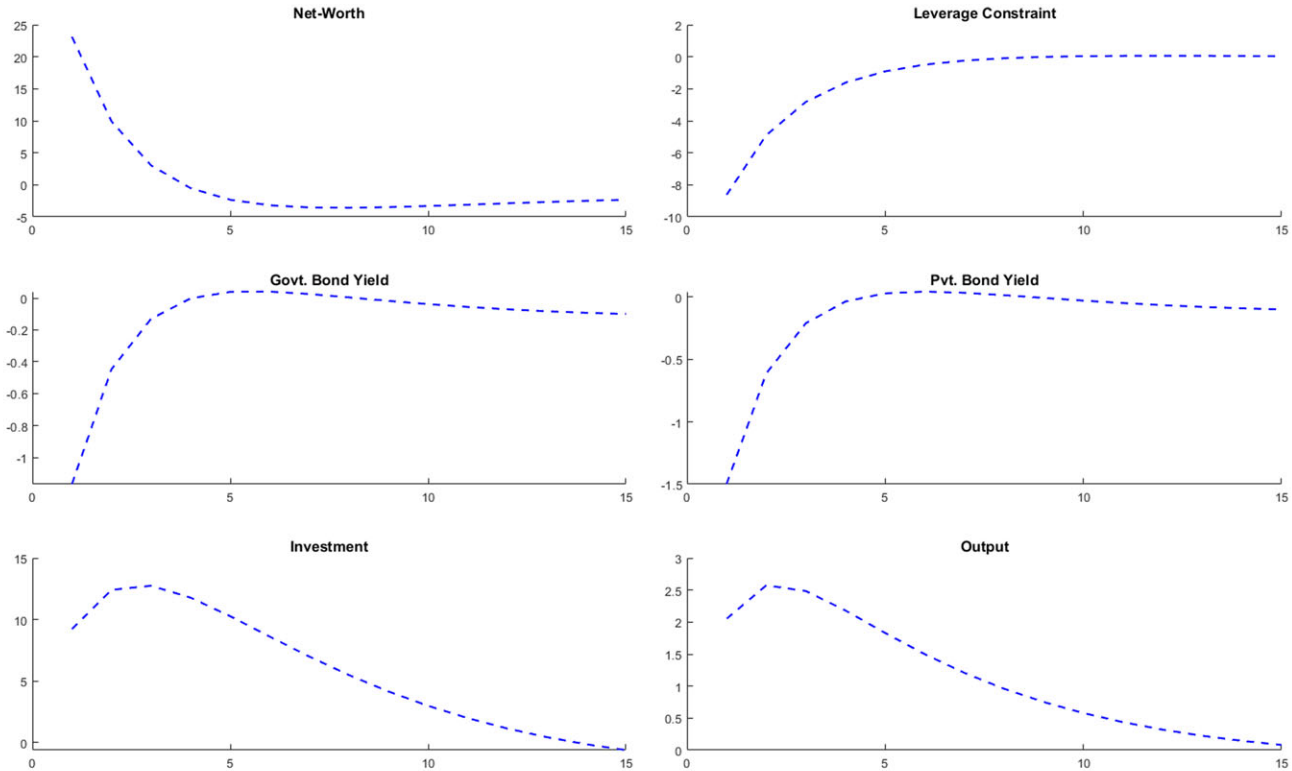

Figure 7. Impulse responses to a negative policy rate shock under no credit regulations.
Note: All variables are in percentage points and all rates are annualized.

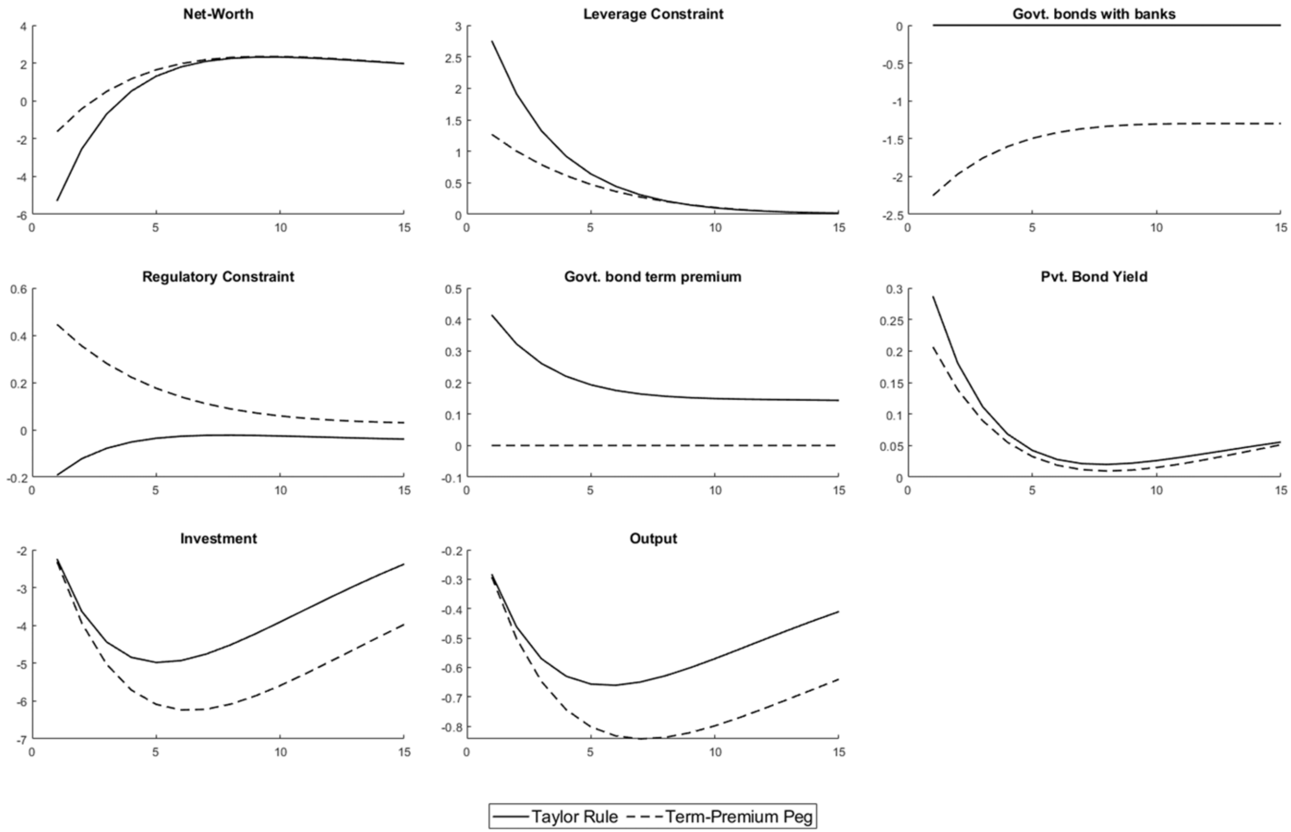

Figure 8. Impulse responses to a positive credit shock under different monetary policy regimes in the presence of credit regulations.
Note: All variables are in percentage points and all rates are annualized.

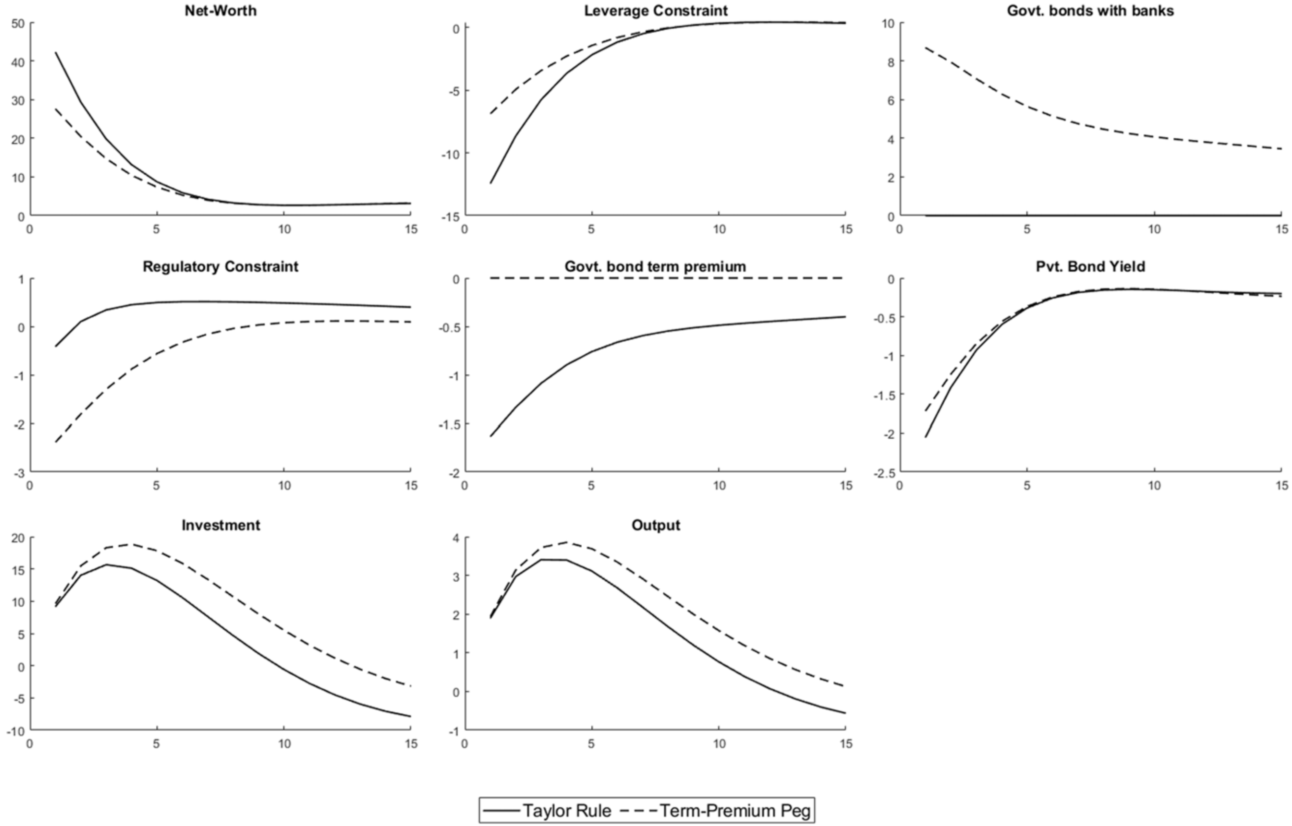

Figure 9. Impulse responses to a positive productivity shock under different monetary policy regimes in the presence of credit regulations.
Note: All variables are in percentage points and all rates are annualized.

presence of business cycles resulting from each shock and compare it to that under the steady state. We measure the welfare cost of business cycles caused by a shock as the fraction ξ of the non-stochastic steady-state consumption stream that households are willing to forego in order to be indifferent between the lifetime utility under the steady state and that under the stochastic equilibrium path of alternative monetary policy regimes. Formally, it means equalizing the present discounted value of lifetime utility across the two consumption and labor sequences, i.e.,

$$U((1-\xi)C, L) = \mathbb{E}[U(C_t^a, L_t^a)] \tag{26}$$

Here, $\{C, L\}$ are the constant steady state consumption and labor values while $\{C_t^a, L_t^a\}$ corresponds to the equilibrium path under alternative policies, and $\mathbb{E}$ denotes the unconditional expectations operator. We solve for ξ numerically by evaluating $U(.)$ on the right-hand side up to the second order.[10]

Note that $\xi > 0$ means the household needs to give up consumption under the steady state if it wants to achieve the same welfare as the alternative policy regime. However, $\xi < 0$ means that the household is better in an alternative regime than in the steady state.

6.1 Credit shock

An adverse credit shock (Figure 8), that is, a positive shock to θ_t, magnifies the agency cost problem by increasing the assets that financial intermediaries can divert. Consequently, the leverage constraint tightens, increasing the yields of government and private bonds. Under a term premium peg, the central bank responds by purchasing government bonds to lower the yields. It follows from quations (11) and (12) that, in the absence of regulatory constraints ($\zeta_{it} = 0$), such a policy completely neutralizes credit shocks.

Intuitively, the purchase of government bonds under this regime relaxes the leverage constraint by changing the composition of the intermediary's assets from government bonds to reserves (see Equation (8)). As shown in Carlstrom et al. (2017), the relaxation of the leverage constraint completely sterilizes the real economy from credit shocks. However, with credit regulations ($\zeta_{it} \neq 0$), the purchase of bonds by the central bank tightens the regulatory constraint. The financial intermediary responds by rebalancing its portfolio and reducing its holding of private bonds. As a consequence of this portfolio effect, the term premiums on private bonds increase, which causes investment and output to fall.

By contrast, under Taylor rule, the absence of a portfolio rebalancing effect relaxes the leverage constraint. Relative to the peg, the lower term premium on private bonds mitigates to some extent the impact of adverse credit shocks. As a result, the fall in investment and output is less in this regime. The comparison of welfare performances of the term-premium peg relative to the simple Taylor rule vindicates the above discussion. Table 2 shows that the simple Taylor rule welfare dominates the term premium peg.

Our results suggest that the presence of regulations reduces the efficacy of a term premium targeting policy in countering credit shocks. As emphasized earlier, these results are in contrast to Carlstrom et al. (2017), who find the term premium peg to be welfare enhancing.

6.2 Productivity shock

Figure 9 shows that a temporary rise in productivity by lowering the marginal cost of production causes inflation to fall. The central bank responds by reducing rates to stabilize inflation. As mentioned earlier, lower interest rates raise the financial intermediary's net worth by increasing the excess returns earned on their assets. The positive impact on net worth relaxes the intermediary's leverage constraint and raises their demand for private bonds. The increase in demand for private bonds raises their price, lowers the yield, and tightens the regulatory constraint. To maintain a fixed proportion under credit regulation, the demand for government bonds also increases, lowering their yield or term premium.

Table 2. Comparison of welfare costs under alternative monetary policy regimes (measured in percentage points of steady state consumption stream)

Credit Shock	
Monetary Policy	Welfare Cost (ξ)
Term-Premium Pegging	0.32
Taylor Rule	0.22
Productivity Shock	
Monetary Policy	Welfare Cost (ξ)
Term-Premium Pegging	3.30
Taylor Rule	3.54

Table 3. Comparison of welfare costs under alternative monetary policy regimes (measured in percentage points of steady state consumption stream) for different values of Γ

Credit Shock		
Monetary Policy	Welfare Cost (ξ) ($\Gamma = 0.27$)	Welfare Cost (ξ) ($\Gamma = 0.33$)
Term-Premium Pegging	0.28	0.49
Taylor Rule	0.20	0.31
Productivity Shock		
Monetary Policy	Welfare Cost (ξ) ($\Gamma = 0.27$)	Welfare Cost (ξ) ($\Gamma = 0.33$)
Term-Premium Pegging	3.16	3.87
Taylor Rule	3.41	3.89

Note: (1) To compute welfare cost, we use second-order approximation on Dynare. It is calculated empirically by simulating a long series for 1,00,000 periods after the shock. (2) Similar to figure 3, the lower and upper bounds for regulatory parameter Γ correspond to the limiting cases of Δ and θ approaching unity in the steady state, respectively.

Under a term premium peg, the central bank responds to the falling term premium by selling government bonds. Such a policy relaxes the regulatory constraint, enabling the intermediary to increase its purchase of private bonds and stimulate investment. Under a Taylor rule, the absence of the above central bank intervention means that the rise in investment and output is lower under this regime. Table 2, which welfare ranks the rules, supports the intuition obtained from the impulse responses. The term premium peg outperforms a simple Taylor rule in the case of productivity shocks. This result is in contrast to those obtained in the case of a credit shock.

In the spirit of Poole (1970), our analysis suggests that the nature of the shock determines the choice of the monetary policy regime. In the presence of credit regulations, the model prescribes adopting a term premium peg when productivity shocks are predominant and a simple Taylor rule when credit shocks are predominant.

Next, we examine the impact on welfare when we change the regulatory constraint parameter Γ. Table 3 indicates that our results are robust to this change—Taylor rule does better under credit shocks, while the term premium peg performs better under productivity shocks. Notice also that the reduction (rise) of the portfolio effect results in a relative improvement (reduction) in the performance of the term premium peg under credit shocks and the Taylor rule under productivity shocks.

7. Conclusion

How does credit regulation affect the transmission of monetary policy? We examine this question in the context of both conventional and unconventional monetary policies. Credit regulation policies that force banks to hold a fraction of their assets in the form of government bonds drive a wedge between the return on government and private bonds. In such an environment, we show that monetary policy transmission is inverted under a quantitative easing program, in contrast to a conventional policy rate shock. Essentially, an expansionary QE program, while lowering the government bond yield, tightens the regulatory constraint, and raises the yield on private bonds. Consequently, investment falls, and the economy contracts.

We then compare the performance from a welfare perspective of an endogenous QE program that pegs the government bond term premium with a simple Taylor rule. Our results indicate that the performance of the endogenous QE program depends on the nature of the shock impacting the economy. While such a program trumps the Taylor rule in the case of productivity shocks, it performs poorly in the case of credit shocks.

The key contribution of this paper is to highlight the differences in the transmission mechanism of conventional and unconventional monetary policies in the presence of credit regulation. A natural extension of our work is to incorporate alternative means of financing, such as equity financing for firms, and to model the maturity structure of debt and bond duration explicitly. We leave this exercise for future work.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/S1365100524000373

Notes

1 Sorkin (2010) lists examples of pressure by the federal government on U.S. banks. Treasury Secretary Hank Paulson, in a meeting of the CEOs of the largest U.S. banks, where they were asked to acquire Lehman Brothers, is said to have remarked, "This is about our capital markets, our country. We will remember anyone who is not seen as helpful."

2 The figure is based on aggregate bond holding by the banks in 202 economies whose data is available in BankFocus.

3 Note that an endogenous QE policy may also involve the central bank selling government bonds to banks, in which case it functions similar to quantitative tightening (QT).

4 See Kuttner (2018) for an excellent survey

5 In this paper, long-term debt is in the form of perpetual bonds as described in detail in Appendix B.

6 The reserves are one-period nominal bonds like household deposits and pay a gross return of R_t^{re} in period $t+1$.

7 In the paper, we consider the regulatory constraint applicable on long-term government bonds only. In Appendix D, we also consider the case when it is applicable on short-term bonds as well.

8 In our quantitative analysis, one period is one quarter and we consider $(1-\kappa)^{-1} = 40$, which means that the long-term bond is actually a 10-year bond.

9 Reserves may appear to have no effect on net worth using the net worth accumulation Equation (6) as $R_t^{re} = R_t^D$, but they can alter net worth through the balance-sheet Equation (5).

10 Similar to Galí and Monacelli (2016), there is no closed-form analytical expression for welfare loss corresponding to our DSGE model. Therefore, we simulate a long series of 1,00,000 periods after the shock so that the expected value of lifetime utility under the alternative policy regime is accurately computed.

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Cite this article: Kumar A, Rao R and Subramanian C (2024). "Conventional vs. unconventional monetary policy under credit regulation." *Macroeconomic Dynamics* **29**(e52), 1–27. https://doi.org/10.1017/S1365100524000373