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Financial Frictions and Credit Spreads

Ke Pang and Pierre L. Siklos*

Abstract

This paper uses the credit-friction model developed by Cúrdia and Woodford, in a series of papers, as the basis for attempting to mimic the behavior of credit spreads in moderate as well as crisis times. We are able to generate movements in representative credit spreads that are, at times, both sharp and volatile. We then study the impact of quantitative easing and credit easing. Credit easing is found to reduce spreads, unlike quantitative easing, which has opposite effects. The relative advantage of credit easing becomes even clearer when we allow borrowers to default on their loans. Since increases in default offset the beneficial effects of credit easing on spreads, the policy implication is that, in times of financial stress, the central bank should be aggressive when applying credit easing policies.

JEL Codes: E43, E44, E51, E58.
Keywords: Credit easing, credit spread, financial friction, quantitative easing.

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Nontechnical Summary

In this paper we propose a strategy that incorporates credit frictions into what has come to be known as the canonical model (e.g., Woodford (2003)). The model used by Cúrdia and Woodford, in a series of recent papers, serves as the basis for attempting to mimic the behavior of credit spreads during moderate as well as crisis times. Next, we consider some experiments to determine the impact of two approaches to monetary policy making implemented during the recent global financial crisis, namely, quantitative easing and credit easing. It is found that their impact on credit spreads is dissimilar and this suggests that policy makers need to be able to quickly identify the source of the financial shock if they are to successfully address extreme stresses to the financial system. It is also worth noting that debt dynamics in the model are such that total credit to GDP in the economy is not as persistent as it is in the realized data. Alternatively, we may wish to modify the intermediation cost technology to permit intermediaries to fail, or households to default on their loans. Failing that, alternative proxies for the largely unobservable intermediation costs should be considered. Changing the inflation target in the version of the Taylor rule used here is another modification we could make. Finally, the current exercise would be more meaningful still by asking whether, if the results derived here are taken to the data, there is support for the interpretation of credit spreads put forward in this paper.

1. Introduction

The financial crisis, which began in earnest in the summer of 2007, has exposed the need for macroeconomic analysis to more explicitly embed imperfections, notably financial frictions, into the canonical macro model that many academics and policy makers routinely employ in policy analysis. While the weaknesses of the canonical model (Woodford (2003)) are well-known (e.g., Goodhart (2008), Tovar (2008), Chari et al. (2009)), the profession has not yet given up on this approach to the analysis of monetary policy.[1] For example, Goodfriend and McCallum (2007) show that an otherwise standard optimizing model, variants of which are now the staple of models used by central banks in policy analysis, is capable of explaining credit spreads. Understanding movements in these spreads, and their behavior in response both to shocks and to policies, is considered to be a central element in modeling the role of financial markets in the macroeconomy (e.g., see also Graeve (2008)). Moreover, it has been known for some time that the credit channel plays a critical role in the monetary policy transmission mechanism (e.g., Bernanke and Gertler (1989, 1995)).Consequently, financial frictions, as reflected in interest rate spreads, can also have large economic effects, as the ongoing financial crisis clearly demonstrates.

Walsh (2009) points out that a good understanding of the "factors that generate movements in spreads, or the degree to which these movements reflect inefficient fluctuations that call for policy responses" still eludes us. In this paper we focus on trying to model the behavior of credit spreads in a DSGE model with financial frictions. Financial frictions come in many forms. One view is that creditors are reluctant to lend for fear of not being repaid. Another type of friction shows up as spreads remaining high because debt is undervalued. Hence, lenders are not making loans that they would otherwise have made. Either way, there is a cost associated with the lending activity, such as the cost of initiating and monitoring lending activity, which is assumed, for the purposes of this paper, to be reflected in the spread. It may be too much to ask, of course, for a modified consensus model to be capable of fully replicating movements in actual credit spreads. Even if we are reasonably successful in explaining a good deal of what moves credit spreads during calm and turbulent times there is always the possibility that the events of 2007–2009 are unlike previous financial crises (e.g., see Cecchetti et al. (2009)). Indeed, recent evidence (e.g., see Gilchrist et al. (2009)) highlights the fact that standard proxies for the credit spread, such as the ones used in this paper, need not yield the greatest predictive power for future economic activity. Nevertheless, it is also clear that monitoring and understanding movements in credit spreads may well be an indirect contributing factor in proposals for reforming monetary and financial policies going forward. For example, Siegel (2010) points out that markets were indeed suspicious of the quality of mortgage backed securities and this was reflected in the behavior of spreads between high quality mortgage securities and corporate bonds in advance of the outbreak of the latest financial crisis. Therefore, while attempts to make the connection between financial frictions and credit spreads are unlikely to be able to capture idiosyncratic elements present in any financial crisis, the stylized model proposed in this paper can replicate the kinds of sharp movements and volatility that were observed in some credit spreads that policy makers have highlighted in describing the global financial crisis.

Figure 1 provides several illustrations of credit spreads, including the libor-ois spread highlighted by Taylor and Williams (2009). Also shown are the 10 year-3 month and the 3 month-fed funds spreads, both of which are the staple of many macroeconomic analyses of the term

[1] As Altig (2005) points out, not only do variants of the New Keynesian approach, whatever its faults, lie at the core of models used by central banks, but also these models provide the necessary context to explain how monetary policy is practiced.

structure (e.g., see Melino (1988)). The Baa-Aaa and the prime rate-fed funds spreads have also been used as indicators of financial stress since they tend to rise during recessions.[2] In spite of differences in the behavior of these spreads they all display certain common features, notably large changes in the levels particularly beginning around 2008, reflecting the rising stress in credit markets, culminating in sudden movements prompted by large shocks to the financial system in the aftermath of the failure of Lehman Brothers.[3]

The aim of this paper then is to apply a simple macro model with financial frictions to replicate actual movements in credit spreads. We adopt the basic credit-friction model developed by Cúrdia and Woodford (2009a,b,c, 2010). However, we assume that the policy authorities use an optimizing model where the policy instrument is adjusted so that the central bank effectively hits a desired inflation rate at an appropriate horizon. The goal is reached because the central bank operates on the basis of optimal policy projections which asymptotically approach a steady state (see Rudebusch and Svensson (1999), or Svensson and Tetlow (2005)). As a result, the policy instrument becomes an implicit function of current information. This keeps the model tractable.

The assumptions in the Cúrdia and Woodford framework that agents are heterogeneous, that credit frictions exist, and that central bank policies should be identified according to whether or not the composition of its balance sheet is affected, are especially appealing under the current circumstances. Nevertheless, a few other modifications to the Cúrdia and Woodford framework are also introduced to enable us to focus more directly on the question of explaining movements in a credit spread. In particular, we solve the model numerically (using a nonlinear method). Also, actual time series for the exogenous driving forces are used to generate a time series pattern for the simulated credit spread. More importantly, we add default risk to the model, in recognition of the possibility that the financial market seizes up from time to time because there is a change in loan default rates. Once the model is outlined, and its equilibrium conditions are derived, we then ask two policy relevant questions. Can a simple credit-friction model explain the credit spread observed in the data? To what extent are these spreads driven by the exogenous shocks in our model or the intermediation costs that drive a wedge between borrowing and lending rates? We next consider the following policy exercises: how can monetary policy influence such spreads? More precisely, what are the qualitative differences between quantitative easing (QE) and credit easing (CE) policies? According to Bernanke (2009), quantitative easing amounts to actions that center on the liabilities of the central bank. In contrast, credit easing policies focus on the composition of the asset side of the central bank's balance sheet. In the present context, credit easing takes place through an increase in the central bank's direct lending to households. Insights about the impact of quantitative easing are obtained by considering an injection of bank reserves. The results reveal that the short-run impact of credit easing and quantitative easing policies are almost diametrically opposite to each other. In the long run, however, the differences between the two policies are more modest, but they still favor the credit easing policy. While a more conclusive policy assessment awaits further refinements to the model, our results go part way to fulfilling one of the 'homework assignments' Kohn (2010), former Vice-Chair of the Board of Governors of the U.S. Federal Reserve, challenged the profession to tackle in future. Our model also shows that quantitative easing need not be inflationary, though this is likely because the inflation target in our model is always met and, hence, is credible in the steady state.

[2] Recessions are represented by the shaded areas in the various figures and the dates are from the NBER reference cycle chronology.

[3] The vertical dashed lines represent a demarcation point as some of the data used as inputs into the model to simulate a credit spread are only available until 2004.

The rest of the paper is organized as follows. Section 2 outlines the main features of the model. The calibration exercise is detailed in section 3. Section 4 describes the solution and provides an account of the model's performance. Section 5 discusses the implications of quantitative versus credit easing monetary policies. Section 6 concludes with a summary and suggests some avenues for future research.

2. Model

Here we follow the basic structure of the Cúrdia and Woodford framework. The model is mostly in line with the standard New Keynesian model, except that it features heterogeneous households and inefficient financial intermediation.

2.1 Households

Households differ in their preferences. In a given period, each household can be one of the two types, $\{b, s\}$, according to their impatience to consume. Type b households are more impatient to consume than type s households. Each period, with probability δ $(0 \leq \delta < 1)$, the household remains the same type as in the previous period; with probability $1-\delta$, a new type is drawn, and the household becomes type b with probability π_b and type s with probability π_s $(0 < \pi_b, \pi_s < 1$, $\pi_b + \pi_s = 1)$.

Household i's lifetime utility is of the form

$$\sum_{t=0}^{\infty} \beta^t \{U^{\tau_t(i)}[c_t(i)] - V^{\tau_t(i)}[h_t(i)]\} \tag{2.1}$$

where $\tau_t(i) \in \{b, s\}$ indicates the household's type in period t. In equilibrium, type b households borrow, while type s households have positive savings in every period.

Households cannot directly borrow from or lend to each other. All financial contracting has to be done through the financial intermediary sector. For simplicity, we assume that only one-period riskless nominal contracts with the intermediary are available for either savers or borrowers. To facilitate aggregation, we assume that households are able to sign state-contingent contracts with one another on random dates to insure against both aggregate risks and idiosyncratic risks. The implications of this assumption are spelled out in Cúrdia and Woodford (2009a,b,c, 2010).[4]

Two factors in this model (heterogeneous households and financial frictions) give a key role for financial intermediation. At the same time, the model is still simple and tractable. We further assume that the random dates on which households have access to insurance are the same dates on which a new type is drawn. Thus, with probability $1-\delta$, household i has access to insurance at the beginning of each period; after receiving the insurance transfer, the household learns its new type, and then makes optimal decisions based on its type and its post-transfer wealth.

[4] In essence, the impact is that households' expectations about their marginal utility of income is identical, regardless of their borrowing or saving histories.

Household i's beginning-of-period (post-transfer) nominal net wealth $A_t(i)$ is given by

$$A_t(i) = [B_{t-1}(i)]^{+}(1 + i^d_{t-1}) + [B_{t-1}(i)]^{-}(1 + i^b_{t-1}) + D^{int}_t(i) + T_t(i) \tag{2.2}$$

where $B_{t-1}(i)$ is the household's nominal net wealth at the end of period $t-1$, $[B]^+ \equiv max(B, 0)$, $[B]^- \equiv min(B, 0)$. i^d_{t-1} is the one-period riskless nominal interest rate that savers receive on their deposits at the beginning of period t from the financial intermediaries. i^b_{t-1} is the interest rate that borrowers need to pay to the intermediaries at the beginning of period t. $D^{int}_t(i)$ represents the distributed profits of the financial intermediaries received by household i at the beginning of period t. $T_t(i)$ is the net insurance transfer received by household i at the beginning of period t. Note that for a household which has no access to insurance, $T_t(i) = 0$, while $\int_0^1 T_t(i)di \equiv 0$.

Household i's end-of-period nominal net wealth $B_t(i)$ is given by the household's budget constraint

$$B_t(i) = A_t(i) - P_t c_t(i) + W_t h_t(i) + D_t(i) + T^g_t(i) \tag{2.3}$$

where W_t is the nominal wage rate in period t. $D_t(i)$ is household i's share in the distributed profits of firms. $T^g_t(i)$ is the net nominal lump-sum government transfer received by household i in period t.

Each household i maximizes its lifetime utility (2.1) subject to (2.2) and (2.3). Household i's optimal labor-supply decision is given by the following intratemporal Euler equation

$$w_t \lambda^{\tau_t(i)}_t = V^{\tau_t(i)}_h [h^{\tau_t(i)}_t] \tag{2.4}$$

where w_t is the real wage rate in period t, $w_t = \frac{W_t}{P_t}$, and $\lambda^{\tau_t(i)}_t$ is the household's marginal utility of real income in period t, $\lambda^{\tau_t(i)}_t = U^{\tau_t(i)}_c [c^{\tau_t(i)}_t]$. Moreover, a borrower's optimal consumption-borrowing decision is given by the following intertemporal Euler equation,

$$\lambda^b_t = \beta \frac{1 + i^b_t}{\Pi_{t+1}} \{[\delta + (1-\delta)\pi_b]\lambda^b_{t+1} + (1-\delta)\pi_s \lambda^s_{t+1}\} \tag{2.5}$$

while a saver's optimal consumption-saving decision is given by

$$\lambda^s_t = \beta \frac{1 + i^d_t}{\Pi_{t+1}} \{(1-\delta)\pi_b \lambda^b_{t+1} + [\delta + (1-\delta)\pi_s]\lambda^s_{t+1}\} \tag{2.6}$$

where Π_{t+1} is the inflation rate between period t and $t+1$, $\Pi_{t+1} = \frac{P_{t+1}}{P_t}$.

2.2 Financial Intermediaries

The financial intermediary sector is perfectly competitive. The technology of financial intermediaries is given by

$$d_t = b_t + \Phi(b_t) \tag{2.7}$$

where d_t is the aggregate real deposit with the intermediaries at the end of period t and b_t is the aggregate real credit from the intermediaries at the end of period t. $\Phi(b_t)$ represents the real resources consumed by the intermediary sector. All intermediaries operate on the same scale. The distributed profits of intermediaries are given by

$$D_{t+1}^{int} = P_t[(1+i_t^b)b_t - (1+i_t^d)d_t] \tag{2.8}$$

Intermediaries, taking interest rates as given, supply credits to maximize their profit (2.8) subject to (2.7). Let ω_t denote the spread between deposit rates and lending rates

$$1 + i_t^b = (1+\omega_t)(1+i_t^d) \tag{2.9}$$

The equilibrium spread is then given by

$$\omega_t = \Phi'(b_t) \tag{2.10}$$

Clearly, it is the intermediation cost (credit friction) that drives the behavior of the spread.

2.3 Firms

There is only one good in the model. The goods sector is perfectly competitive. Firms, taking goods price and wage rate as given, maximize their profits

$$D_t = (1-\tau_t)P_tY_t - W_th_t \tag{2.11}$$

subject to an isoelastic production function

$$Y_t = Z_th_t^{\alpha}, \quad 0 < \alpha \leq 1 \tag{2.12}$$

τ_t is the rate of a proportional tax on the firm's revenue. Z_t is the productivity shock. The equilibrium real wage is given by

$$w_t = \alpha(1-\tau_t)Z_th_t^{\alpha-1} \tag{2.13}$$

2.4 Government

Government runs a balanced budget every period,

$$\tau_t = g_t + \tau_t^g \tag{2.14}$$

where g_t is the government expenditure to GDP ratio, $g_t = \frac{G_t}{Y_t}$, and τ_t^g is the government transfer to GDP ratio, $\tau_t^g = \frac{T_t^g}{P_tY_t}$.

2.5 Monetary Policy

The monetary authority sets the policy rate (i.e., the deposit rate i_t^d) according to a Taylor rule:

$$i_t^d = \bar{\imath}^d \left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\gamma_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\gamma_y}, \quad \gamma_\pi, \gamma_y \geq 0 \tag{2.15}$$

where $\bar{X} = [\overline{\Pi}, \overline{Y}]$ represents the targeted (steady state) level of the corresponding variable X. Here, we focus on the steady state with zero inflation ($\bar{\Pi} \equiv 1$). γ_π and γ_y reflect the stance of monetary policy, and the relative importance that the central bank attaches to inflation and output stabilization.[5]

2.6 Market Clearing Conditions

We close the model with the market clearing condition for the goods market

$$Y_t = \pi_b c_t^b + \pi_s c_t^s + G_t + \Phi(b_t) \tag{2.16}$$

and the market clearing condition for the labor market

$$h_t = \pi_b h_t^b + \pi_s h_t^s \tag{2.17}$$

2.7 Dynamics of Bank Credit

The aggregate real credit b_t from the financial intermediaries is the state variable of this model. It is important to understand how bank credit changes over time.

Integrating all borrowers in period t, their net beginning-of-period assets can be written as

$$\int_{B_t} A_t(i)di = -\delta P_{t-1} b_{t-1}(1 + i_{t-1}^b) + \delta \pi_b D_t^{int} + (1-\delta)\pi_b A_t \tag{2.18}$$

where the aggregate beginning-of-period assets A_t of all households are given by

$$A_t = P_{t-1}[d_{t-1}(1 + i_{t-1}^d) - b_{t-1}(1 + i_{t-1}^b)] + D_t^{int} \tag{2.19}$$

Next, integrate all borrowers' budget constraint,

$$P_t b_t = -\int_{B_t} A_t(i)di + \pi_b(P_t c_t^b - W_t h_t^b - D_t - T_t^g) \tag{2.20}$$

Substituting (2.7)-(2.9), (2.11), (2.14), (2.16), and (2.18)–(2.19) into (2.20), we have

$$\begin{aligned} b_t = {} & \pi_b \pi_s [(c_t^b - c_t^s) - w_t(h_t^b - h_t^s)] - \pi_b \Phi(b_t) \\ & + \frac{\delta(1 + i_{t-1}^d)}{\Pi_t}[b_{t-1} + \pi_b \Phi(b_{t-1}) + \pi_s b_{t-1}\omega_{t-1}] \end{aligned} \tag{2.21}$$

[5] Cúrdia and Woodford (2009c) conclude that monetary policy functions are not improved by adding a proxy for the credit spread. The contemporaneous form of the reaction function is also consistent with the standard portrayal of the Taylor rule. Under the setup of this paper a more forward-looking policy reaction function would not add any additional insights to the conclusions about the relative differences between quantitative easing and credit easing policies.

2.8 Equilibrium

The equilibrium is defined as a set of quantities $\{c_t^b,\ c_t^s,\ h_t^b,\ h_t^s,\ b_t,\ Y_t,\ h_t\}$, and a set of prices $\{i_t^d,\ \Pi_t,\ \omega_t,\ w_t\}$, that satisfy equation (2.4) for each type, and equations (2.5)–(2.6), (2.10), (2.12)–(2.17), and (2.21) given the aggregate exogenous driving forces $\{Z_t,\ g_t,\ \tau_t\}$.

3. Model Calibration

Households' preferences are of the forms

$$U^\tau(c_t^\tau) = \frac{\theta^\tau (c_t^\tau)^{1-\frac{1}{\sigma^\tau}}}{1-\frac{1}{\sigma^\tau}}, \quad \theta^\tau > 0,\ \sigma^\tau > 0 \tag{3.22}$$

$$V^\tau(h_t^\tau) = \frac{\phi^\tau (h_t^\tau)^{1+\nu}}{1+\nu}, \quad \phi^\tau > 0,\ \nu \geq 0 \tag{3.23}$$

where θ^τ and ϕ^τ are type-specific preference parameters. ν is the elasticity of labor supply. σ^τ is the intertemporal elasticity of substitution of each type of household. In particular, we assume that borrowers are more willing to substitute intertemporally than savers, $\sigma^b > \sigma^s$.

The intermediation cost is assumed to take the following linear-quadratic form

$$\Phi(b_t) = \phi_1 b_t + \phi_2 (b_t - \bar{b})^2, \quad \phi_1, \phi_2 > 0 \tag{3.24}$$

where ϕ_1 can be interpreted as the unit cost of initiating and monitoring loans. Moreover, $\bar{\omega} = \phi_1$ in the steady state. The quadratic term captures the utilization cost of the financial intermediary sector. It is conceivable that any country's financial system has certain equilibrium capacity. Running above or below capacity can, accordingly, be costly.[6]

The model is calibrated at an annual frequency. We set $\delta = 0.9$ so that the expected time until a household has access to insurance is 10 years. We assume that there are equal numbers of borrowers and savers, $\pi_b = \pi_s = 0.5$. In addition, we calibrate the discount factor β so that the annual deposit rate is 4%. Normalizing ϕ^s to unity, ϕ^b is calibrated so that the two types of households work the same amount of time in the long run, $\bar{h}^b = \bar{h}^s$. Furthermore, ϕ_1 is calibrated so that the steady state credit spread is 2%.[7] Finally, we calibrate the preference parameters θ^b and θ^s so that the steady state debt to GDP ratio is 80%.[8]

Actual time series of the exogenous driving forces $\{Z_t,\ g_t,\ \tau_t\}$ are constructed using data from Chen et al. (2008).[9] Figure 2 plots the actual series of these driving forces over the 1960–2004

[6] Cúrdia and Woodford (2009a,b,c, 2010) assume that $\Phi(b_t)$ is a convex function of the outstanding credit, i.e., $\Phi(b_t) = \phi b_t^\eta,\ \ \phi > 0,\ \eta > 1$. There are two drawbacks to this assumption. First, to generate the type of movements of spreads observed in the data, η has to be very high, i.e., $\eta = 51.6$ in their benchmark calibration (the results are not shown but are available on request). Second, spreads have to be positive in the steady state. In contrast, a linear-quadratic intermediation cost allows us to calibrate the model to any long-run level of the credit spreads (even negative numbers), and, at the same time, replicate the dynamics of spreads using a much simpler and more intuitive functional form.

[7] For example, the mean credit spread between the yield on 10-year U.S. government bonds and 3-month Treasury bills is 1.84% between 1984 and 2009. The year 1984 is chosen to avoid including the period when monetary policy procedures changed at the Fed during Paul Volcker's chairmanship of the FOMC.

[8] W.l.o.g., the steady state (potential) output is normalized to unity ($\bar{Y} \equiv 1$).

[9] We have used data from other sources, and the results are robust. $\bar{Z}$ is always normalized to unity, $\bar{Z} \equiv 1$. To obtain the TFP levels data we arbitrarily create an index set to 1 in 1959. We apply an HP filter to the log level

period for which data are available. We set their steady state values at the corresponding sample means. Table 1 provides the full list of parameters in the benchmark case. Notice that we have set $\phi_2 = 1$. The results are robust to the choice of ϕ_1 and ϕ_2 (see the appendix for sensitivity analyses).

Our strategy is to compute the transitional dynamics of the credit-friction model, given the initial deposit rate (i_0^d) and the initial level of private debt (b_0). We obtain our solution by numerically solving a system of non-linear equations. The baseline model can be reduced to a minimum of eight endogenous variables $\{c_t^b,\ c_t^s,\ h_t^b,\ h_t^s,\ b_t,\ i_t^d,\ \Pi_t,\ \omega_t\}$ with eight associated equilibrium conditions in each period. We allow 200 periods for the economy to converge to the steady state. We stack all the 1,600 equations together and solve the resulting system for the 1,600 unknowns. The sparsity of the Jacobian matrix makes solving such a big nonlinear system practical. We calculate the close-form Jacobian and use the large scale algorithm of the 'fsolve'function in Matlab to solve the model.

4. Solution of the Benchmark Model

We now show our basic numerical results. We report five sets of results: (1) the benchmark case with all exogenous driving forces; (2) only TFP and all the other shocks set to their steady state values; (3) all except TFP shocks; (4) only firm revenue tax shocks; (5) only government expenditure shocks.

Figure 3 plots the model-generated credit spread against the observed spreads between the ten-year government bond yield and the three-month government bond yield (upper left panel), between the three-month government bond yield and the federal fund rate (upper right panel), between the prime rate and the federal fund rate (lower left panel), and between the Moody's Baa and Aaa rated corporate bond yields (lower right panel). Recall that, in our setup, we can simply change the shift parameter arbitrarily to facilitate matching the mean levels of the simulated and realized spreads. Hence, it is a simple matter to modify the simulations to lower it from the steady state of 2% to some other historical average. For example, the simulated spread could be reduced by a constant factor so that it overlaps the spread between three-month government bonds and the fed funds rate (top right panel of Figure 3). Nevertheless, to ensure comparability across estimates of the spread we retain the 2% steady state assumption throughout. The baseline model does a good job of explaining the first two types of spreads. Indeed, simple regressions (see Table 2) of the actual spreads on the simulated spread suggest that a 1bp rise in the latter raises the actual spreads by about 0.59 bp. The model not only mimics the variability but also is able to account for the level of the ten-year - three-month spread. The model is less successful in replicating the behavior of the other spreads shown in the figure except possibly for the volatility in the three-month - fed funds spread. The simulated spread is inversely related to the actual spreads between the prime rate and the federal fund rate and between the Moody's Baa and Aaa rated corporate bond yields (although not statistically sig-

of the TFP data (using a smoothing parameter of 100) before obtaining deviations from trend. Other proxies for TFP are available but these tend to be less closely related to output growth. An additional complication arises due to the fact that the treatment of capital differs across measures and the Chen et al. proxy maybe more suitable in modeling an economy with a financial system.

nificant in the former). There may be institutional factors not properly captured by the model which can partly explain this result.[10]

Figure 4 plots the model-generated credit spread with respect to the data when we only use the TFP series as exogenous drivers. In this and the following counterfactual experiments, the other exogenous variables are held constant at their mean levels during the sample period, which are also their assumed steady state levels. Figure 5 plots the model-generated credit spread with respect to the data when all exogenous variables except TFP series are used. Figure 6 plots the model-generated credit spread with respect to the data when only firm revenue taxes vary over time. Finally, Figure 7 plots the model-generated credit spread with respect to the data driven by government expenditures. These figures reveal that, even though as shown in Table 3 TFP shocks are the most important, followed by tax shocks, all shocks are necessary to explain the levels and the variability in credit spreads. As Jermann and Quadrini (2009) have also reported, productivity shocks alone can only partially explain changes and the volatility of spreads. Therefore, either separate shocks matter at different times in generating sharp movements in credit spreads or a complex combination of shocks is required to replicate the behavior of credit spreads. If the latter is the more accurate description this merely confirms the adage of many central bankers, namely the need to look at everything rather than attempting to react to a single event or shock, even if it can be correctly identified.

5. Credit Easing versus Quantitative Easing

This section explores two other dimensions of central bank policy in addition to the conventional monetary policy (interest-rate policy/Taylor rule). When a credit policy is adopted, the central bank will choose the quantity of funds to lend to households. An increase in the central bank's direct lending to private agents is considered to be akin to a credit easing policy. Since a central bank normally does not lend to households, at least not directly, this is how 'unconventional' monetary policy is practiced in our model. A pure (narrowly defined) credit easing policy is one that changes the central bank's asset composition while keeping the size of the balance sheet unchanged. Central banks typically reduce the holding of conventional assets (treasury securities) or receive treasury deposits to hold more unconventional assets (credit to the private sector). Note that credit easing is effectively a form of a fiscal policy pursued by the central bank. It is independent of the interest rate policy or other kinds of unconventional monetary policies.

A pure (narrowly defined) quantitative policy is one that changes the size of the central bank's balance sheet while keeping its portfolio structure unchanged. Until recently, most central bank assets have been "Treasuries only". Central banks expand or reduce high-powered money (reserves plus currency) through open market operations (buying or selling treasury securities), which essentially fine-tunes the policy rate. The ability to vary the size of the central bank's balance sheet without affecting the policy rate guided by a Taylor rule or once the policy rate reaches the zero lower bound, is acquired by paying interest on reserves. This gives a floor to the policy rate and allows central banks to adjust bank reserves for reasons other than targeting

[10] While changes in the prime rate are invariably tied to those in fed funds, they can be, and frequently are, changed by individual banks according to other criteria. Since the early 1990s the 3% premium of the prime rate over fed funds is a departure from its previous behavior, perhaps reflecting the improved transparency in how the fed funds rate is set and changes in it are publicly communicated. Nevertheless, at the end of the sample, the simulated and the realized spreads are approximately the same.

the policy rate. More importantly, it strengthens the quantitative policy by providing an exit strategy such that central banks are able to increase the policy rate to contain inflation even when they have a greatly expanded balance sheets.[11]

Taking the decisions of credit easing and quantitative easing as given, we focus on studying the impacts of such policies both at the steady state and in periods of financial stress (when the economy is hit by a financial shock modeled as an increase in default risk).

5.1 Credit Easing

Here, we modify the benchmark model by allowing the central bank to lend to borrowers directly. Total credit in the economy is given by

$$b_t = L_t + L_t^{cb} \tag{5.25}$$

where L_t is the quantity of real loans made by intermediaries. L_t^{cb} is the quantity of real loans issued by the central bank. The profit maximization problem of the financial intermediaries becomes

$$Max\ \ D_{t+1}^{int} = P_t[(1+i_t^b)(1-\chi_t)L_t - (1+i_t^d)d_t] \tag{5.26}$$
$$s.t.\ \ d_t = L_t + \Phi(L_t) \tag{5.27}$$

where $\Phi(L_t) = \phi_1 L_t + \phi_2(L_t - \bar{L})^2$. χ_t is the default risk. In each period, banks lose a fraction χ_t of their loans. Higher χ_t means higher risk of default (i.e., more uncertainty in the financial market). For simplicity, we assume that $\bar{\chi} = 0$ and $\bar{L}^{cb} = 0$ in the steady state. The equilibrium spread can be rewritten as

$$\omega_t = \frac{\Phi'(b_t - L_t^{cb}) + \chi_t}{1 - \chi_t} \tag{5.28}$$

Additionally, we assume that central bank lending also consumes real resources. In particular, $\Phi^{cb}(L_t^{cb}) = \psi L_t^{cb}$. It is rather difficult to measure intermediation costs, especially the cost of central bank initiated intermediation. These costs are most likely not directly observable. However, it is reasonable to think that the marginal cost of central bank lending is at least the same if not higher than that of the private intermediaries ($\psi \geq \phi_1$) due to lack of experience and financial expertise, among other factors that may determine these costs. As a result, the goods market clearing condition becomes

$$Y_t = \pi_b c_t^b + \pi_s c_t^s + G_t + \Phi(L_t) + \Phi^{cb}(L_t^{cb}) \tag{5.29}$$

Furthermore, the dynamics of bank credit are now given by

$$\begin{aligned} b_t = {} & \pi_b \pi_s[(c_t^b - c_t^s) - w_t(h_t^b - h_t^s)] - \pi_b[\Phi(b_t - L_t^{cb}) + \Phi^{cb}(L_t^{cb})] \\ & + \frac{1+i_{t-1}^d}{\Pi_t}[b_{t-1}(1+\omega_{t-1})(\pi_b + \delta\pi_s) + \delta\pi_b\Phi(b_{t-1} - L_t^{cb}) \\ & \qquad + \delta\pi_b(b_{t-1} - L_{t-1}^{cb}) - \pi_b(1+\omega_{t-1})(1-\chi_{t-1})(b_{t-1} - L_t^{cb})] \end{aligned} \tag{5.30}$$

The other equilibrium conditions are the same as before.

[11] The foregoing definitions correspond to Bernanke's (2009) differentiation of quantitative versus credit easing policies. Moreover, the definition of quantitative easing appears to correspond to the Bank of Japan's monetary policy during the 2001–2006 period (e.g., see Shiratsuka (2009)).

5.2 Quantitative Easing

We now introduce bank reserves into the baseline model. Quantitative easing typically refers to an increase in the monetary base which, in principle, provides the necessary liquidity to boost private lending through deposit expansion. Following an injection of reserves in the banking system, private banks need to decide how many loans to issue and reserves to hold while taking interest rates as given. In this case, the total credit in the economy is still b_t. The profit maximization problem of the financial intermediaries becomes

$$Max\;\; D_{t+1}^{int} = P_t[(1+i_t^b)(1-\chi_t)b_t + (1+i_t^m)m_t - (1+i_t^d)d_t] \tag{5.31}$$

$$s.t.\;\; d_t = b_t + \Phi(b_t) - (R_t^{cb} - m_t) \tag{5.32}$$

where R_t^{cb} represents the injection of bank reserves. m_t is the amount of reserves held by the banks and i_t^m is the interest paid on the reserves. For simplicity, we assume that $\bar{R}^{cb} = 0$ in the steady state. It is easy to see that the optimal holding of reserves equals zero, $m_t = 0$, as long as the interest paid on reserves is no greater than the interest paid on deposits, $i_t^m \leq i_t^d$. Intuitively, banks will use up their reserves first in this case because financing loans using reserves is cheaper than using deposits. As a result, the equilibrium spread can be rewritten as

$$\omega_t = \frac{\Phi'(b_t) + \chi_t}{1 - \chi_t} \tag{5.33}$$

Moreover, the dynamics of bank credit become

$$\begin{aligned} b_t &= \pi_b \pi_s[(c_t^b - c_t^s) - w_t(h_t^b - h_t^s)] - \pi_b \Phi(b_t) \\ &+ \frac{1+i_{t-1}^d}{\Pi_t}\{\delta b_{t-1}(1+\omega_{t-1}) + \delta\pi_b[\Phi(b_{t-1}) - R_{t-1}^{cb}] \\ &\quad - \pi_b b_{t-1}\Phi'(b_{t-1}) + (1-\delta)\pi_b b_{t-1}\omega_{t-1}\} \end{aligned} \tag{5.34}$$

The other equilibrium conditions are the same as before.

5.3 Policy Assessment

We now consider the impact of various central bank policies on credit spreads. The results are shown in Figures 8 through 12. The vertical axes are expressed in percent as deviations from the steady state values for the parameters in question (see Table 1).

Figure 8 plots the impulse responses following a one-time increase in central bank credit at the steady state, measured as 1% of steady state credit, $L^{cb} = 0.01\bar{b}$. This is the equivalent of credit easing in our model. Spreads (ω) are reduced, at least in the first period, as is the borrowing rate from intermediaries (i^b). Although the spread rises in period 2, before returning to the steady state, the cumulative effect remains a fall in the spread. How effective is credit easing? For example, the impulse responses suggest that a 5% increase in central bank lending, relative to the steady state, can wipe out a 2% credit spread. It is instructive to compare, for example, the labor - ois spread plotted in Figure 1 against a summary of changes in the U.S. Fed's balance sheet (shown in the appendix). The largest reduction in this spread takes place almost simultaneously when the credit easing policies of the Fed reached their zenith. Total credit increases by over 0.7% in period 1, but central bank lending to private agents crowds out some of the private credit (i.e., L decreases).

Figure 9 plots the impulse responses following a one-time injection of bank reserves at the steady state, measured as 1% of steady state credit, $R^{cb} = 0.01\bar{b}$. This is the quantitative easing policy in our framework. Unlike credit easing, quantitative easing initially raises the credit spread by a modest 4% (that is, from 2% to 2.09%), although, after three periods, the cumulative impact of a quantitative easing policy is also reflected in a small reduction in the spread. Nevertheless, it is worth noting that the impact of a credit easing policy is almost five times larger than for quantitative easing. Under quantitative easing the rise in the debt-to-GDP ratio is far smaller than under credit easing. Finally, aggregate deposits (d) also suffer from a fall and this is reflected in borrowing rates (i^b). Clearly, the impacts of quantitative versus credit easing on credit spreads are very different. More strikingly, total credit in the economy increases in both cases at the beginning, but quantitative easing leads to a sharp contraction in credit after the first period.

Next, we consider the impact of a financial shock, defined in terms of a change in the loan default rate, and the policy implications thereof. Figure 10 plots the impulse responses following a one-time increase in the default risk at the steady state, $\chi = 0.01$. Worrying that households may default on their loans, banks lend less (by over 0.5%). Notice that a modest rise in default risk leads to sharply higher credit spreads. Not surprisingly, of course, borrowing rates also rise. Aggregate deposits and credits, nevertheless, fall. Figures 11 and 12 consider how the credit and quantitative easing policies fare when there is a default risk shock. We find that credit easing is no longer as effective as when default risk remains at the steady state (see Figure 8). Indeed, after three periods, the net effect of the default risk shock is virtually zero. This suggests that, for credit easing to be an effective policy under the circumstances, the central bank has to implement it in a very aggressive fashion. Turning to quantitative easing, spreads are now higher. Hence, it now seems clear that quantitative easing is inappropriate when financial markets are under stress. Moreover, a quantitative easing policy has the effect of producing a reduction in credit in the economy. Further, robustness tests (shown in the appendix) demonstrate that the foregoing conclusions are unchanged even when we change the cost of central bank intermediation.

6. Conclusions

This paper has considered some of the challenges faced by the standard optimizing model that macroeconomists and central banks use to assess the implications of various policies. In particular, we propose a strategy that incorporates credit frictions into what has come to be known as the canonical model (e.g., Woodford (2003)). The model used by Cúrdia and Woodford, in a series of recent papers, serves as the basis for attempting to mimic the behavior of credit spreads during moderate as well as crisis times. We are able to generate movements in our representative credit spreads that are, at times, both sharp and volatile. Next, we consider some experiments to determine the impact of two approaches to monetary policy making implemented during the recent global financial crisis, namely, quantitative easing and credit easing. It is found that their impact on credit spreads is dissimilar and this suggests that policy makers need to be able to quickly identify the source of the financial shock if they are to successfully address extreme stresses to the financial system. In other words, while the model is able to generate different predictions about the short-term effects of pursuing quantitative versus credit easing policies, and their effectiveness at influencing spreads in the desired direction, the simulations are informative about the root cause of a financial crisis only if it arises from a change in the loan default rate. Clearly, experimenting with different types of financial shocks might well permit a more precise diagnosis of changes in certain spreads. It is also worth noting that debt dynamics in the model are such that total credit to GDP in the economy is not as persistent as it is in the realized data. Alternatively, we may wish to modify the intermediation cost technology to permit intermediaries to fail, or households to default on their loans. Failing that, alternative proxies for the largely unobservable intermediation costs should be considered. Changing the inflation target in the version of the Taylor rule used here is another modification we could make. For example, there is evidence that a more robust rule is obtained if changes in the output gap, or the rate of change in output, replace the level of the output gap. Finally, the current exercise would be more meaningful still by asking whether, if the results derived here are taken to the data, there is support for the interpretation of credit spreads put forward in this paper.

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Appendix

Table 1: List of Parameters - Benchmark

α	0.75	β	0.9512
ν	0.1	ϕ^b	1.2177
σ^b	12.5	θ^b	2.3044
σ^s	2.5	θ^s	1.6937
γ_π	1.5	ϕ_1	0.02
γ_y	0.5	ϕ_2	1
ϕ^s	1	$\bar{Z}$	1
δ	0.9	$\bar{g}$	0.15
π_b	0.5	$\bar{\tau}$	0.3
π_s	0.5		

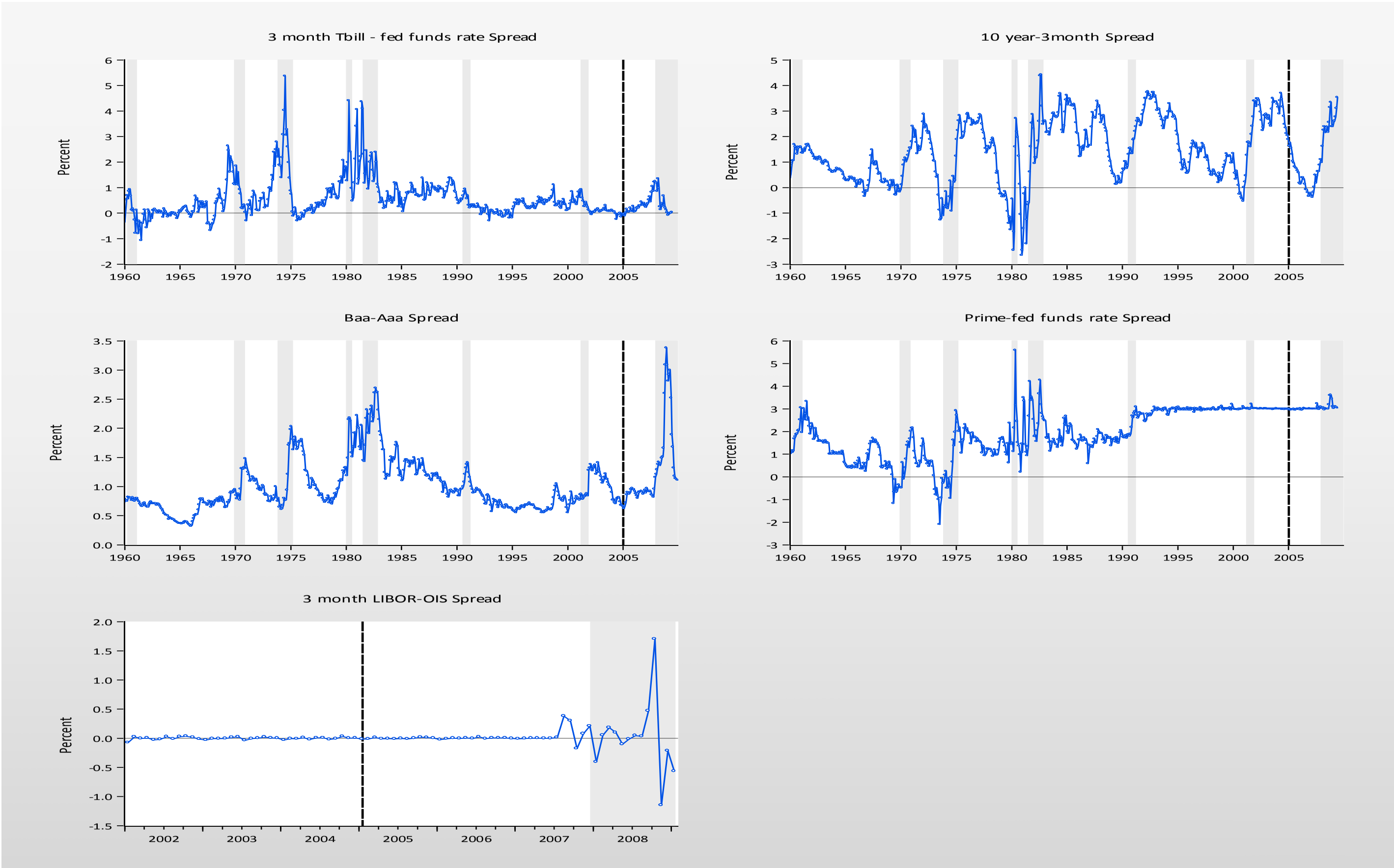
Table 2: Simple OLS Tests - Benchmark

	ω_{10y3m}	ω_{3mfed}	ω_{pfed}	ω_{ba}
ω	.585	.5861	$-.06415$	$-.2089$
	$(0.041)^{**}$	$(0.000)^{***}$	(0.803)	$(0.043)^{**}$
$constant$	.2939	-1.7323	1.9752	1.4045
	(0.612)	$(0.000)^{***}$	$(0.001)^{***}$	$(0.000)^{***}$

Table 3: Pairwise Correlations - Benchmark

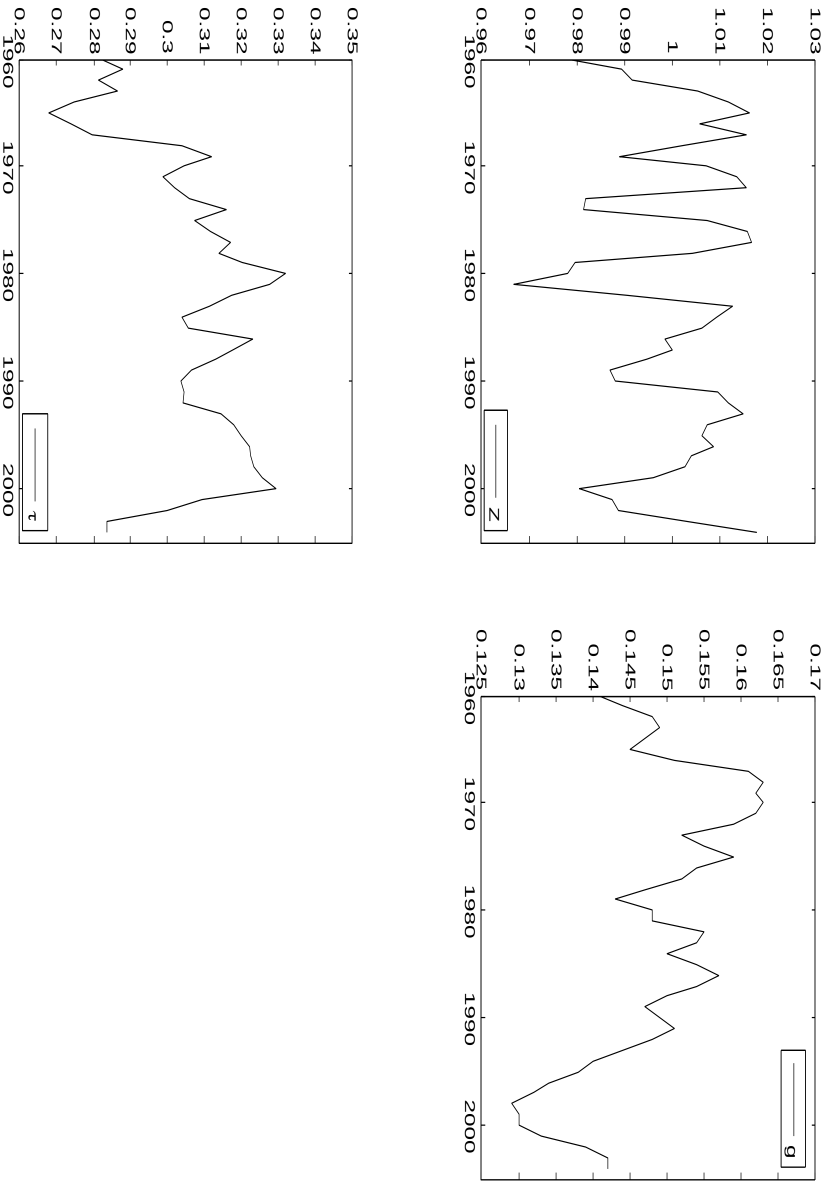
	ω	ω_{tfp}	ω_τ	ω_g
ω	1			
ω_{tfp}	0.8924	1		
	$(0.0000)^{***}$			
ω_τ	0.8042	0.4577	1	
	$(0.0000)^{***}$	$(0.0016)^{***}$		
ω_g	-0.1034	-0.2904	0.0402	1
	(0.4992)	$(0.0530)^{*}$	(0.7934)	

Figure 1: Varieties of Spreads



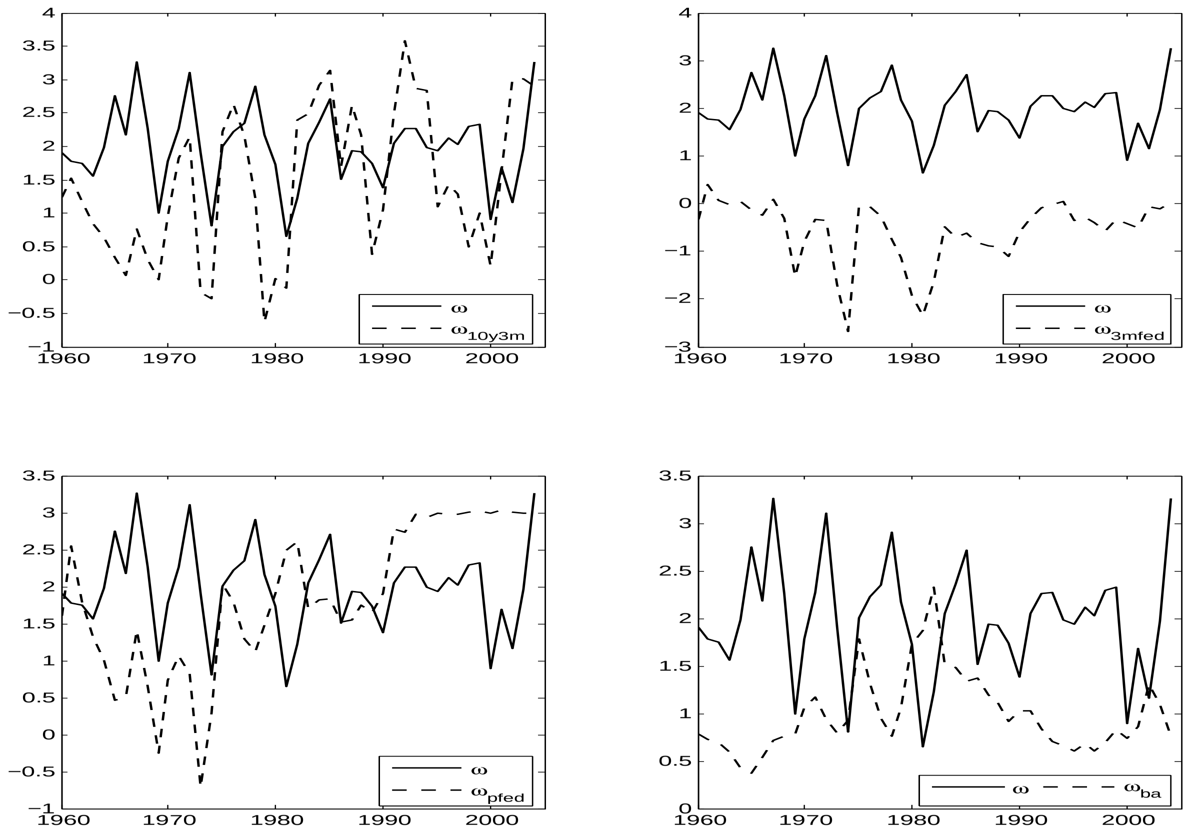
Note: The data were collected from FRED (http://research.stlouisfed.org/fred2/) and Datastream, at monthly frequency. Spreads are calculated as the differential in the interest rate pairs shown in each one of the Figures. The sample begins in 1960 to match the simulations, which are expressed in annual terms, as discussed in the paper. The vertical dashed lines mark the last year for which we have data for the actual time series of the exogenous driving forces in the model.

Figure 2: Exogenous Driving Forces



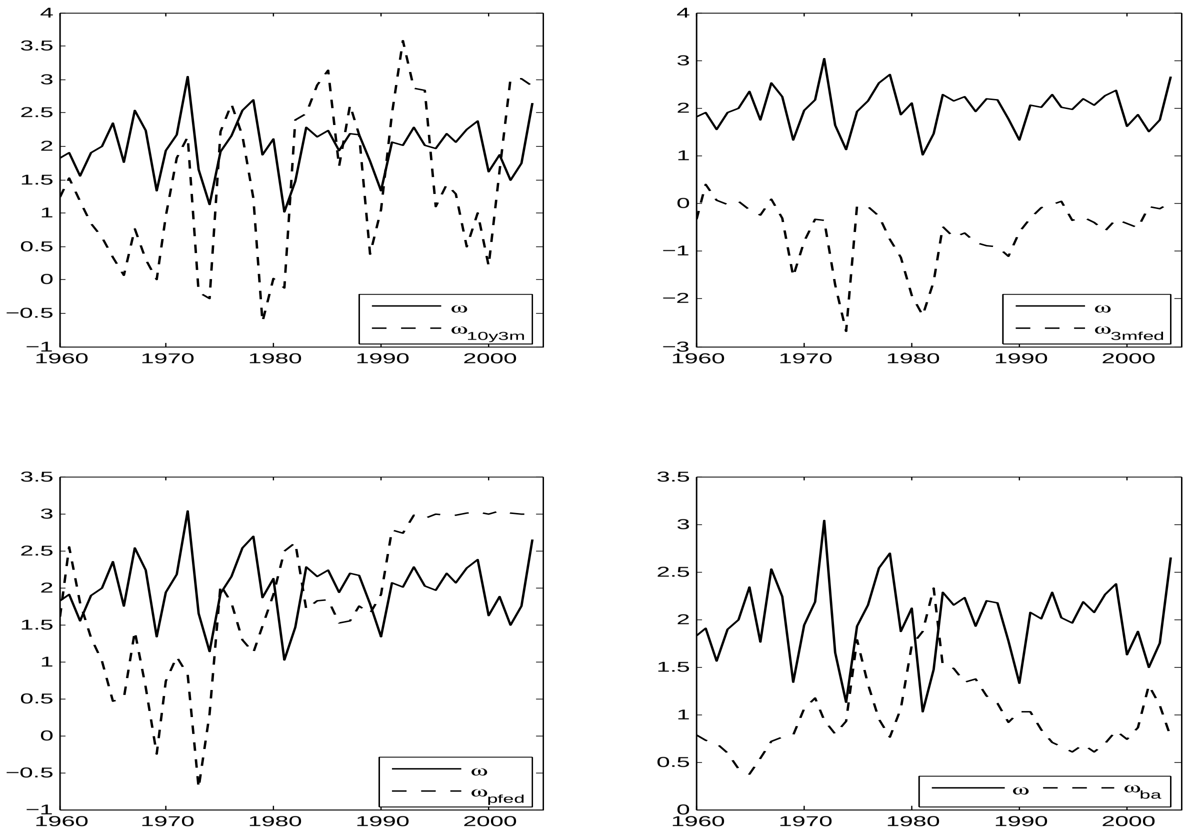
Source: Chen et al. (2008).

Figure 3: Benchmark Model with All Shocks



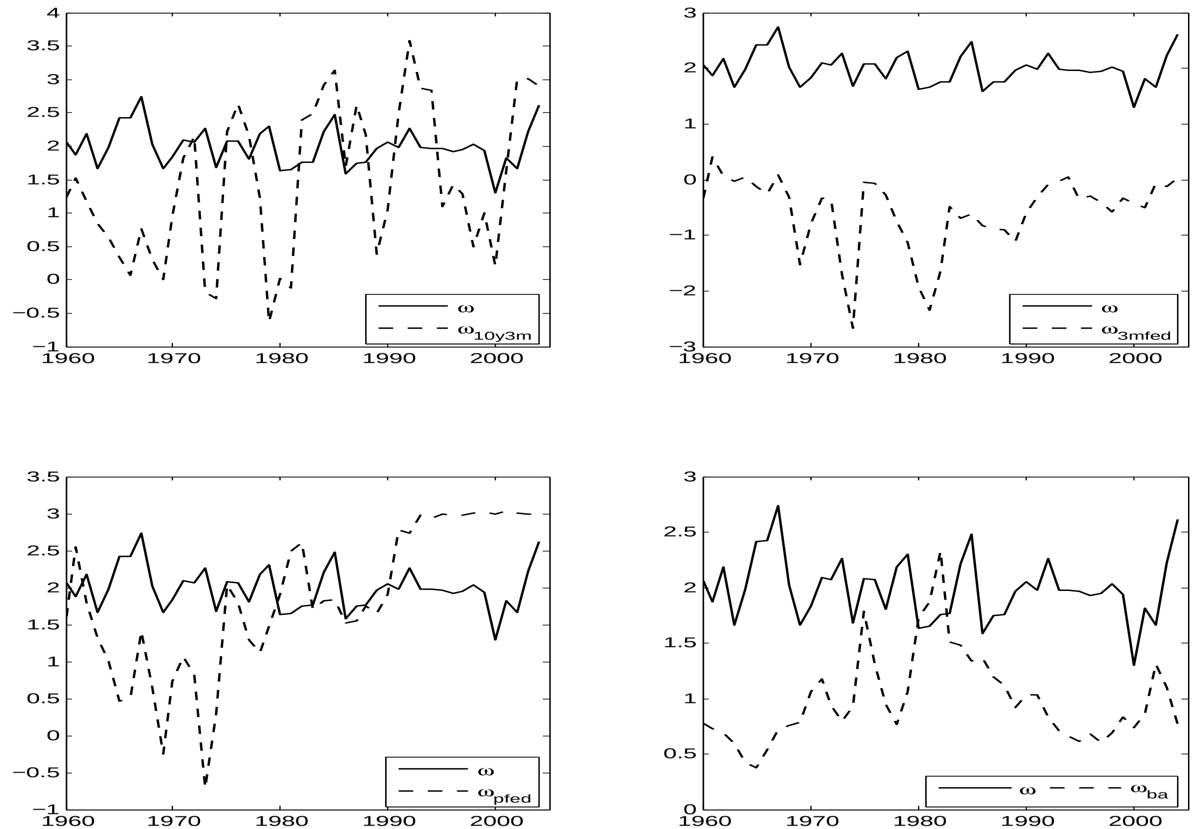
Note: ω is the simulated spread, ω_{ij} is the realized spread (also see Figure 1). The monthly data were converted to annual frequency via arithmetic averaging.

Figure 4: Benchmark Model with Only TFP



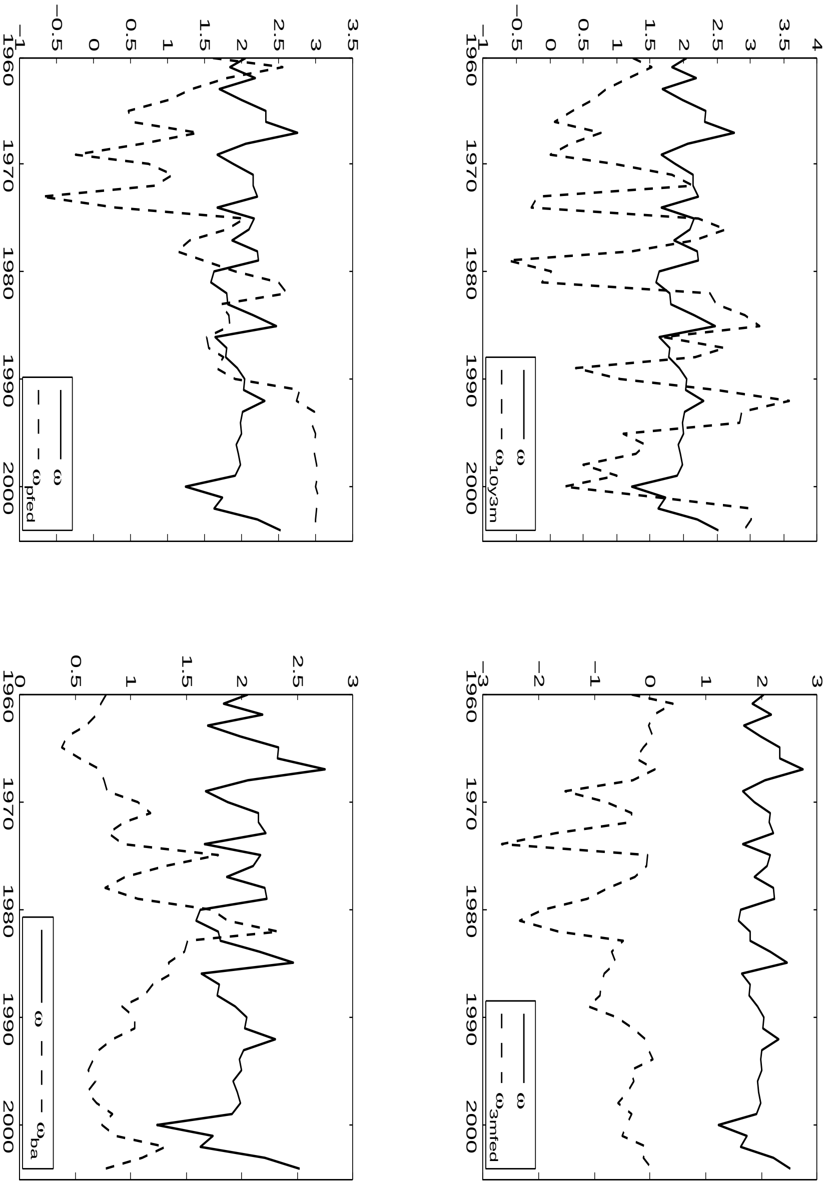
See notes to Figure 3.

Figure 5: Benchmark Model with All Except TFP



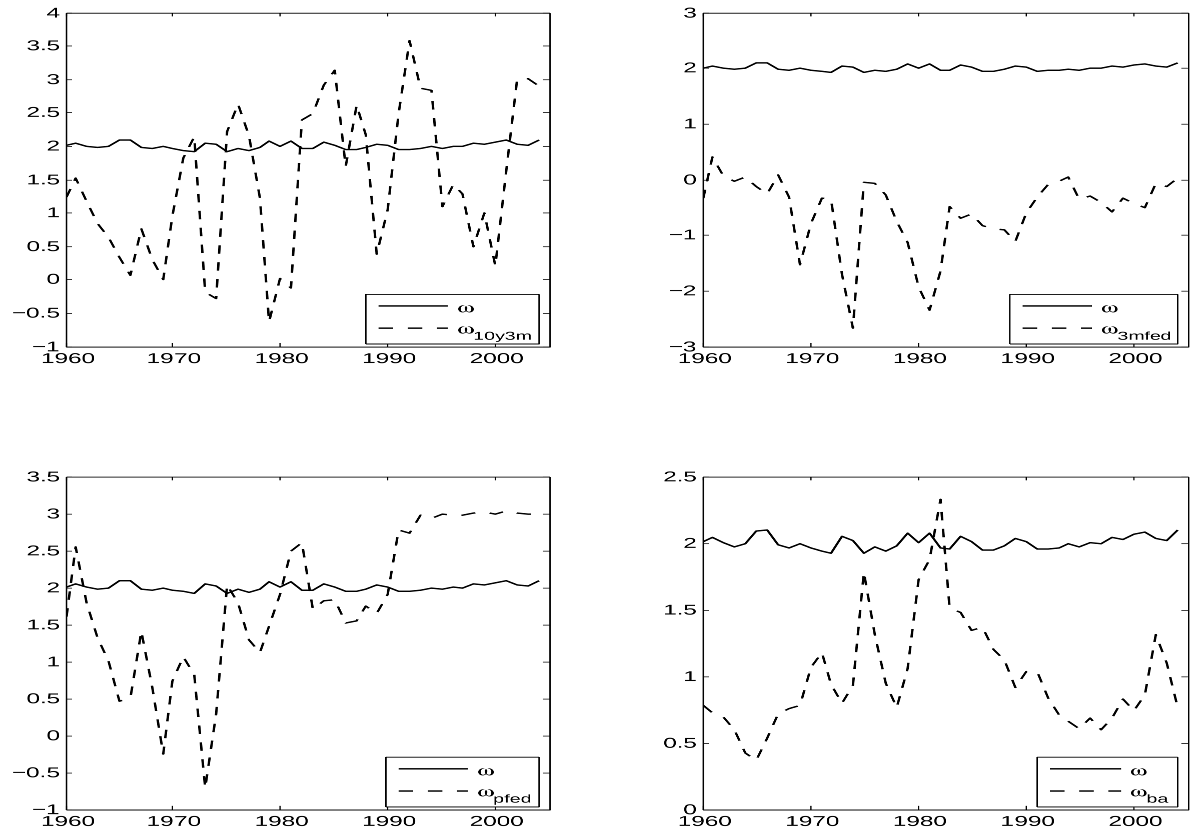
See notes to Figure 3.

Figure 6: Benchmark Model with Only τ



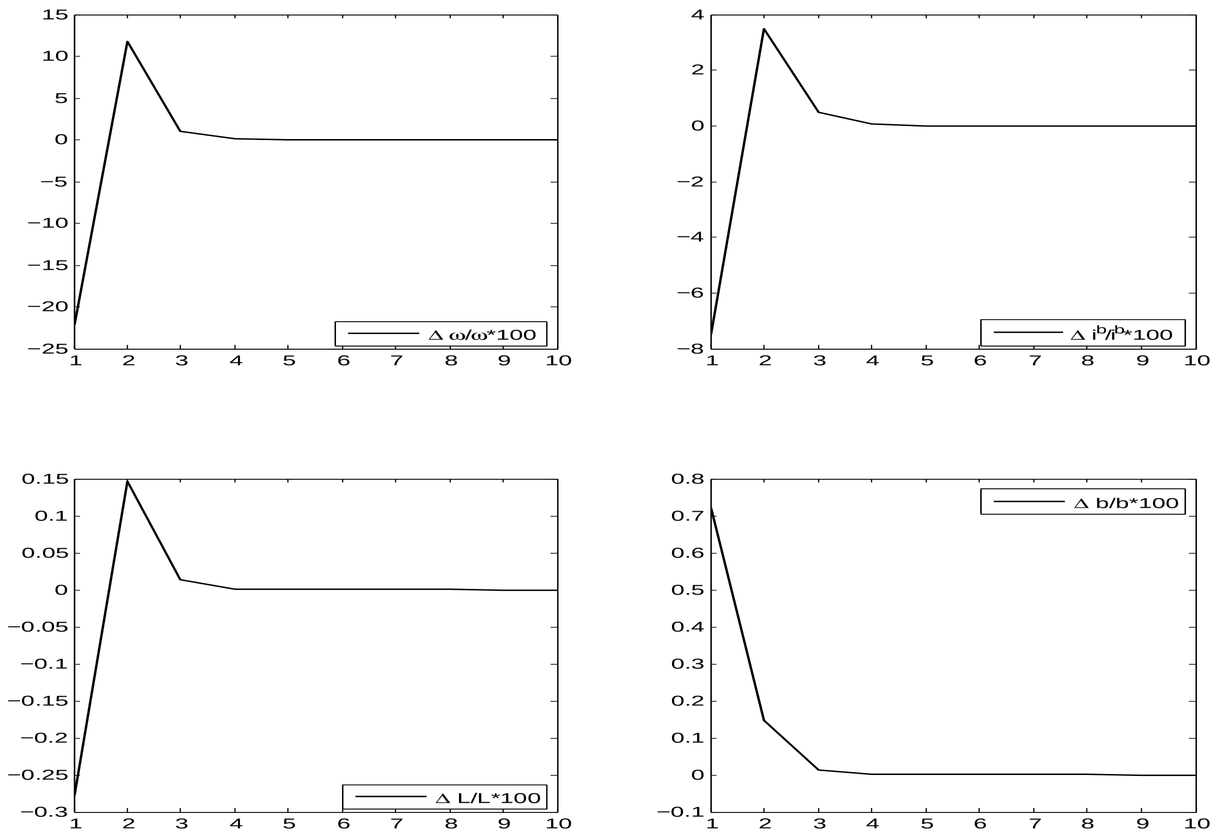
See notes to Figure 3.

Figure 7: Benchmark Model with Only g



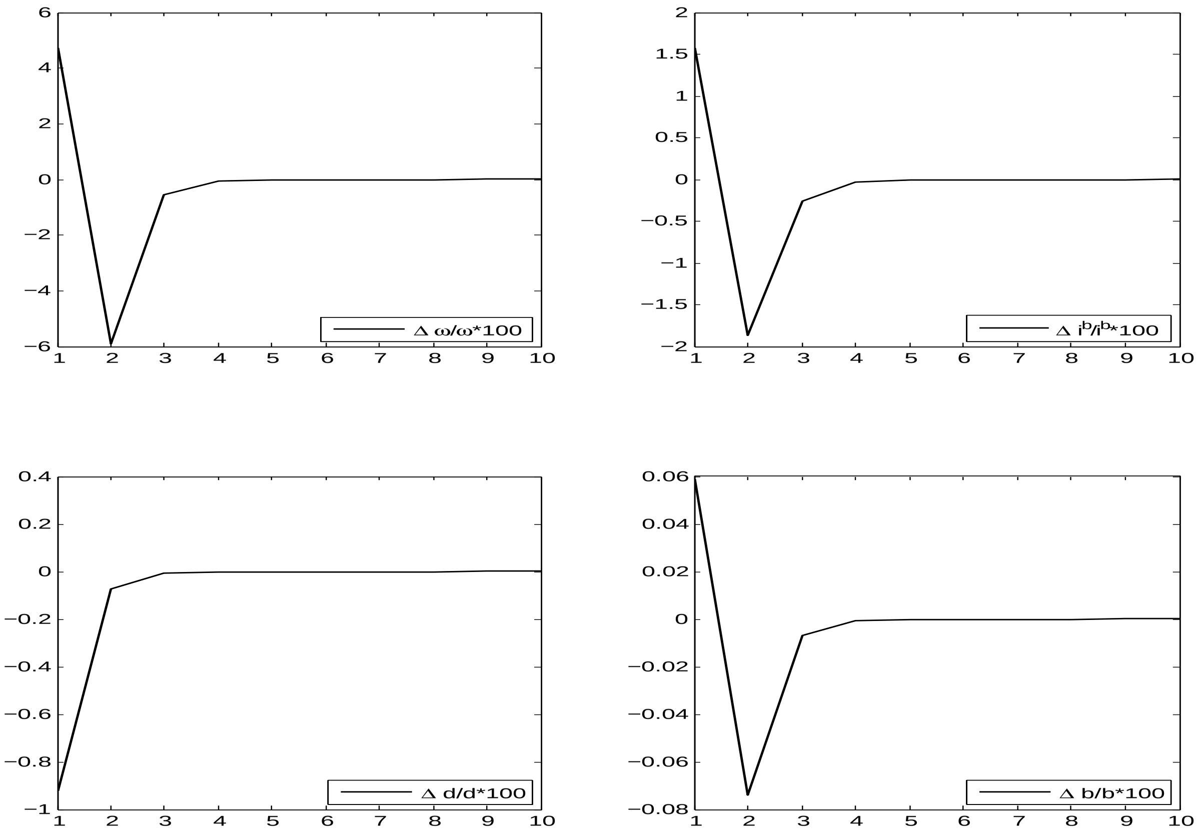
See notes to Figure 3.

Figure 8: Credit Easing



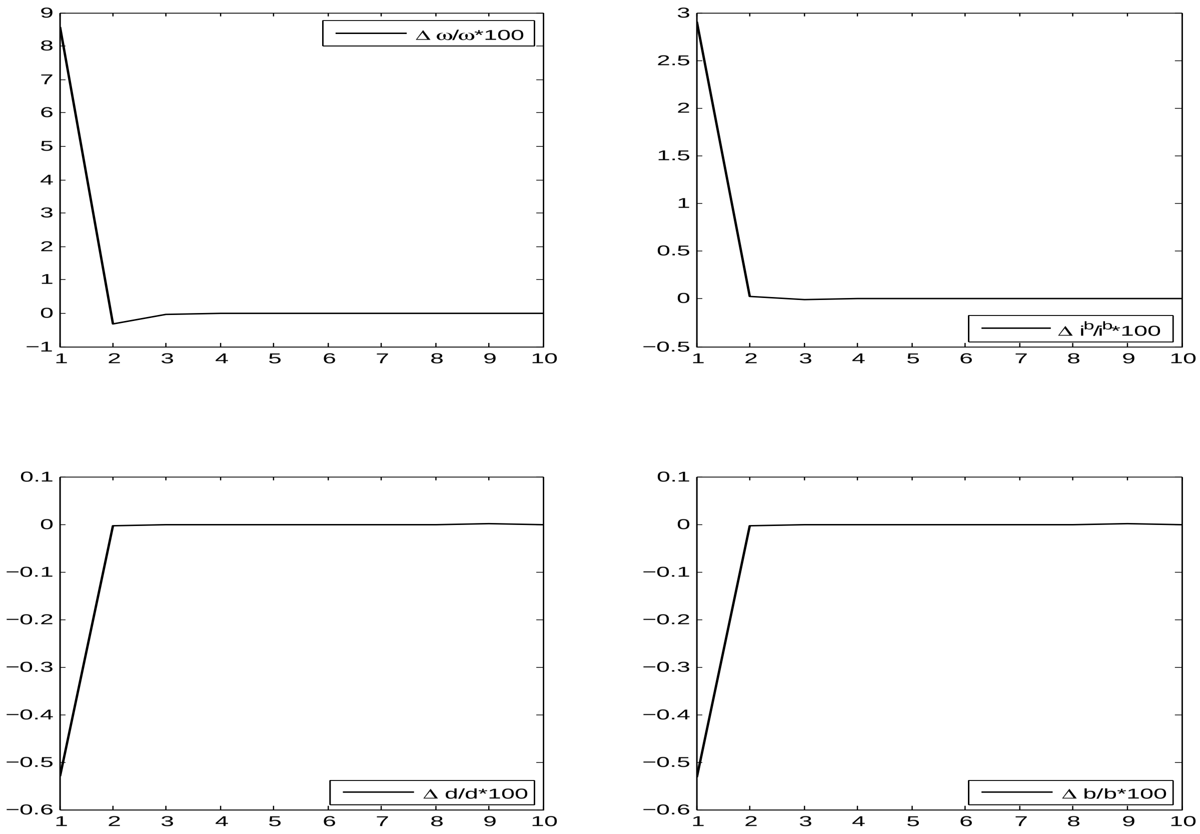
Note: The vertical axes are in percent. The horizontal axes are time periods (years). All impulse responses are expressed as deviations from the steady state and measure the response to a 1% shock relative to steady state values (see Table 1). For the spread the steady state is $.02$, while the steady state level for b, the debt-to-GDP ratio, is 0.8. $L = b - L^{cb}$, see equation (5.25). i^b is the interest rate that borrowers pay for loans from intermediaries.

Figure 9: Quantitative Easing



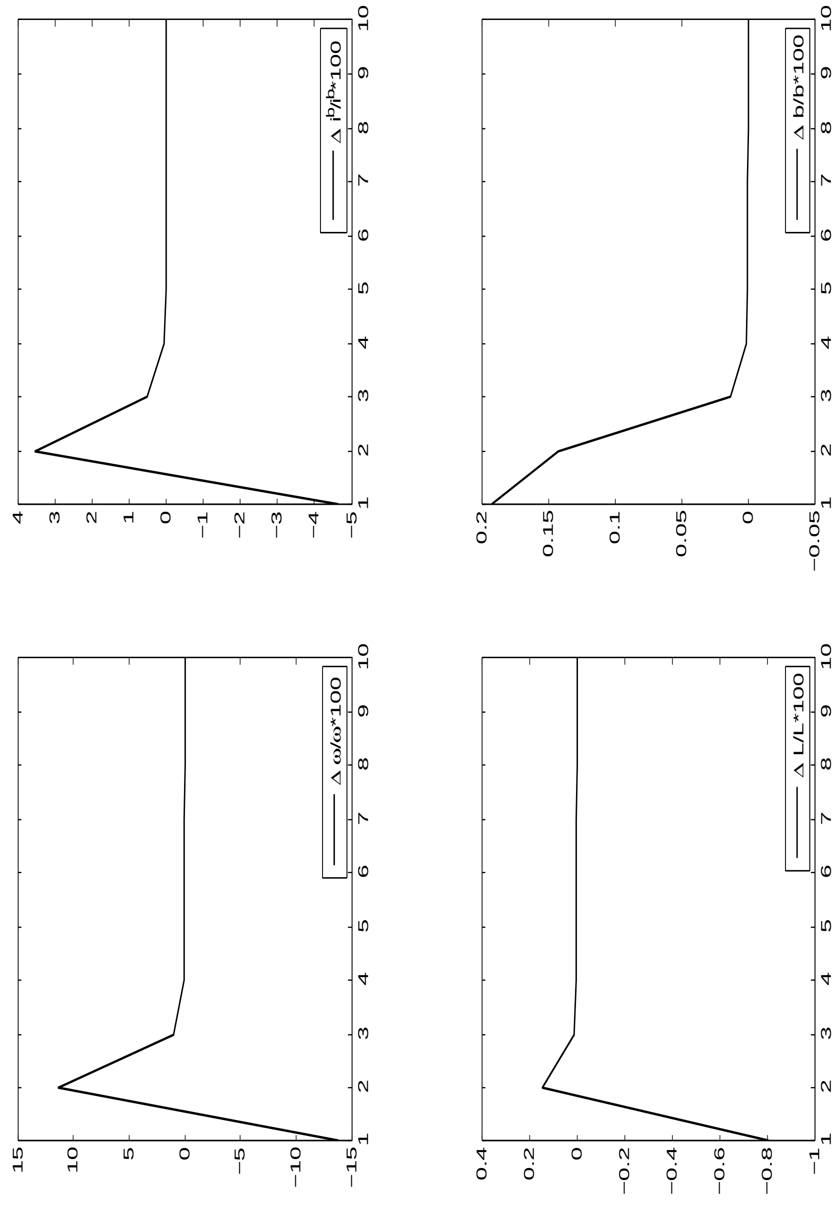
See notes to Figure 8. d is aggregate (real) deposits.

Figure 10: Default Risk



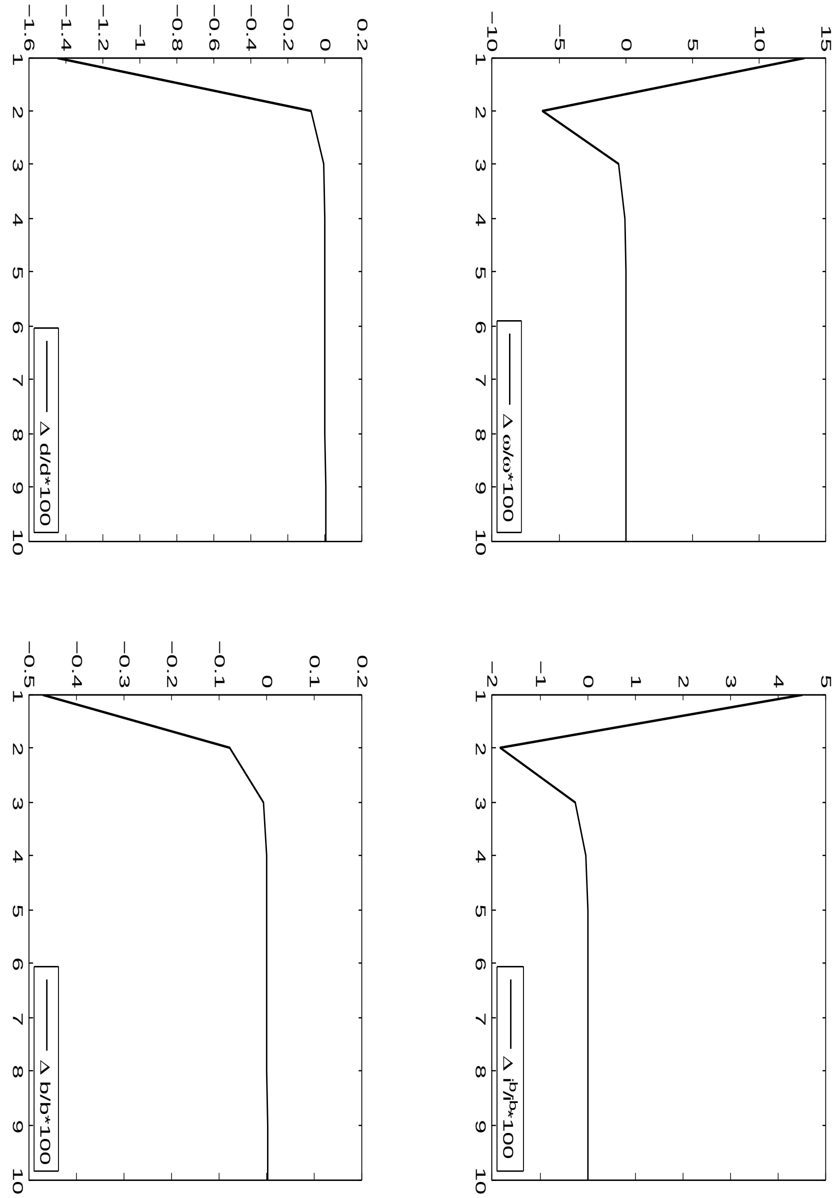
See notes to Figure 9. Default risk is zero at the steady state.

Figure 11: Credit Easing Following A Default Risk Shock



See Notes to Figure 9.

Figure 12: Quantitative Easing Following A Default Risk Shock



See Notes to Figure 9.

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