Credit Spreads and Monetary Policy*

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January 24, 2010

Abstract

We consider the desirability of modifying a standard Taylor rule for a central bank's interest-rate policy to incorporate either an adjustment for changes in interest-rate spreads (as proposed by Taylor, 2008, and by McCulley and Toloui, 2008) or a response to variations in the aggregate volume of credit (as proposed by Christiano *et al.*, 2007). We consider the consequences of such adjustments for the way in which policy would respond to a variety of types of possible economic disturbances, including (but not limited to) disturbances originating in the financial sector that increase equilibrium spreads and contract the supply of credit. We conduct our analysis using the simple DSGE model with credit frictions developed in Cúrdia and Woodford (2009a), and compare the equilibrium responses to a variety of disturbances under the modified Taylor rules to those under a policy that would maximize average expected utility. According to our model, a spread adjustment can improve upon the standard Taylor rule, but the optimal size is unlikely to be as large as the one proposed, and the same type of adjustment is not desirable regardless of the source of the variation in credit spreads. A response to credit is less likely to be helpful, and the desirable size (and even sign) of response to credit is even less robust to alternative assumptions about the nature and persistence of the disturbances to the economy.

*Prepared for the FRB-JMCB research conference "Financial Markets and Monetary Policy," Washington, DC, June 4-5, 2009. We thank Argia Sbordone, John Taylor and John Williams for helpful discussions, and the NSF for research support of the second author. The views expressed in this paper are those of the authors and do not necessarily reflect positions of the Federal Reserve Bank of New York or the Federal Reserve System.

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The recent turmoil in financial markets has confronted the central banks of the world with a number of unusual challenges. To what extent do standard approaches to the conduct of monetary policy continue to provide reasonable guidelines under such circumstances? For example, the Federal Reserve aggressively reduced its operating target for the federal funds rate in late 2007 and January 2008, though official statistics did not yet indicate that real GDP was declining, and according to many indicators inflation was if anything increasing; a simple "Taylor rule" (Taylor, 1993) for monetary policy would thus not seem to have provided any ground for the Fed's actions at the time. Obviously, they were paying attention to other indicators than these ones alone, some of which showed that serious problems had developed in the financial sector.[1] But does a response to such additional variables make sense as a general policy? Should it be expected to lead to better responses of the aggregate economy to disturbances more generally?

Among the most obvious indicators of stress in the financial sector since August 2007 have been the unusual increases in (and volatility of) the spreads between the interest rates at which different classes of borrowers are able to fund their activities.[2] Indeed, McCulley and Toloui (2008) and Taylor (2008) have proposed that the intercept term in a "Taylor rule" for monetary policy should be adjusted downward in proportion to observed increases in spreads. Similarly, Meyer and Sack (2008) propose, as a possible account of recent U.S. Federal Reserve policy, a Taylor rule in which the intercept — representing the Fed's view of "the equilibrium real funds rate" — has been adjusted downward in response to credit market turmoil, and use the size of increases in spreads in early 2008 as a basis for a proposed magnitude of the appropriate adjustment. A central objective of this paper is to assess the degree to which a modification of the classic Taylor rule of this kind would generally improve the way in which the economy responds to disturbances of various sorts, including in particular to those originating in the financial sector. Our model also sheds light on the question whether it is correct to say that the "natural" or "neutral" rate of interest is lower when credit spreads increase (assuming unchanged fundamentals otherwise), and to the extent that it is, how the size of the change in the natural rate compares to the size of the change in credit spreads.

Other authors have argued that if financial disturbances are an important source

[1]For a discussion of the FOMC's decisions at that time by a member of the committee, see Mishkin (2008).

[2]See, for example, Taylor and Williams (2008a, 2008b).

of macroeconomic instability, a sound approach to monetary policy will have to pay attention to the balance sheets of financial intermediaries. It is sometimes suggested, for example, that a Taylor rule that is modified to include a response to variations in some measure of aggregate credit would be an improvement upon conventional policy advice (see, *e.g.,* Christiano *et al.,* 2007). We also consider the cyclical variations in aggregate credit that should be associated with both non-financial and financial disturbances, and the desirability of a modified Taylor rule that responds to credit variations in both of these cases.

Many of the models used both in theoretical analyses of optimal monetary policy and in numerical simulations of alternative policy rules are unsuitable for the analysis of these issues, because they abstract altogether from the economic role of financial intermediation. Thus it is common to analyze monetary policy in models with a single interest rate (of each maturity) — "the" interest rate — in which case we cannot analyze the consequences of responding to variations in spreads, and with a representative agent, so that there is no credit extended in equilibrium and hence no possibility of cyclical variations in credit. In order to address the questions that concern us here, we must have a model of the monetary transmission mechanism with both heterogeneity (so that there are both borrowers and savers at each point in time) and segmentation of the participation in different financial markets (so that there can exist non-zero credit spreads).

The model that we use is one developed in Cúrdia and Woodford (2009a), as a relatively simple generalization of the basic New Keynesian model used for the analysis of optimal monetary policy in sources such as Goodfriend and King (1997), Clarida *et al.* (1999), and Woodford (2003). The model is still highly stylized in many respects; for example, we abstract from the distinction between the household and firm sectors of the economy, and instead treat all private expenditure as the expenditure of infinite-lived household-firms, and we similarly abstract from the consequences of investment spending for the evolution of the economy's productive capacity, instead treating all private expenditure as if it were all non-durable consumer expenditure (yielding immediate utility, at a diminishing marginal rate). The advantage of this very simple framework, in our view, is that it brings the implications of the credit frictions into very clear focus, by using a model that reduces, in the absence of those frictions, to a model that is both simple and already very well understood. The model is also one in which, at least under certain ideal circumstances, a Taylor rule with no adjustment for financial conditions would represent optimal policy. It is thus of particular interest in this context to ask what kinds of possible adjustments for financial conditions are desirable when credit frictions are introduced into the model.

In section 1, we review the structure of the model, stressing the respects in which the introduction of heterogeneity and imperfect financial intermediation requires the equations of the basic New Keynesian model to be generalized, and discuss its numerical calibration. Section 2 then analyzes the consequences of modifying a standard Taylor rule to incorporate an automatic response to either changes in credit spreads or in a measure of aggregate credit. We consider the welfare consequences of alternative policy rules, from the standpoint of the average level of expected utility of the heterogenous households in our model. Section 3 then summarizes our conclusions about these alternatives, and briefly compares them with the way in which financial conditions should be taken into account under a forecast-targeting approach.

1 A New Keynesian Model with Financial Frictions

Here we briefly describe the model developed in Cúrdia and Woodford (2009a). (The reader is referred to that paper for more details.) In particular, we explain the significance of each of the 10 types of exogenous disturbances that figure in our subsequent discussion of the way in which the consequences of alternative monetary policy rules depend on the underlying sources of economic instability. We also briefly discuss the numerical calibration of the model.

1.1 Sketch of the Model

We depart from the assumption of a representative household in the standard model, by supposing that households differ in their preferences. Each household i seeks to maximize a discounted intertemporal objective of the form

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[u^{\tau_t(i)} \left(c_t(i); \xi_t\right) - \int_0^1 v^{\tau_t(i)} \left(h_t\left(j; i\right); \xi_t\right) dj \right],$$

where $\tau_t\left(i\right) \in \{b, s\}$ indicates the household's "type" in period t. Here $u^b(c; \xi)$ and $u^s(c; \xi)$ are two different period utility functions, each of which may also be shifted by the vector of aggregate taste shocks ξ_t, and $v^b(h;\xi)$ and $v^s(h;\xi)$ are correspondingly two different functions indicating the period disutility from working. As in the basic NK model, there is assumed to be a continuum of differentiated goods, each produced by a monopolistically competitive supplier; $c_t(i)$ is a Dixit-Stiglitz aggegator of the household's purchases of these differentiated goods. The household similarly supplies a continuum of different types of specialized labor, indexed by j, that are hired by firms in different sectors of the economy; the additively separable disutility of work $v^\tau(h;\xi)$ is the same for each type of labor, though it depends on the household's type and the common taste shock.

Each agent's type $\tau_t(i)$ evolves as an independent two-state Markov chain. Specifically, we assume that each period, with probability $1-\delta$ (for some $0 \leq \delta < 1$) an event occurs which results in a new type for the household being drawn; otherwise it remains the same as in the previous period. When a new type is drawn, it is b with probability π_b and s with probability π_s, where $0 < \pi_b, \pi_s < 1, \pi_b + \pi_s = 1$. (Hence the population fractions of the two types are constant at all times, and equal to π_τ for each type τ.) We assume moreover that

$$u_c^b(c;\xi) > u_c^s(c;\xi)$$

for all levels of expenditure c in the range that occur in equilibrium. (See Figure 1, where these functions are graphed in the case of the calibration discussed below.) Hence a change in a household's type changes its relative impatience to consume, given the aggregate state ξ_t; in addition, the current impatience to consume of all households is changed by the aggregate disturbance ξ_t.

We also assume that the marginal utility of additional expenditure diminishes at different rates for the two types, as is also illustrated in the figure; type b households (who are borrowers in equilibrium) have a marginal utility that varies less with the current level of expenditure, resulting in a greater degree of intertemporal substitution of their expenditures in response to interest-rate changes. Finally, the two types are also assumed to differ in the marginal disutility of working a given number of hours; this difference is calibrated so that the two types choose to work the same number of hours in steady state, despite their differing marginal utilities of income. For simplicity, the elasticities of labor supply of the two types are not assumed to differ.

The coexistence of the two types with differing impatience to consume creates a social function for financial intermediation. In the present model, as in the basic

New Keynesian model, all output is consumed either by households or by the government;[3] hence intermediation serves an allocative function only to the extent that there are reasons for the intertemporal marginal rates of substitution of households to differ in the absence of financial flows. The present model reduces to the standard representative-household model in the case that one assumes that $u^b(c;\xi) = u^s(c;\xi)$ and $v^b(h;\xi) = v^s(h;\xi)$.

We assume that most of the time, households are able to spend an amount different from their current income *only* by depositing funds with or borrowing from financial intermediaries,[4] and that the same nominal interest rate i_t^d is available to all savers, and that a (possibly) different nominal interest i_t^b is available to all borrowers,[5] independent of the quantities that a given household chooses to save or to borrow. (For simplicity, we also assume that only one-period riskless nominal contracts with the intermediary are possible for either savers or borrowers.) The assumption that households cannot engage in financial contracting other than through the intermediary sector represents the key financial friction.

The analysis is simplified by allowing for an additional form of financial contracting. We assume that households are able to sign state-contingent contracts with one another, through which they may insure one another against both aggregate risk and the idiosyncratic risk associated with a household's random draw of its type, but that households are *only intermittently* able to receive transfers from the insurance agency; between the infrequent occasions when a household has access to the insurance agency,[6] it can only save or borrow through the financial intermediary sector mentioned in the previous paragraph. The assumption that households are *eventually* able to make transfers to one another in accordance with an insurance contract signed earlier means that they continue to have identical expectations regarding their

[3]The "consumption" variable is therefore to be interpreted as representing all of private expenditure, not only consumer expenditure. For discussion, see Woodford (2003, pp. 242-243).

[4]To be more precise, we assume that savers can hold either government debt or deposits with intermediaries, but in equilibrium these must pay the same interest rate i_t^d, or the market would not clear.

[5]Here "savers" and "borrowers" identify households according to whether they choose to save or borrow, and not by their "type".

[6]For simplicity, these are assumed to coincide with the infrequent occasions when the household draws a new "type"; but the insurance payment is claimed before the new type is known, and cannot be contingent upon the new type.

marginal utilities of income far enough in the future, regardless of their differing type histories.

As long as certain inequalities discussed in our previous paper are satisfied,[7] it turns out that in equilibrium, type b households choose always to borrow from the intermediaries, while type s households deposit their savings with them (and no one chooses to do both, given that $i_t^b \geq i_t^d$ at all times). Moreover, because of the asymptotic risk-sharing, one can show that all households of a given type at any point in time have a common marginal utility of real income (which we denote λ_t^τ for households of type τ) and choose a common level of real expenditure c_t^τ. Household optimization of the timing of expenditure requires that the marginal-utility processes $\{\lambda_t^\tau\}$ satisfy the two Euler equations

$$\lambda_t^b = \beta E_t \left[\frac{1+i_t^b}{\Pi_{t+1}} \left\{ \left[\delta + (1-\delta)\,\pi_b\right] \lambda_{t+1}^b + (1-\delta)\,\pi_s \lambda_{t+1}^s \right\} \right], \tag{1.1}$$

$$\lambda_t^s = \beta E_t \left[\frac{1+i_t^d}{\Pi_{t+1}} \left\{ (1-\delta)\,\pi_b \lambda_{t+1}^b + \left[\delta + (1-\delta)\,\pi_s\right] \lambda_{t+1}^s \right\} \right] \tag{1.2}$$

in each period. Here $\Pi_t \equiv P_t/P_{t-1}$ is the gross inflation rate, where P_t is the Dixit-Stiglitz price index for the differentiated goods produced in period t. Note that each equation takes into account the probability of switching type from one period to the next. The two marginal utilities are in turn monotonic functions of the level of expenditure of the corresponding type, as shown in Figure 1. We allow, however, for exogenous disturbances to the relation between expenditure and the marginal utility of income, letting $\bar{\lambda}_t^\tau = -(c_t^\tau/\bar{C}_t^\tau)^{-\sigma_\tau^{-1}}$ for each type τ, where $\bar{C}_t^\tau$ is an exogenous factor, representing variation in the spending opportunities available to a given type.

It follows from the same assumptions that optimal labor supply in any given period will be the same for all households of a given type. Specifically, any household of type τ will supply hours $h^\tau(j)$ of labor of type j, so as to satisfy the first-order condition

$$\mu_t^w v_h^\tau(h_t^\tau(j);\xi_t) = \lambda_t^\tau W_t(j)/P_t, \tag{1.3}$$

where $W_t(j)$ is the wage for labor of type j, and the exogenous factor μ_t^w represents a possible "wage markup" (the sources of which are not further modeled). The disutility

[7] We verify that in the case of the numerical parameterization of the model discussed below, these inequalities are satisfied at all times, in the case of small enough random disturbances of any of the kinds discussed.

of working is assumed to be proportional to $(h_t/\bar{H}_t)^{1+\nu}$ for each type, where $\bar{H}_t$ is an exogenous preference shock and $\nu \geq 0$. The two exogenous factors μ_t^w and $\bar{H}_t$ are two alternative sources of exogenous variation in labor supply.

We furthermore assume an isoelastic production function

$$y_t(i) = Z_t h_t(i)^{1/\phi}$$

for each differentiated good i, where $\phi \geq 1$ and Z_t is an exogenous, possibly time-varying productivity factor, common to all goods. We can then determine the demand for each differentiated good as a function of its relative price using the usual Dixit-Stiglitz demand theory, and determine the wage for each type of labor by equating supply and demand for that type. This theory of the demand for each type of labor implies that both the total wage bill and the total disutility of work associated with a given level of output Y_t of the composite good will be increasing in

$$\Delta_t \equiv \int \left(\frac{p_t(i)}{P_t}\right)^{-\theta\phi(1+\nu)} di \geq 1, \tag{1.4}$$

a measure of the dispersion of individual goods prices (taking its minimum possible value, 1, if and only if all prices are identical), where $\theta > 1$ is the elasticity of substitution among differentiated goods in the Dixit-Stiglitz aggregator. Except for the need to aggregate the labor supply of the two types, the labor market model is the same as in the basic New Keynesian model, and so is our theory of the marginal cost of producing individual goods. We assume as usual Calvo-style staggered price adjustment by the producers of individual goods, in which a constant fraction $0 < \alpha < 1$ of goods prices remain unchanged from one period to the next.

With this theory of expenditure decisions on the one hand and wage determination on the other, we can determine the amount by which each type will be a net borrower or saver in a given period. In equilibrium, the net savings of the type s must exceed outstanding real government debt b_t^g by precisely the quantity of deposits that intermediaries will attract in order to finance the quantity of loans that the type b demand. This allows us to derive a law of motion (stated in the appendix) for aggregate private borrowing b_t, according to which b_t is a function of λ_t^b and λ_t^s (the determinants, together with taste shocks, of aggregate expenditure by each of the two types); of Y_t and Δ_t (the determinants, together with taste and technology shocks, of aggregate labor income of each of the two types); of b_{t-1} and b_{t-1}^g (which imply the previous period aggregate net asset positions of each of the two types); of the real *ex post* returns from $t-1$ to t on both private and public debt; and of the quantity b_t^g of new public borrowing.

It remains to specify the frictions associated with financial intermediation, that determine both the spread between borrowing and lending rates and the resources consumed by the intermediary sector. We allow for two sources of credit spreads — one of which follows from an assumption that intermediation requires real resources, and the other of which does not — which provide two distinct sources of "purely financial" disturbances in our model. On the one hand, we assume that real resources $\Xi_t(b_t)$ are consumed in the process of originating loans of real quantity b_t, and that these resources must be produced and consumed in the period in which the loans are originated.[8] The function $\Xi_t(b_t)$ is assumed to be non-decreasing and at least weakly convex.

In addition, we suppose that in order to originate a quantity of loans b_t that will be repaid (with interest) in the following period, it is necessary for an intermediary to also make a quantity $\chi_t b_t$ of loans that will not be repaid, where the loss rate χ_t is an exogenously varying non-negative quantity.[9] We assume as an unavoidable byproduct of a bank's lending activities that it will create a certain number of opportunities for borrowers to take out loans without being made to repay. For simplicity in closing the model, we treat the opportunities for fraudulent borrowing as being distributed equally across all households (who take advantage of such opportunities to the extent that they arise); this is treated as windfall income by those households, and is independent of the quantity of legitimate (enforceable) loans that the same household may take out. Intermediaries are unable to distinguish the borrowers who will default from those who will repay, and so must offer loans to both on the same terms, but we suppose that they are able to accurately predict the fraction of loans that will not be repaid as a function of a given scale of expansion of their lending activity.[10]

Hence total (real) outlays in the amount $b_t + \chi_t b_t + \Xi_t(b_t)$ are required in a given

[8]The use of a reduced-form loan-origination technology to derive equilibrium credit spreads follows authors such as Goodfriend and McCallum (2007).

[9]In Cúrdia and Woodford (2009a), we consider a more general specification in which expected losses from bad loans may be a convex function of the volume of lending.

[10]This kind of information asymmetry is used as a simple way of generating an equilibrium credit spread in Geanakoplos and Dubey (2009).

period in order to originate a quantity b_t of loans that will be repaid (yielding $(1+i_t^b)b_t$ in the following period). Competitive loan supply by intermediaries then implies that

$$1 + i_t^b = (1 + i_t^d)(1 + \omega_t), \tag{1.5}$$

where the equilibrium credit spread ω_t satisfies

$$\omega_t = \omega_t(b_t) \equiv \chi_t + \Xi_t'(b_t). \tag{1.6}$$

It follows that in each period, the credit spread ω_t will be a non-negative-valued, non-decreasing function of the real volume of private credit b_t. This function may shift over time, as a consequence of exogenous shifts in either the resource cost function $\Xi_t(b)$ or the loss rate χ_t. Allowing these functions to be time-varying introduces the possibility of "purely financial" disturbances, of a kind that will be associated with increases in credit spreads and/or reduction in the supply of credit.

Our model of the government sector allows three distinct fiscal disturbances, specified by exogenous processes for the level of government purchases G_t, the proportional income tax rate τ_t, and the level of real government debt b_t^g, each of which can be independently specified. The residual income flow each period required to balance the government's budget is assumed to represent a lump-sum tax or transfer, equally distributed across households regardless of type.

Finally, we assume that the central bank is able to control the deposit rate i_t^d (the rate at which intermediaries are able to fund themselves), though this is no longer also equal to the rate i_t^b at which households are able to borrow, as in the basic NK model. Monetary policy can then be represented by an equation such as

$$i_t^d = i_t^d(\Pi_t, Y_t), \tag{1.7}$$

of the kind advocated by Taylor (1993). (This is of course only one simple specification of monetary policy; we consider central-bank reaction functions with additional arguments in section 2.)

1.2 Numerical Calibration

The numerical values for parameters used in our calculations below are taken from Cúrdia and Woodford (2009a), and are summarized in Table 1. Many of the model's parameters are also parameters of the basic NK model, and in the case of these

Table 1: Numerical parameter values under the baseline calibration (case of a convex intermediation technology).

π_b	0.5	s_b	0.782	$(\theta-1)^{-1}$	0.15	$\bar{\tau}$	0.2
δ	0.975	s_s	0.618	ϕ^{-1}	0.75	$\bar{\mu}^w$	1
β	0.987	σ_b	13.8	α	0.66	$\bar{\chi}$	0
ν	0.105	σ_s	2.76	$\bar{b}^g/\bar{Y}$	0	$1+\bar{\omega}$	$(1.02)^{1/4}$
$\bar{h}^b/\bar{h}^s$	1	$\bar{\lambda}^b/\bar{\lambda}^s$	1.22	$\bar{b}/\bar{Y}$	3.2	η	5

parameters we assume similar numerical values as in the numerical analysis of the basic NK model in Woodford (2003, Table 6.1.), which in turn are based on the empirical model of Rotemberg and Woodford (1997).[11] The new parameters that are needed for the present model are those relating to heterogeneity or to the specification of the credit frictions. The parameters relating to heterogeneity are the fraction π_b of households that are borrowers, the degree of persistence δ of a household's "type", the steady-state expenditure level of borrowers relative to savers, and the interest-elasticity of expenditure of borrowers relative to that of savers, σ_b/σ_s.[12]

In the calculations reported here, we assume that $\pi_b = \pi_s = 0.5$, so that there are an equal number of borrowers and savers. We assume that $\delta = 0.975$, so that the expected time until a household has access to the insurance agency (and its type is drawn again) is 10 years. This means that the expected path of the spread between lending and deposit rates for 10 years or so into the future affects current spending decisions, but that expectations regarding the spread several decades in the future are nearly irrelevant.

We calibrate the model so that private expenditure is 0.7 of total output in steady state, and furthermore calibrate the degree of heterogeneity in the steady-state expen-

[11] Specifically, the values assumed for ν, α, θ, and ϕ in Table 1 are the same as in Rotemberg and Woodford. The value assumed for β is slightly different; β is calibrated to imply the same steady-state real policy rate ($\bar{r}^d = 0.01$/quarter) as in Rotemberg and Woodford, but a slightly higher rate of time preference is required here because of the positive steady-state credit spread. The average of the elasticities σ_τ is also chosen so as to imply the same interest-elasticity of aggregate expenditure as in Rotemberg and Woodford.

[12] Another new parameter that matters as a consequence of heterogeneity is the steady-state level of government debt relative to GDP, $\bar{b}^g/\bar{Y}$; here we assume that $\bar{b}^g = 0$.

diture of the two types so that the implied steady-state debt $\bar{b}$ is equal to 80 percent of annual steady-state output.[13] This value matches the median ratio of private (non-financial, non-government, non-mortgage) debt to GDP over the period 1986-2008.[14] This requires the values of s_b and s_s shown in the table, where $s_\tau \equiv \bar{c}^\tau/\bar{Y}$ is the steady-state expenditure share for each type τ (using bars to denote the steady-state values of variables). We assume an average intertemporal elasticity of substitution for the two types that is the same as that of the representative household in the model of Rotemberg and Woodford (1997),[15] and determine the individual values of σ_τ for the two types on the assumption that σ_b/σ_s is equal to 5. This is an arbitrary choice,[16] though the fact that borrowers are assumed to have a greater willingness to substitute intertemporally is important, as this results in the prediction that an exogenous tightening of monetary policy (a positive intercept shift added to (1.7)) results in a reduction in the equilibrium volume of credit b_t (see Cúrdia and Woodford, 2009a). This is consistent with the VAR evidence on the effects of an identified monetary policy shock presented in Lown and Morgan (1992).[17]

It is also necessary to specify the unperturbed values of the functions $\omega(b)$ and $\Xi(b)$ that describe the financial frictions, in addition to making clear what kinds of random perturbations of these functions we wish to consider when analyzing the effects of "financial shocks." We assume that $\bar{\chi}$, the steady-state value of the exogenous loss rate χ_t, is zero, so that the steady-state credit spread is due entirely to the marginal resource cost of intermediation; but we do allow for exogenous shocks to the loss

[13] In our quarterly model, this means that $\bar{b}/\bar{Y} = 3.2$.

[14] We exclude mortgage debt when calibrating the degree of heterogeneity of preferences in our model, since mortgage debt is incurred in order to acquire an asset, rather than to consume current produced goods in excess of current income.

[15] Specifically, the average elasticity $\bar{\sigma}$ defined in the appendix has the same value as in the earlier model.

[16] In the appendix, we show how our numerical results would differ under the alternative assumption that $\sigma_b/\sigma_s = 2$; few of our qualitative conclusions would be affected, though with such a modest degree of asymmetry, the model implies, counterfactually, that private credit should expand when monetary policy is tightened.

[17] It is also consistent with the evidence in Den Haan *et al.* (2004) for the effects of a monetary shock on consumer credit, though commercial and industrial loans are shown to rise. The result for C&I loans may reflect substitution of firms toward bank credit owing to decreased availability of other sources of credit, rather than an actual increase in borrowing; see Bernanke and Gertler (1995) on this point.

rate, and this is the kind of "financial shock" considered in the figures below. In giving particular emphasis to financial shocks involving an increase in markups but no increase in the real resources used in banking, we follow Gerali *et al.* (2008).[18]

For the intermediation technology, we assume that

$$\Xi(b) = \tilde{\Xi} b^{\eta} \tag{1.8}$$

for some $\eta \geq 1$. Here $\tilde{\Xi}_t$ is an exogenous factor, and this represents a second kind of purely financial disturbance. Regardless of the specification of η, in our numerical analyses we assume a steady-state credit spread $\bar{\omega}$ equal to 2.0 percentage points per annum, following Mehra *et al.,* (2008).[19] (Combined with our assumption that "types" persist for 10 years on average, this implies a steady-state "marginal utility gap" $\bar{\Omega} \equiv \bar{\lambda}^b/\bar{\lambda}^s = 1.22$, so that there would be a non-trivial welfare gain from transferring further resources from savers to borrowers.)

In our baseline calibration, we assume that $\eta = 5$, implying that marginal cost of loan supply has an elasticity of 4. (This means that a 10 percent increase in the volume of lending will increase the equilibrium credit spread by about 1 percentage point.) We emphasize the case of a convex technology ($\eta > 1$), as this corresponds to the idea of a finite lending capacity at a given point in time, due to scarce factors such as intermediary capital and expertise that are here treated as exogenous. The assumption that $\eta > 1$ also allows our model to match the prediction of VAR estimates that an unexpected tightening of monetary policy is associated with a slight reduction in credit spreads (see, *e.g.,* Lown and Morgan, 2002, and Gerali *et al.,* 2008). In the appendix, we discuss the sensitivity of our results to the particular value of η assumed, comparing results for values as low as 1 or as high as 50.

[18] These authors cite the Eurosystem's quarterly Bank Lending Survey as showing that since October 2007, banks in the euro area had "strongly increased the margins charged on average and riskier loans" (p. 24).

[19] Mehra *et al.* argue for this calibration by dividing the net interest income of financial intermediaries (as reported in the National Income and Product Accounts) by a measure of aggregate private credit (as reported in the Flow of Funds).

2 Instrument Rules that Respond to Financial Conditions

We turn now to the consequences of alternative specifications of the central-bank reaction function, in particular the effects of including a direct response to some measure of financial conditions. We first discuss the welfare criterion that we use to evaluate candidate policy rules, and then turn to our results for some particular examples of modified Taylor rules.

2.1 Welfare criterion

We shall suppose that the objective of policy is to maximize the average ex ante expected utility of the households. As shown in Cúrdia and Woodford (2009a), this implies an objective of the form

$$E_0 \sum_{t=0}^{\infty} \beta U(Y_t, \lambda_t^b, \lambda_t^s, \Delta_t; \tilde{\xi}_t) \tag{2.1}$$

where

$$\begin{aligned} U(Y_t, \lambda_t^b, \lambda_t^s, \Delta_t; \tilde{\xi}_t) \;\; \equiv \;\; & \pi_b \bar{u}^b(\lambda_t^b; \bar{C}_t^b) + \pi_s \bar{u}^s(\lambda_t^s; \bar{C}_t^s) \\ & - \phi(\lambda_t^b/\lambda_t^s) \bar{H}_t^{-\nu} \left(\frac{Y_t}{Z_t}\right)^{\phi(1+\nu)} \Delta_t. \end{aligned} \tag{2.2}$$

Here $\tilde{\xi}_t$ is a vector of exogenous disturbances to tastes and technology (consisting of $\bar{C}_t^b, \bar{C}_t^s, \bar{H}_t, Z_t$), and for each type τ, the function $\bar{u}^\tau(\lambda; \bar{C})$ indicates the level of utility achieved by type τ when its marginal utility of income is λ and the current taste shock is $\bar{C}$. Thus the first two terms on the right-hand side of (2.2) indicate the average utility obtained from expenditure.

Note that the final term in (2.2) represents the average disutility of working, averaging both over the entire continuum of types of labor j and over the two types of households, using the model of equilibrium labor supply discussed in section 1.1. The factor Δ_t is the index of price dispersion (1.4), which matters because the disutility of labor required to produce quantity Y_t of the composite good depends on the composition of demand. Note that in the Calvo model of price adjustment, this dispersion measure evolves according to a law of motion

$$\Delta_t = h(\Delta_{t-1}, \Pi_t),$$

where the function $h(\Delta, \Pi)$ is defined as in Benigno and Woodford (2005). This link is what makes inflation stabilization relevant for welfare in our model. Finally, the factor $\phi(\lambda_t^b/\lambda_t^s)$ is a positive quantity, increasing in the relative marginal utility, reflecting the fact that the inefficiency of the way in which labor effort is divided between the two types is greater the greater the gap between their marginal utilities of income (owing to the inefficiency of financial intermediation).

Using this welfare criterion, we can compute the equilibrium responses to the various types of shocks in our model under an optimal policy commitment (the Ramsey policy problem). This problem is treated in more detail in Cúrdia and Woodford (2009a). Here we are interested not in characterizing fully optimal policy, but in the extent to which various simple modifications of the Taylor rule would result in a closer approximation to Ramsey policy. One way in which we judge the closeness of the approximation is by comparing the responses to shocks under candidate policy rules to those that would occur under the Ramsey policy.

We also evaluate the level of welfare associated with alternative simple rules (modified Taylor rules of various types), using a method proposed by Benigno and Woodford (2008). Under this approach, one computes (for the equilibrium associated with each candidate policy rule) the value of a quadratic approximation to the Lagrangian for an optimization problem that corresponds to the continuation of a previously chosen Ramsey policy; this approximate Lagrangian is minimized by a time-invariant linear rule under which the responses to shocks are the same (to a linear approximation) as under the optimal policy. By computing the value of this Lagrangian under a given time-invariant policy rule, we have a criterion that would rank as best (among all possible linear rules) a rule that achieves exactly the responses to shocks associated with the Ramsey policy. We use this method to rank the benefits from alternative spread-adjusted or credit-adjusted Taylor rules; this is a more formal way of assessing the degree to which a given modification of the Taylor rule leads to responses to shocks that are closer to those implied by Ramsey policy.[20]

[20] See Altissimo *et al.* (2005) for discussion of a numerical method that can be used to compute this welfare measure.

2.2 Spread-Adjusted Taylor Rules

We first consider central-bank reaction functions of the form

$$\hat{\imath}_t^d = r_t^n + \phi_\pi \pi_t + \phi_y \log(Y_t/Y_t^n) - \phi_\omega \hat{\omega}_t, \tag{2.3}$$

for alternative values of the response coefficients $\phi_\pi, \phi_y, \phi_\omega$. Taylor (1993) proposes a linear response to variations in the inflation rate and in the output gap, with coefficients $\phi_\pi = 1.5, \phi_y = 0.5/4$,[21] which are the values used in our baseline calibration as well. We define the output gap relative to the "natural rate of output" Y_t^n, by which we mean the flexible-price equilibrium level of output in the case that the distortions μ_t^w, τ_t, ω_t and Ξ_t are all set equal to their steady-state values.[22] The intercept term r_t^n similarly represents the "natural rate of interest," which we define as the equilibrium real rate of interest under the same counterfactual; both r_t^n and Y_t^n are functions of the exogenous variations in tastes, technology, and government purchases.[23]

This kind of policy rule has the property that, in the absence of variation in any of the three distortion factors, it will be consistent with an equilibrium in which both inflation and the output gap are completely stabilized, and equal to zero at all times.[24] Moreover, for response coefficients in a certain range, the policy rule implies a determinate rational-expectations equilibrium, which in the absence of variation in

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[21] Taylor (1993) reports the value $\phi_y = 0.5$, because he writes the equation in terms of annualized, rather than quarterly, rates of interest and of inflation. Thus his variables correspond to $4\hat{\imath}_t^d$ and $4\pi_t$ in our notation.

[22] If these distortions, as well as the desired markup of prices over marginal cost due to monopolistic competition, were set equal to zero, Y_t^n would correspond to the welfare-maximizing level of output at each point in time. We consider instead a flexible-price equilibrium with the actual steady-state levels of the distortions, so that the output gap will equal zero in a steady state with a zero inflation rate, and will be zero on average in the equilibria implied by policy rule (2.3).

[23] The definitions of both Y_t^n and r_t^n in terms of the exogenous disturbances are the same as in Woodford (2003, chap. 4), except that the intertemporal elasticity of substitution of the representative household must be replaced by an average of the coefficients σ_τ, as discussed in the appendix.

[24] As shown in the appendix, the present model implies an "intertemporal IS equation" and an aggregate-supply equation of exactly the same form as in the basic New Keynesian model, except for the presence of additional additive terms that are functions of the expected evolution of the credit spread. Hence the consistency of this form of Taylor rule with complete stabilization follows as in Woodford (2003, chap. 4). Note that it is essential to this conclusion that the rule includes adjustments for variations in r_t^n and Y_t^n.

the distortions, will be the equilibrium with zero inflation. (We here consider only response coefficients in that range; for all of the numerical cases discussed below, or in the appendix, the Taylor values for ϕ_π and ϕ_y are among those that imply determinacy.[25] Finally, at least in the case of zero steady-state distortions, the equilibrium with zero inflation and a zero output gap at all times is optimal, so that a policy rule of this kind would be an example of an optimal policy.[26])

In the absence of any adjustment for financial conditions, however (*i.e.*, in the case of the standard Taylor rule, with $\phi_\omega = 0$), the policy rule (2.3) does *not* result in a desirable response to purely financial disturbances, as illustrated in Figure 2 below. Yet because the Taylor rule would be optimal, at least under certain circumstances, in the absence of credit frictions, it is of interest to consider the extent to which the introduction of credit frictions makes it desirable to modify the standard Taylor rule by responding in addition to measures of financial conditions. Here we consider the advantages of adding a term proportional to $\hat{\omega}_t$, the deviation of $\log(1+\omega_t)$ from its steady-state level.

Rules with $\phi_\omega > 0$ reflect the idea that the funds rate should be lowered when credit spreads increase, so as to prevent the increase in spreads from "effectively tightening monetary conditions" in the absence of any justification from inflation or high output relative to potential. They essentially correspond to the proposal of authors such as McCulley and Toloui (2008) and Taylor (2008), except that we consider the possible advantages of a spread adjustment that is less than the size of the increase in credit spreads. (The proposal of these authors corresponds to the case $\phi_\omega = 1$; here we primarily consider possible rules in the range $0 \leq \phi_\omega \leq 1$.) We consider the consequences of alternative values for ϕ_ω, and compare the equilibrium responses to

[25]In the case of a linear intermediation technology ($\eta = 1$), the credit spread $\{\omega_t\}$ will evolve exogenously, and the conditions for determinacy are identical to those presented in Woodford (2003, chap. 4), as the derivation there continues to apply. In this case, $\phi_\pi > 1$ and $\phi_y > 0$ are sufficient conditions for determinacy. In the case of a modest degree of convexity (η not too large) and moderate values of ϕ_ω, the conditions for determinacy are not much affected. Our numerical investigations indicate that even when $\eta = 50$, a rule of the form (2.3) with $\phi_y = 0$ and $0 \leq \phi_\omega \leq 1$ implies a determinate equilibrium (under our baseline parameters) as long as $\phi_\pi > 1.01$, and the required level of ϕ_π is (as usual) even lower when $\phi_y > 0$. Indeterminacy becomes a problem, for values of ϕ_π, ϕ_y near those proposed by Taylor (1993), only in the case of values of ϕ_ω very much higher than 1; and the values required are much higher when $\eta = 5$, as in our baseline calibration.

[26]In at least certain special cases, the rule would be optimal even in the presence of non-zero steady-state distortions, as discussed in Benigno and Woodford (2005).

shocks under this kind of policy to those under an optimal policy commitment.

2.2.1 Responses to Financial Disturbances

We first consider the consequences of alternative values for ϕ_ω for the economy's response to a disturbance originating in the financial sector, since this is the case that motivates the policy proposal. In our model, there are two possible reasons for the function $\omega_t(b)$ to shift: a change in the loss rate χ_t, or a change in the cost function $\Xi_t(b)$ (which we model as a change in the multiplicative factor $\tilde{\Xi}_t$). We consider financial disturbances of both types, but obtain fairly similar conclusions in the two cases (for a shock of either type that increases $\omega_t(\bar{b})$ by a given amount); our discussion will emphasize the case of an exogenous change in the loss rate.[27] In our numerical exercises, all exogenous disturbances are assumed to follow AR(1) processes, with serial correlation coefficient $0 \leq \rho < 1$. (The persistence ρ may be different for different shocks.)

Figure 2 shows the responses of endogenous variables to an exogenous increase in χ_t, of a size that would increase the credit spread by 4 percentage points (as an annualized rate) for a given volume of private credit, with persistence $\rho = 0.9$.[28] (Because of the contraction of credit that results, the equilibrium increase in the credit spread shown in the figure is less than 4 percent.[29]) Responses are shown in the case of five different possible values of ϕ_ω, ranging between 0 and 1. Under the baseline Taylor rule ($\phi_\omega = 0$), such a disturbance leads not only to an increase in the credit spread and a contraction of aggregate credit, but also to a substantial fall in aggregate real activity and to a drop in the rate of inflation. (These responses are shown by the dashed lines in the figure.) This contraction of output is inefficient; under an optimal monetary policy commitment (shown by the solid lines in the figure), output would

[27] The consequences of the two types of financial disturbances are quite different when we consider their implications for optimal central-bank credit policy, in Cúrdia and Woodford (2009b).

[28] Here, as in all subsequent figures, the model is calibrated as indicated in Table 1.

[29] This is clearly a large shock, relative to what occurs with any frequency during normal periods; but increases in spreads even larger than this were observed in the fall of 2008. We do not here consider a larger shock, in order to avoid having to deal with the consequences of the zero lower bound on nominal interest rates. In the case of a disturbance large enough to cause the zero bound to bind, the simple Taylor rule is an even less desirable policy, and a contemporaneous spread adjustment of the kind proposed in (2.3) does little to remedy its defects; instead, a history-dependent policy is needed, as discussed in Cúrdia and Woodford (2009b).

Table 2: Optimal value of the spread-adjustment coefficient ϕ_ω in policy rule (2.3), in the case of financial disturbances of either of two types, if the coefficients ϕ_π, ϕ_y are fixed at the values recommended by Taylor (1993). Each column indicates a particular type of disturbance, for which the policy rule is optimized; each row indicates a different possible degree of persistence for the disturbance. Results are presented under each of three possible assumptions about the degree of convexity η of the intermediation technology.

	$\eta = 1$		$\eta = 5$		$\eta = 50$	
ϕ_ω^*	χ_t	$\tilde{\Xi}_t$	χ_t	$\tilde{\Xi}_t$	χ_t	$\tilde{\Xi}_t$
$\rho = 0.00$	1.84	1.30	0.86	0.61	0.85	0.64
$\rho = 0.50$	1.62	1.40	0.84	0.71	0.84	0.72
$\rho = 0.90$	0.26	0.28	0.66	0.63	0.82	0.75
$\rho = 0.99$	-2.43	-2.36	0.13	0.18	0.69	0.66

decline much less. Nor would inflation be allowed to decrease as under the Taylor rule; indeed, initially it would rise slightly.

The figure also shows that a positive spread adjustment can largely remedy the defects of the simple Taylor rule, in the case of a shock to the economy of this kind. And the optimal degree of adjustment is a substantial fraction of the increase in the credit spread, though it is smaller than the 100 percent adjustment proposed by Taylor and by McCulley and Toloui (the case shown by the dashed lines with lighter-colored dots). The responses of both output and inflation under Ramsey policy would (to a fair approximation) lie between those implied by a 50 percent spread adjustment and a 75 percent spread adjustment. If we optimize our welfare criterion over policy rules with alternative values of ϕ_ω, assuming that this type of disturbance is the only kind that ever occurs, the welfare maximum is reached when $\phi_\omega = 0.66$, as shown in Table 2.

It is interesting to observe in Figure 2 that, while a superior policy involves a reduction in the policy rate relative to what the unadjusted Taylor rule would prescribe, this does not mean that under such a policy the central bank actually cuts its interest rate target more sharply in equilibrium. The size of the fall in the policy rate (shown in the middle left panel) is about the same regardless of the value of ϕ_ω;

but when ϕ_ω is near 1, output and inflation no longer have to decline in order to induce the central bank to accept an interest-rate cut of this size, and in equilibrium they do not decline. (In fact, the nominal policy rate does fall a little more, and since expected inflation does not fall, the *real* interest rates faced by both savers and borrowers fall more substantially when ϕ_ω is a large fraction.) The contraction of private credit in equilibrium is also virtually the same regardless of the value of ϕ_ω. Nonetheless, aggregate expenditure falls much less when ϕ_ω is positive; the expenditure of borrowers no longer has to be cut back so much in order to reduce their borrowing, because their labor income no longer falls in response to the shock, and there is an offsetting increase in the expenditure of savers.

As Table 2 shows, a very similar conclusion is reached in the case of an exogenous increase in $\tilde{\Xi}_t$ of the same assumed persistence. The broad conclusion that the optimal adjustment coefficient ϕ_ω is greater than 0.5 (though less than 1) is also robust to a consideration of a value of η larger than 5 (so that credit supply is less elastic than under our baseline calibration), or financial disturbances that are less persistent than the one assumed in Figure 2. However, under the baseline calibration, the optimal spread adjustment is much smaller in the case of very persistent financial disturbances. Figure 3 shows the equilibrium responses under the same 5 candidate policy rules (and under optimal policy), in the case of an exogenous increase in χ_t with persistence $\rho = 0.99$. In this case, a 100 percent spread adjustment clearly loosens policy far too much, and the welfare-maximizing adjustment is only $\phi_\omega = 0.13$. As the figure makes clear, it is still true in this case that an optimal policy would be more expansionary than the simple Taylor rule in the year following the shock; but a contemporaneous spread adjustment does not provide a very good approximation to optimal policy, because spreads remain elevated for several years (under the hypothesis of a very persistent disturbance) while the optimal departure from the simple Taylor rule would be much more transitory.

In the case of a less convex intermediation technology, the dependence of the optimal spread adjustment on the degree of persistence of the disturbance is much more severe: the optimal adjustment may be well above 100 percent (for sufficiently transitory shocks), but can also be strongly *negative* (for sufficiently persistent shocks). Hence even in the case that we are only concerned with the policy's implication in the case of purely financial disturbances, we do not obtain a single recommendation that is independent of the persistence of the disturbances; and since a given economy is

Table 3: Optimal value of the spread-adjustment coefficient ϕ_ω in policy rule (2.3), in the case of a variety of non-financial disturbances, if the coefficients ϕ_π, ϕ_y are again fixed at the values recommended by Taylor (1993). Each column indicates a particular type of disturbance, for which the policy rule is optimized; each row indicates a different possible degree of persistence for the disturbance.

ϕ_ω^*	$\bar{C}_t^b$	$\bar{C}_t^s$	G_t	b_t^g	$Z_t, \bar{H}_t$	μ_t^w	τ_t
$\rho = 0.00$	0.24	0.57	1.84	0.60	0.97	16.41	14.12
$\rho = 0.50$	0.21	0.28	1.73	0.71	0.90	12.09	11.73
$\rho = 0.90$	-0.13	-0.12	-0.07	0.62	-0.11	13.03	13.02
$\rho = 0.99$	-1.47	-1.47	-1.46	0.16	-1.47	21.77	21.78

surely subject to disturbances of different expected degrees of persistence at different times, this means that a contemporaneous spread adjustment cannot be found that will have desirable consequences under all circumstances.

One might conclude from Table 2 that lack of robustness should not be so great a concern, as long as the intermediation technology can be assumed to be sufficiently convex. But the case of η well above 1 raises another difficulty, and this is that in this case, non-financial disturbances will result in endogenous variations in the credit spread, to the extent that they affect the equilibrium volume of lending, because of (1.6). Hence a spread adjustment in (2.3) will affect the economy's response to other kinds of disturbances as well, and in ways that may or may not be desirable. In fact, the desirability of such an adjustment will vary greatly, depending on the type of disturbances to which the economy is subject. Here we illustrate this point by showing how the optimal response would be different in the case of a variety of different types of disturbances. We first consider the optimal response coefficient in the case that one is concerned only with the economy's response to a disturbance of a single type (though we consider many different individual types); and we then briefly discuss how the responses to disturbances of different types can be traded off against one another.

2.2.2 Responses to Non-Financial Disturbances

Table 3 shows the optimal response coefficients ϕ_ω in the case of a variety of types of non-financial disturbances, each of which may be more or less persistent.[30] Probably the most interesting contrast with our conclusions regarding responses to financial disturbances is found in the case of disturbances to various components of aggregate expenditure, owing to exogenous variation in $\bar{C}_t^b$, $\bar{C}_t^s$, or G_t. Figure 4 shows the responses of the endogenous variables to an exogenous increase in $\bar{C}_t^b$, in the case $\rho = 0.9$. In response to this kind of shock, the baseline Taylor rule is too inflationary a policy; but because the shock (increasing the spending opportunities of borrowers) increases credit demand and hence the equilibrium credit spread, a positive spread adjustment will result in an even *looser* monetary policy response, which makes policy even less similar to the optimal policy. And indeed, the corresponding entry in Table 3 indicates that the optimal spread adjustment would actually be slightly *negative.*

Figure 5 instead shows the responses in the case of an exogenous increase in $\bar{C}_t^s$, again assuming $\rho = 0.9$. In the case of this kind of shock, the baseline Taylor rule is too disinflationary a policy; but because the shock (increasing the spending opportunities of savers) reduces the supply of funds to intermediaries and hence the equilibrium credit spread, a positive spread adjustment will result in an even *tighter* monetary policy response, again making policy even farther from optimal. Again, the optimal spread adjustment is slightly negative. The picture is similar in the case of an increase in government purchases (not shown), and again the optimal ϕ_ω would be negative.

Table 3 indicates that the conclusions in the last two paragraphs are quite sensitive to the degree of persistence of disturbances of these kinds: the optimal ϕ_ω can be anything from a large positive quantity (in the case of sufficiently transitory shocks) to a large negative quantity (in the case of even more persistent shocks than those considered above). (This is because the degree to which the baseline Taylor rule is too loose or too tight varies with the persistence of the disturbance.) But this simply illustrates our most general point, which is that the type of spread adjustment that is desirable for some disturbances will be problematic for others.

While an increase in b_t^g (a debt-financed increase in government transfers) might

[30] In this case, we report results only for our baseline calibration, in which $\eta = 5$; the corresponding results for smaller or larger values of η are reported in the appendix.

also be considered a "demand" disturbance, its consequences are different from the three shocks just mentioned. As shown in Figure 6, the effects of this kind of shock under the various spread-adjusted rules are quite similar to the effects of a purely financial disturbance (though with the opposite sign of the disturbance considered in Figure 2). Essentially, this disturbance matters for output and inflation determination only because of its effect on the supply of credit to private borrowers: because government borrowing crowds out private borrowing, equilibrium credit spreads fall. This is also associated with increases in output and inflation that are inefficient, and would be limited by an optimal monetary policy response (as shown by the solid lines in Figure 6). A spread-adjusted Taylor rule achieves something closer to optimal policy, especially for a spread adjustment on the order of $\phi_\omega = 0.5$. (Because the spread falls in response to this shock, the spread adjustment implies greater tightening of policy in response to the fiscal shock than would occur under the baseline Taylor rule, and this prevents output and inflation from increasing.) As shown in Table 3, the optimal spread adjustment would in fact be $\phi_\omega = 0.62$ in the case of a debt shock with a persistence of 0.9, and again this result is not too sensitive to the assumed degree of persistence of the disturbance, under our baseline calibration.[31]

Our conclusions are different in the case of non-distortionary "supply shocks," by which we mean exogenous variation in either the productivity factor Z_t or the labor-supply preference shock $\bar{H}_t$.[32] Figure 7 shows the responses in the case of a productivity disturbance with persistence $\rho = 0.9$; in this case, the baseline Taylor rule is already somewhat too inflationary in response to such a shock (except in the quarter of the shock), so a positive spread adjustment lowers welfare. But as indicated in Table 3, this is again a case in which the welfare consequences of a spread adjustment are quite different depending on the degree of persistence of the disturbance. The optimal spread adjustment would be nearly 100 percent in the case of sufficiently transitory disturbances, while it would be a large negative value in the case of highly persistent ones.

They are different in yet another way in the case of variations in the distortion

[31] As in the case of the financial disturbances, the optimal ϕ_ω declines, but is still positive, in the case of a very persistent shock.

[32] In fact, only a certain geometric average of these factors matters for the determination of any of the variables that are relevant for welfare in our model. Hence the welfare implications of a given policy are the same in the case of either type of shock, and there is accordingly only a single column in Table 3 for these two shocks.

factors μ_t^w or τ_t. Figure 8 shows the responses in the case of an increase in the tax rate with persistence $\rho = 0.9$; in this case, because the effect of the shock on the equilibrium credit spread is very small, even a 100 percent spread adjustment has little effect on the equilibrium responses. The figure shows that in the case of a sufficiently large response to the credit spread (an interest rate adjustment that is several times the size of the change in the spread), a positive spread adjustment can better approximate optimal policy.[33] As indicated in Table 3, the optimal spread adjustment for shocks of this kind would be greater than 10, regardless of the persistence of the shock. But a response of that kind would be far from optimal in the case of any other type of disturbance.

2.2.3 Welfare Tradeoffs

Thus we find that while a positive spread adjustment can lead to a closer approximation to optimal policy under some circumstances, the degree of adjustment that is called for (and even its sign) is quite different in the case of different types of disturbances. How should one weigh the possible advantages of a spread adjustment in a case like that shown in Figure 2 against its disadvantages in cases like those shown in Figures 4, 5, or 7? An overall judgment about the merits of a spread adjustment will depend, obviously, on which types of disturbances are expected to occur more often (or to have a larger magnitude when they occur). But even given a judgment about which disturbances are of greatest importance, the optimal coefficients reported in Table 3 do not provide enough information for a judgment about the desirability of a spread adjustment. For example, in the case of shocks to the tax rate, an increase in ϕ_ω from 0 to 1 will not make the equilibrium responses shown in Figure 8 much more similar to the optimal ones; but might the change nonetheless improve those responses enough to outweigh the increased sub-optimality of the responses to a productivity shock shown in Figure 7?

To answer this question, Table 4 reports the welfare change (relative to the baseline Taylor rule with $\phi_\omega = 0$) implied by a spread adjustment of a given size, in the case of each of the 10 types of disturbances considered in Tables 2 and 3.[34] The variance

[33] Results are very similar in the case of a shock to the wage markup (not shown).

[34] For reasons of space, this table considers only shocks with persistence $\rho = 0.9$ or 0.99, and the baseline calibration in which $\eta = 5$. Results for alternative calibrations of the model are reported in the appendix.

Table 4: Welfare consequences of increasing ϕ_ω, in the case of different disturbances. Each column indicates a different type of disturbance, while each row corresponds to a given degree of spread adjustment. A value of 1 means a welfare increase equivalent to a permanent 0.001 percent increase in consumption by households of both types.

$\varphi \times 10^5$	χ_t	$\tilde{\Xi}_t$	$\bar{C}_t^b$	$\bar{C}_t^s$	G_t	b_t^g	$Z_t, \bar{H}_t$	μ_t^w	τ_t
Baseline persistence ($\rho_\xi = 0.90$)									
$\phi_\omega = 0.25$	27.592	27.588	-1.069	-2.939	-0.365	28.169	-0.071	9.425	9.322
$\phi_\omega = 0.50$	42.519	41.715	-3.203	-8.883	-1.217	42.540	-0.219	18.774	18.570
$\phi_\omega = 0.75$	44.201	41.766	-6.422	-17.890	-2.566	42.474	-0.447	28.042	27.740
$\phi_\omega = 1.00$	32.034	27.100	-10.746	-30.015	-4.421	27.311	-0.755	37.225	36.825
High persistence ($\rho_\xi = 0.99$)									
$\phi_\omega = 0.25$	0.252	4.155	-3.920	-9.577	-2.147	2.727	-0.447	7.712	7.703
$\phi_\omega = 0.50$	-15.889	-10.151	-8.468	-20.686	-4.638	-13.120	-0.965	15.365	15.347
$\phi_\omega = 0.75$	-49.053	-43.636	-13.646	-33.331	-7.476	-48.254	-1.554	22.955	22.929
$\phi_\omega = 1.00$	-99.880	-97.029	-19.457	-47.522	-10.663	-103.395	-2.216	30.484	30.450

assumed for each shock is one that would result (under the baseline Taylor rule) in fluctuations in aggregate output around trend with a variance equal to the variance of detrended US real GDP.[35] Because the contributions to welfare from different independent disturbances are additive (in the quadratic approximation to welfare, explained in Benigno and Woodford, 2008, and Altissimo *et al.*, 2005, and used in computing this table), the net welfare effect of a given spread adjustment can be computed by taking a weighted average of the numbers reported in a given row of the table. For example, a spread adjustment of $\phi_\omega = 0.75$ would be preferable to an adjustment of only 0.50 if χ_t shocks of persistence $\rho = 0.9$ are the only source of uncertainty in the economy, but it would not be preferable if only 20 percent of the variance of output is due to shocks of that kind,[36] while the other 80 percent of

[35]HP filtering quarterly per capita real GDP over the period 1948:1 to 2009:3 yields a standard deviation of output fluctuations of 1.71 percentage points.

[36]Here we refer to the variance of aggregate output relative to trend on the assumption that monetary policy is described by the baseline Taylor rule.

the variance of output is due to productivity shocks of persistence $\rho = 0.99$. (In the latter case, the gain from increasing ϕ_ω to 0.50 would be 0.8(-0.965)+ 0.2(42.519) = 7.732, while the gain from increasing it to 0.75 would be only 0.8(-1.554)+0.2(44.201) = 7.597.)

Table 4 indicates that the types of disturbances that matter the most for welfare comparisons among the policies considered in the table are those that change the size of economic distortions: variations in the tax rate, in the wage markup, or in the purely financial disturbances that change the size of the credit spread. (Variations in the size of debt-financed government transfers should also be considered essentially a shock to the size of a distortion, namely the gap between the marginal utility of expenditure of the two types.) This is because these are the types of disturbances for which the baseline Taylor rule does not already represent a relatively good approximation to optimal policy; hence even small adjustments can have non-trivial welfare consequences. To the extent that disturbances of these kinds (other than very highly persistent financial shocks) are believed to account for a substantial fraction of aggregate variability, a positive spread adjustment (even one of the size proposed by Taylor and by McCulley and Toloui) is likely to improve welfare. On the other hand, if most economic variability is due to technology shocks, preference shocks, or variations in government purchases, as implied by many quantitative DSGE models, then no positive spread adjustment may be desirable.[37]

2.3 Responding to Variations in Aggregate Credit

Some have suggested that because of imperfections in financial intermediation, it is more important for central banks to monitor and respond to variations in the volume of bank lending than would be the case if the "frictionless" financial markets of Arrow-Debreu theory were more nearly descriptive of reality. A common recommendation in this vein is that monetary policy should be used to help to stabilize aggregate private credit, by tightening policy when credit is observed to grow unusually strongly and loosening policy when credit is observed to contract. For example, Christiano *et*

[37]This conclusion depends importantly on the fact that our baseline Taylor rule includes adjustments for variations in the natural rate of output and in the natural rate of interest, which allows the rule to respond relatively well to the non-distorting shocks. See the appendix for the consequences of adjustments for financial conditions in the case that the baseline rule contains no adjustments for variations in the natural rates.

Table 5: Optimal value of the response coefficient ϕ_b in policy rule (2.4), for the same set of possible disturbances and alternative calibrations as in Table 2.

	$\eta = 1$		$\eta = 5$		$\eta = 50$	
ϕ_b^*	χ_t	$\tilde{\Xi}_t$	χ_t	$\tilde{\Xi}_t$	χ_t	$\tilde{\Xi}_t$
$\rho_\xi = 0.00$	0.015	0.015	0.171	0.162	1.117	0.952
$\rho_\xi = 0.50$	0.007	0.006	0.085	0.086	0.415	0.398
$\rho_\xi = 0.90$	-0.001	-0.001	0.028	0.031	0.060	0.065
$\rho_\xi = 0.99$	-0.008	-0.008	-0.002	0.000	0.000	0.003

al. (2007) propose that a Taylor rule that is adjusted in response to variations in aggregate credit may represent an improvement upon an unadjusted Taylor rule.

In order to consider the possible advantages of such an adjustment, we replace (2.3) by a reaction function of the form

$$\hat{\imath}_t^d = r_t^n + \phi_\pi \pi_t + \phi_y \log(Y_t/Y_t^n) + \phi_b \hat{b}_t, \tag{2.4}$$

for some coefficient ϕ_b, the sign of which we shall not prejudge, where $\hat{b}_t$ is the deviation of $\log b_t$ from its steady-state level. (Christiano *et al.*, like most proponents of credit-based policies, argue for the desirability of a positive response coefficient.) Figure 9 illustrates the consequences of alternative degrees of response (of either sign) to credit variations, in the case of the same kind of financial disturbance as in Figure 2. Since the baseline Taylor rule allows financial conditions to tighten too much in response to this kind of shock (just as in Figure 2), and aggregate credit declines, a moderately positive value of ϕ_b can mitigate the consequences of the shock to some extent.

However, it is apparent from Figure 9 that no value of ϕ_b provides as close an approximation to optimal policy as can be achieved through a suitable size of spread adjustment. The reason is that the contraction of credit caused by the shock is much more persistent than the increase in the credit spread, owing to the intrinsic dynamics of private indebtedness.[38] An adjustment proportional to the deviation of the credit spread from its normal level has more nearly the correct time path to

[38]The credit spread returns to its normal level faster than the disturbance to the level of χ_t dissipates, as the credit spread is endogenously reduced as aggregate debt contracts. Credit returns

approximate Ramsey policy than does an adjustment proportional to the deviation of credit from its normal level. As Table 5 shows, the optimal credit adjustment ϕ_b can be quite small (and need not even be positive), in the case of very persistent financial disturbances (which is when the difference just cited is most extreme). Unless the relevant financial disturbances are extremely transitory ($\rho = 0.5$ or lower) *and* the intermediation technology is highly convex (η is well above 5), the optimal value of ϕ_b is not likely to be very large.

And once again, an adjustment that is desirable in the case of (some kinds of) financial disturbances may not have desirable consequences for the economy's response to other types of disturbances. In the case of non-financial disturbances (and assuming $\eta > 1$), the equilibrium response of $\hat{\omega}_t$ to any shock is a fixed multiple of the response of $\hat{b}_t$, so that any rule of the form (2.4) has the same consequences as a particular rule of the form (2.3). However, the sign of the response must be reversed: a value $\phi_b < 0$ is required to produce the same responses to non-financial disturbances as a rule with $\phi_\omega > 0$. Insofar as some kinds of non-financial disturbances (notably, variations in the distortion factors $\hat{\mu}_t^w, \tau_t$, and b_t^g) imply that there are significant welfare benefits from a positive spread adjustment (see Table 4), these same types of disturbances imply significant gains from a *negative* credit adjustment (and correspondingly significant *losses* from a positive ϕ_b). To the extent that disturbances of these types are of any quantitative importance as sources of economic variability, it is difficult to argue for the desirability of a positive credit adjustment in a model like ours.

3 Comparison with Flexible Inflation Targeting

An alternative way of taking financial conditions into account in the conduct of monetary policy involves not the use of an instrument rule such as (2.3) or (2.4), but rather the use of an econometric model to adjust the path of the policy rate as necessary to ensure that the paths of inflation and real activity satisfy some "target criterion."[39] If the model used to produce the projections implies that financial conditions are

to its normal level more slowly than the disturbance dissipates, because even when χ_t is nearly at its steady-state level, debt remains lower than normal as the amount of past debt to roll over is low.

[39] For general arguments in favor of such an approach, see Svensson (2003), Svensson and Woodford (2005), and Woodford (2007).

relevant to inflation and output determination — like the model proposed here — then financial conditions will influence the path chosen for the policy rate under such a rule, even if the target criterion itself does not involve any financial variables.

For example, Benigno and Woodford (2005) show that in the representative-household version of the present model, policy is optimal if and only if a target criterion of the form

$$\pi_t + \phi \Delta x_t = 0 \tag{3.1}$$

is satisfied each period, where $\phi > 0$, the output gap is defined as $x_t \equiv \log(Y_t/Y*_t)$, and Y_t^* is a certain function of exogenous disturbances.[40] Cúrdia and Woodford (2009a) show that (3.1) continues to provide a reasonably good approximation to optimal policy, even in the presence of heterogeneity and credit frictions.[41] For example, Figure 10 shows the economy's response to the same kind of financial disturbance as in Figures 2 and 9, in the case of a policy that adjusts the policy rate to ensure that (3.1) is satisfied (the lines labeled "Flex Target"). This policy represents a much closer approximation to optimal policy than does the unadjusted Taylor rule, also shown in the figure. But this result is not specific to the particular kind of disturbance considered in Figure 10; a similarly good approximation to the optimal responses is obtained in the case of each of the 10 types of disturbances considered in section 2.2, and under varying assumptions about their degree of persistence.

The spread adjustment proposed in (2.3) improves upon the standard Taylor rule because it represents a (crude) approximation to the kind of adjustment of the path of the policy rate required by the target criterion (3.1). Because in our model aggregate demand (and to some extent, aggregate supply as well) depends on the expected path of the credit spread as well as the path of the policy rate, the reaction function that implements (3.1) involves a response to the path of the credit spread in addition to inflation and real activity. But the terms omitted in the baseline Taylor rule are not a simple multiple of the current credit spread, and so no simple rule of the form (2.3) is equivalent to (3.1). Indeed, the rule of the form (2.3) that best approximates flexible inflation targeting varies depending on the nature and persistence of the disturbances to the economy.

[40] The target level of output Y_t^* coincides with the concept of the "natural rate of output" Y_t^n used in (2.3) in certain special cases, but is not identical to it.

[41] In certain special cases that they discuss, (3.1) corresponds to fully optimal policy, even with heterogeneity and financial disturbances.

A response to aggregate credit, as in (2.4), is even less useful as an approximation to the target criterion (3.1), since aggregate credit as such is not the additional variable in the structural relation between the path of the policy rate and aggregate demand. Of course, the relation (1.6) implies a systematic relationship between variations in the spread and variations in aggregate credit; but this relationship is not the same in the case of financial and non-financial disturbances. Since it is increases in the spread that perturb the relationship between the path of the policy rate and aggregate demand, regardless of whether the increase in the spread is associated with an increase or a decrease in credit, a suitably chosen spread-adjusted Taylor rule provides a more robust guideline for policy than any rule in the class (2.4).

But flexible inflation targeting, if properly implemented, is superior to even a spread-adjusted rule — at least to simple rules of the kind proposed by Taylor (2008) or McCulley and Toloui (2008). A forecast-targeting central bank will properly take account of many credit spreads rather than just one; it will take account of whether changes in credit spreads indicate disruptions of the financial sector as opposed to endogenous responses to developments elsewhere in the economy; and it will calibrate its response depending on its best guess about the likely persistence of disturbances on a particular occasion. Of course, the degree to which such an approach should be expected to improve upon a simple rule depends on the quantity and quality of information available for use in the construction of projections; and the use of a more complex (and inevitably more judgmental) approach creates greater challenges with regard to transparency and accountability. Nonetheless, the advantages of such an approach seem to us even more salient under the more complex circumstances associated with financial market disruptions.

4 Conclusion

We have analyzed the implications of a family of simple instrument rules for monetary policy in which a baseline Taylor rule is modified by introducing a contemporaneous response to the size of a credit spread. We have found that a spread adjustment of this kind can reduce the distortions caused by a financial disturbance that increases equilibrium credit spreads; and the extent to which this is true is roughly the same whether the increase in spreads is due to an increase in the risk of bad loans or an increase in the resource cost of loan origination. This modification of the standard

Taylor rule can also improve the economy's response to certain other types of disturbances as well — most notably, variations in the size of debt-financed government transfers (which mainly affect the allocation of resources by relaxing or increasing the financial constraints faced by private borrowers), but also (at least in our baseline calibration) variations in the size of other economic distortions (due to taxes or market power).

However, the optimal size of such a spread adjustment, even from the standpoint of minimizing the welfare losses due to financial disturbances, is likely to be smaller than the adjustment (100 percent of the increase in the spread) proposed by McCulley and Toloui (2008) and by Taylor (2008), and depends on the degree of persistence of the disturbances. Moreover, the optimal size of such an adjustment (and indeed, the benefit of adjusting at all) is even less clear when the implications of the policy for the effects of other types of economic disturbances are considered. If a substantial fraction of economic variability is due to relatively persistent disturbances to technology, preferences, or government purchases, the benefits of the spread adjustment in mitigating the effects of financial disturbances may be outweighed by its reduction of the efficiency of the monetary response to those other shocks.

A modification of the standard Taylor rule that would lower the federal funds rate more when aggregate credit decreases can also mitigate the effects of financial disturbances to some extent, but we find that rules of this kind are less effective for this purpose than is a suitably calibrated spread-adjusted Taylor rule. We also find it less plausible that a credit adjustment would be desirable once the consequences for the economy's responses to other shocks are also taken into account; so the proposal of a spread-adjusted Taylor rule makes more sense than a credit-adjusted rule, at least in the context of our model. Nonetheless, a flexible inflation targeting approach to the conduct of monetary policy, of the kind discussed further in Cúrdia and Woodford (2009a), is superior to either of these alternatives, especially from the standpoint of the robustness of a single numerical target criterion to alternative types of economic disturbances.

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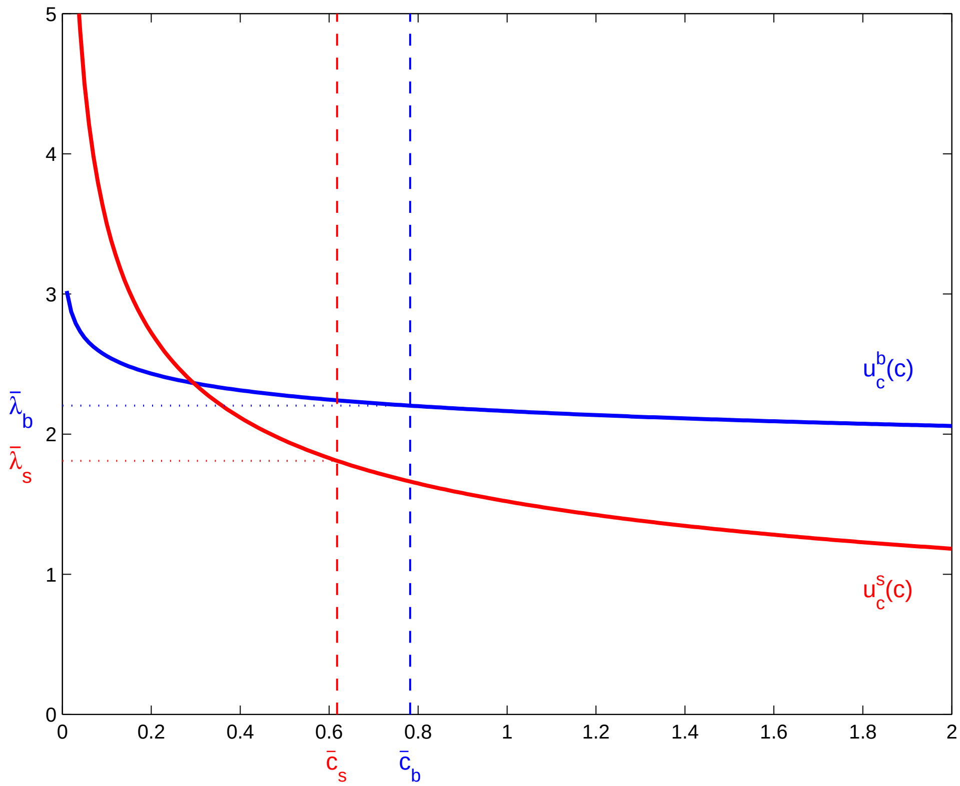

Figure 1: Marginal utilities of consumption for households of the two types. The values $\bar{c}^s$ and $\bar{c}^b$ indicate steady-state consumption levels of the two types, and $\bar{\lambda}^s$ and $\bar{\lambda}^b$ their corresponding steady-state marginal utilities.

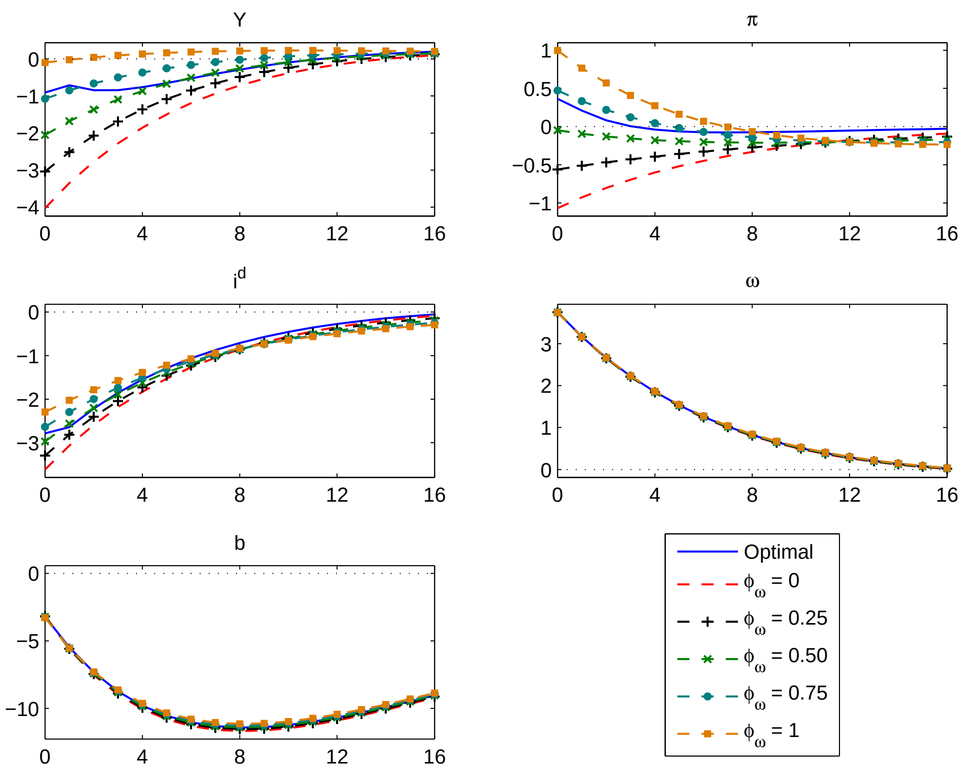

Figure 2: Impulse responses to a shock to χ_t that increases $\omega_t(\bar{b})$ initially by 4 percentage points (annualized), under alternative degrees of spread adjustment, for persistence $\rho = 0.9$.

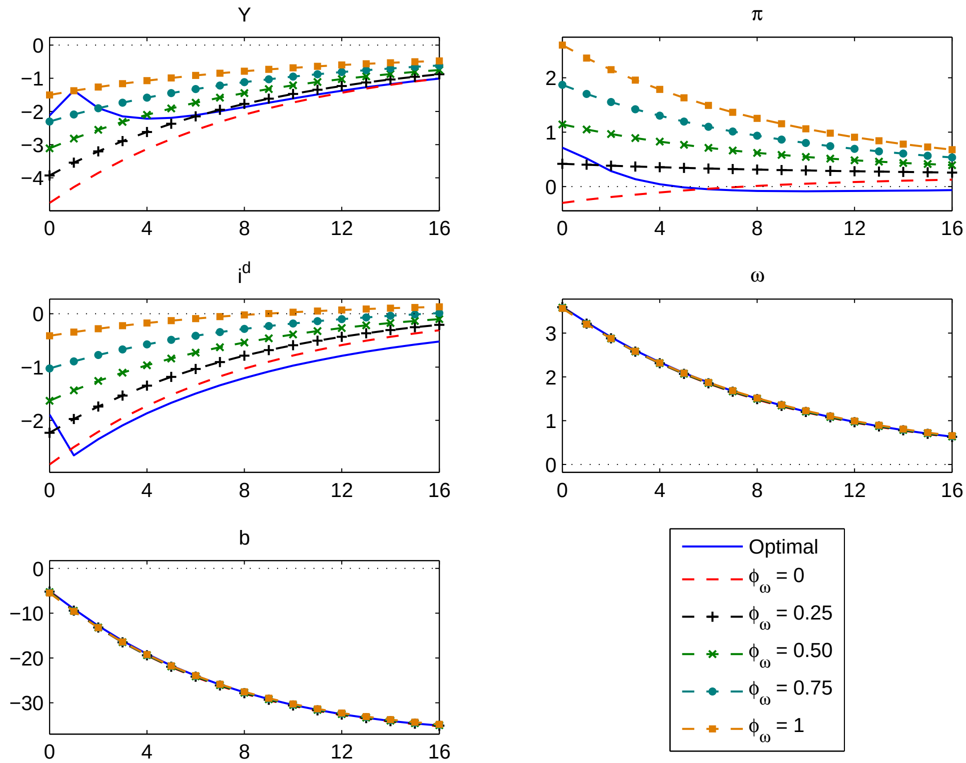

Figure 3: Impulse responses to a shock to χ_t of the same initial magnitude as in Figure 2, for persistence $\rho = 0.99$.

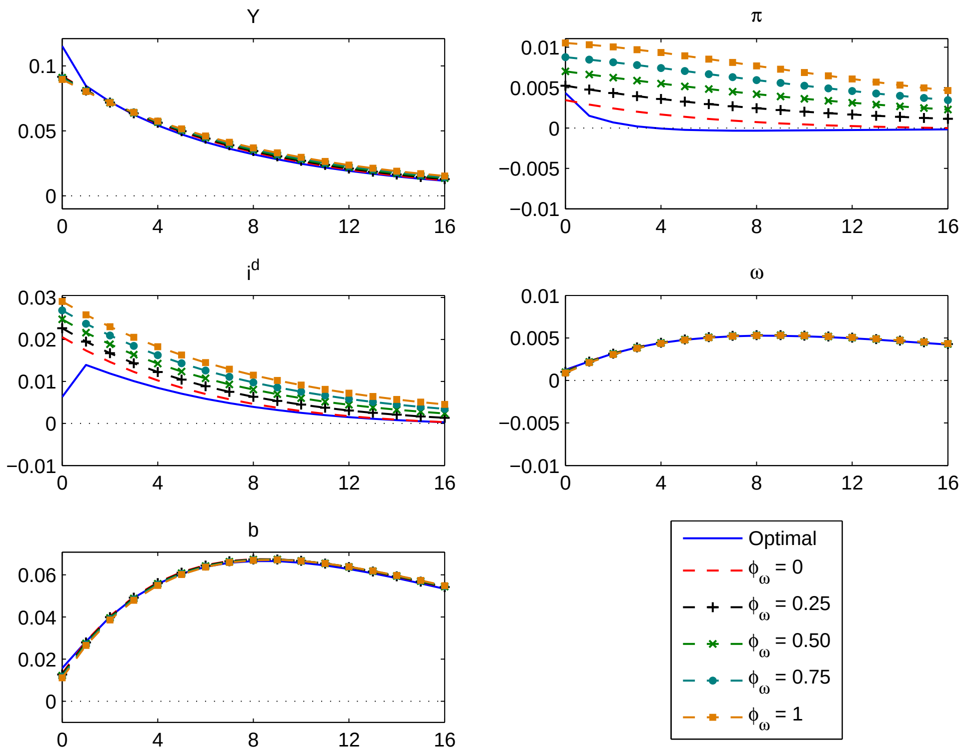

Figure 4: Impulse responses to a 1 percent increase in $\bar{C}^b_t$, under alternative degrees of spread adjustment.

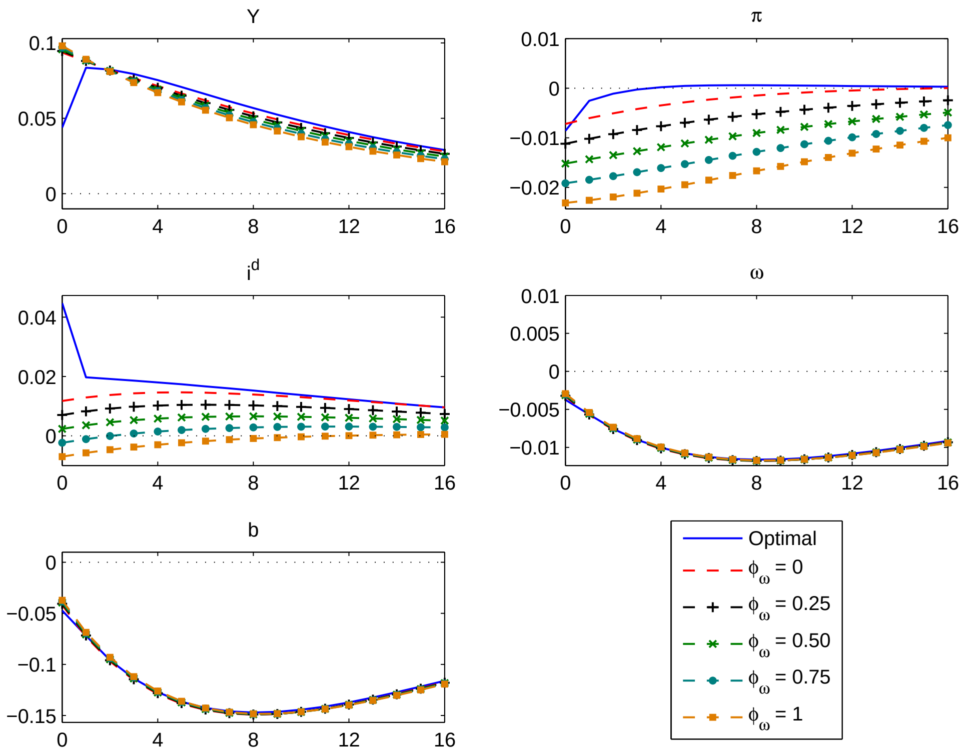

Figure 5: Impulse responses to a 1 percent increase in $\bar{C}^s_t$, under alternative degrees of spread adjustment.

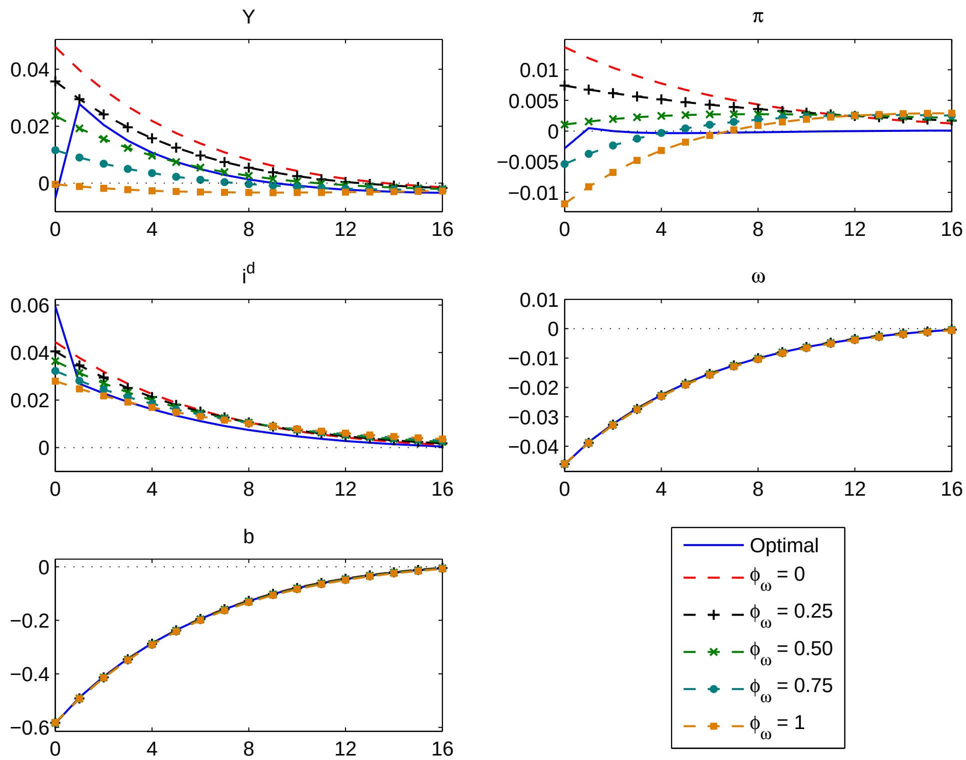

Figure 6: Impulse responses to an increase in b_t^g equal to 1 percent of annual steady-state output, under alternative degrees of spread adjustment.

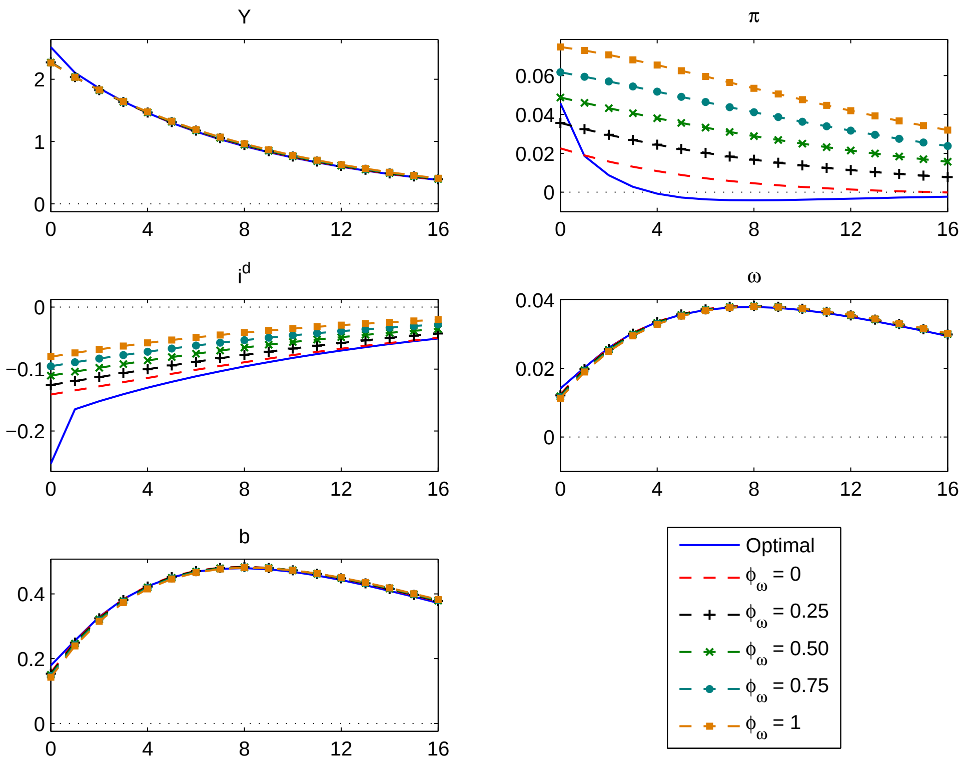

Figure 7: Impulse responses to a 1 percent increase in Z_t, under alternative degrees of spread adjustment.

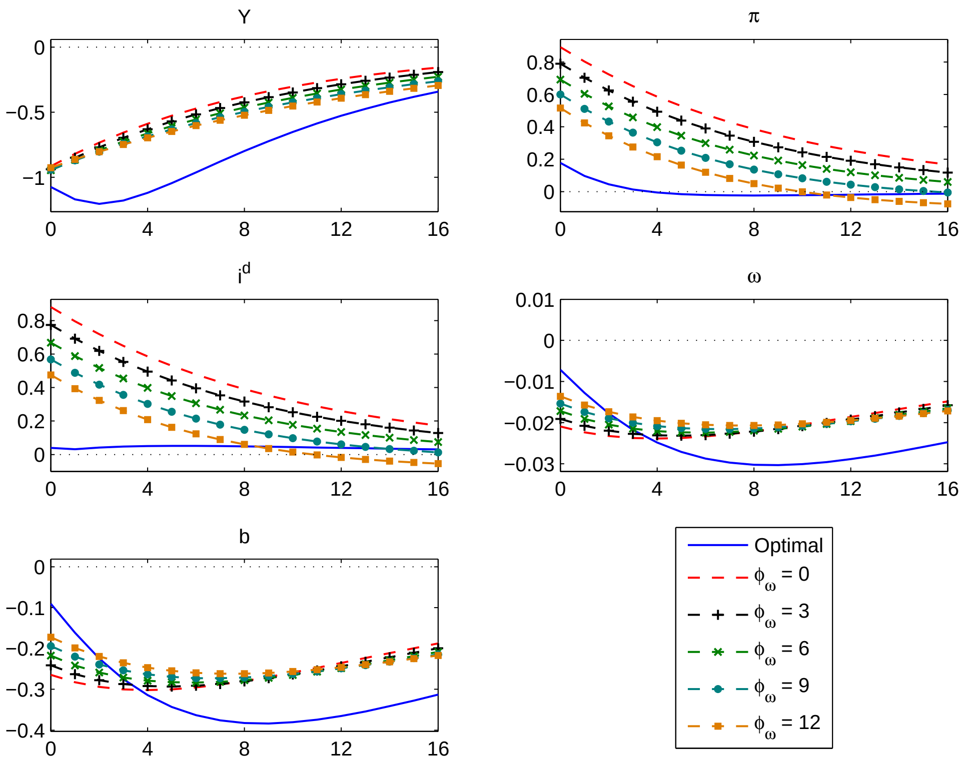

Figure 8: Impulse responses to a 1 percent increase in τ_t, under alternative degrees of spread adjustment.

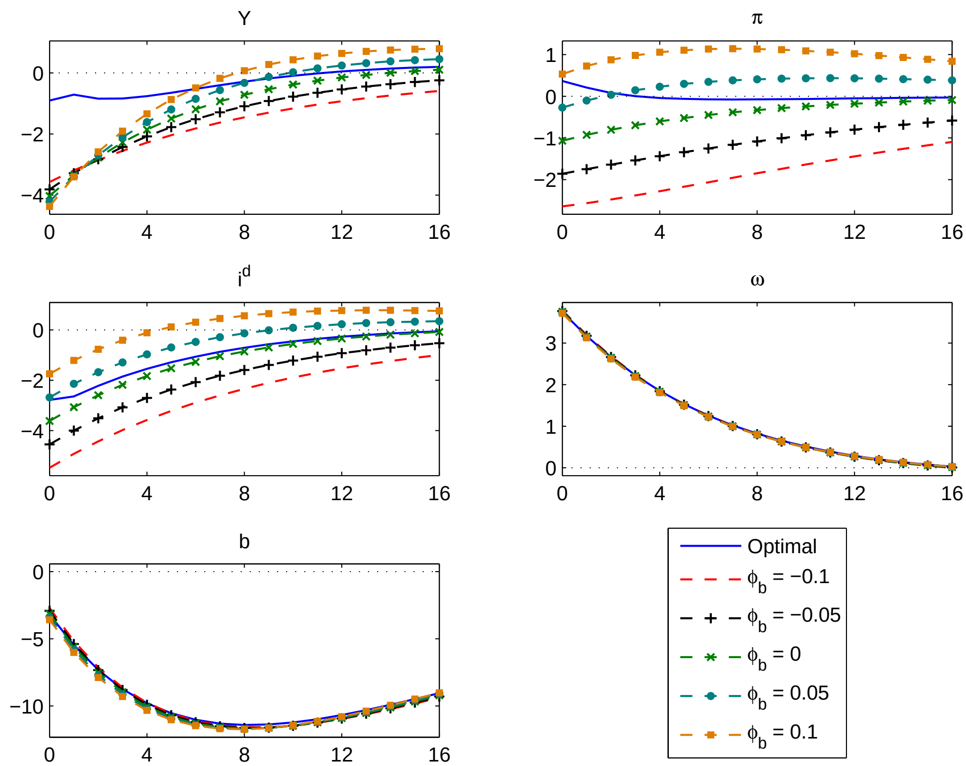

Figure 9: Impulse responses to a shock to χ_t that increases $\omega_t(\bar{b})$ initially by 4 percentage points (annualized), under alternative degrees of response to aggregate credit.

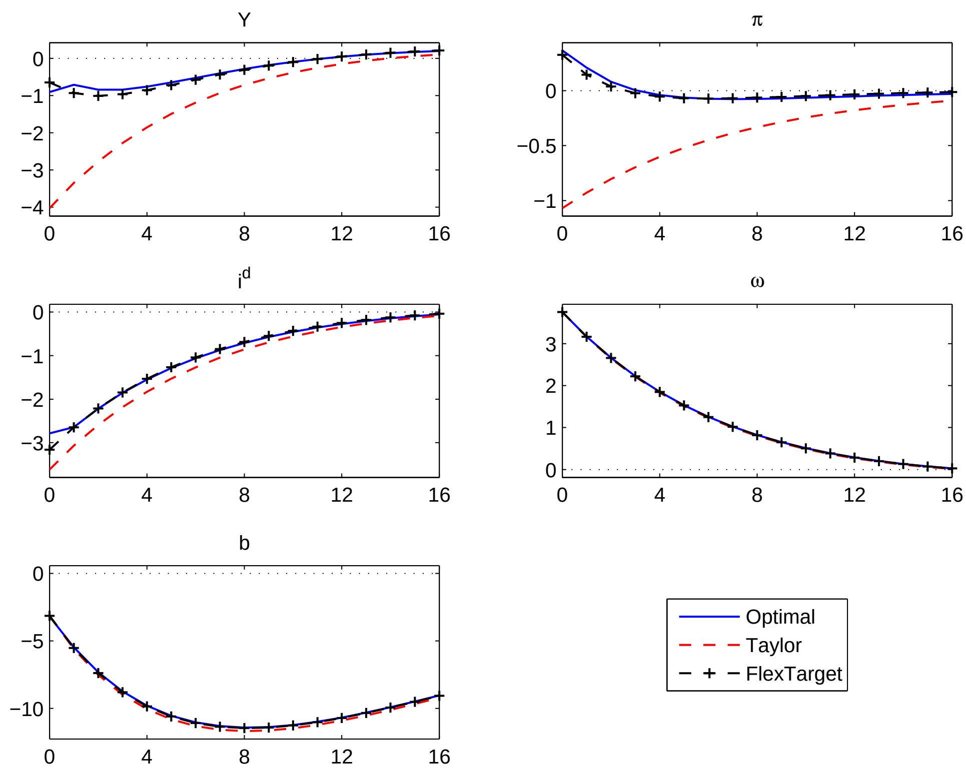

Figure 10: Impulse responses to a shock to χ_t that increases $\omega_t(\bar{b})$ initially by 4 percentage points (annualized), under optimal policy, the Taylor rule, and flexible inflation targeting.