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Monetary Policy and Credit Supply Shocks

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The depth and duration of the 2007–09 recession serves as a powerful reminder of the real consequences of financial shocks. Although channels through which disruptions in financial markets can affect economic activity are relatively well understood from a theoretical perspective, assessing their quantitative implications for the real economy remains a considerable challenge. This paper examines the extent to which the workhorse New Keynesian model—augmented with the standard financial accelerator mechanism—is capable of producing the dynamics of the U.S. economy during the recent financial crisis. To do so, we employ the methodology of Gilchrist and Zakrajšek (2011) to construct a measure of shocks to the financial sector, which is then used to simulate the model over the crisis period. The results indicate that a reasonably calibrated version of the model can closely match the observed decline in economic activity and can account for the sharp widening of nonfinancial credit spreads, a decline in nominal short-term interest rates, and for the persistent disinflation experienced in the wake of financial disruptions. Given its empirical relevance, we then use this framework to analyze the potential benefits of a monetary policy rule that allows the short-term nominal rate to respond to

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changes in financial conditions as measured by movements in credit spreads. The results indicate that such a spread-augmented policy rule can effectively dampen the negative consequences of financial disruptions on real economic activity, while engendering only a modest increase in inflation.
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The complexity and sophistication of today's financial instruments and institutions—in a global economy with a high degree of financial integration—were undoubtedly the major factors behind the extraordinarily rapid transmission of financial shocks during the recent crisis. When rising delinquencies on subprime mortgages in the first half of 2007, triggered by the end of the housing boom in the United States, started to lead to large losses on related structured credit products, investors became greatly concerned about structures of securitized financial products more generally and began to pull back from risk taking. In the late summer of 2007, with investors' risk appetite diminished substantially, the short-term funding markets in the United States and abroad became severely disrupted, and liquidity in private credit markets dropped sharply.

The initial financial turmoil did not appear to leave much of an imprint on real economic activity. However, the persistent and escalating pressures on bank balance sheets caused a pronounced tightening of aggregate credit conditions, a drop in asset values, and a slump in business and consumer confidence. Indeed, on December 1, 2008, the NBER's Business Cycle Dating Committee determined that a peak in U.S. economic activity occurred sometime in December 2007. And in spite of a number of unprecedented policy actions by the Federal Reserve and other U.S. government entities to arrest and mitigate the ensuing contraction in economic activity, the 2007–09 downturn has entered the record as the most severe recession, in terms of both its depth and duration, of the postwar period.

The destructive power of this "adverse feedback loop" between financial conditions and the real economy has led to much soul-searching among policymakers and economists. The debate among the former, in particular, has focused on whether central banks should respond only to inflation in the price of goods and economic slack, or if they should also respond to movements in asset prices. The latter group, in contrast, has responded by developing a slew of new dynamic general equilibrium models, in which the deterioration in the equity capital position, or net worth, of financial intermediaries—by reducing the supply of credit—leads to and amplifies the ensuing economic downturn.[1]

[1]Empirical studies documenting the real-side effects of adverse credit-supply shocks include Peek and Rosengren (1997 and 2000), Calomiris and Mason (2003), and Ashcraft (2005). From a theoretical perspective, Goodfriend and McCallum (2007) investigate the role of banks that produce loans and deposits using a production function that requires, as inputs,

Although channels through which disruptions in financial markets can influence economic activity are relatively well understood from a theoretical perspective, assessing their quantitative implications for the real economy remains a considerable challenge. This paper examines the extent to which the workhorse macroeconomic model with financial frictions—the New Keynesian model of Christiano, Eichenbaum, and Evans (2005) (CEE hereafter) and Smets and Wouters (2007) (SW hereafter) and augmented with the financial accelerator mechanism of Bernanke, Gertler, and Gilchrist (1999) (BGG hereafter)—can generate cyclical fluctuations of the type and magnitude experienced by the U.S. economy during the 2007–09 crisis.

The paper consists of two parts. In the first part, employing the approach used recently by Gilchrist and Zakrajšek (2011), we use secondary market prices of bonds issued by U.S. financial institutions to decompose financial intermediary credit spreads into two components: (1) a component capturing the usual countercyclical movements in expected defaults; and (2) a component representing the cyclical changes in the relationship between default risk and credit spreads—the so-called *financial bond premium*—which, we argue, represents the shifts in the risk attitudes of financial intermediaries, the marginal investors pricing corporate debt claims. Using an identified vector autoregression (VAR) framework, we show that shocks to the financial bond premium that are orthogonal to the current state of the economy, the net worth position of the nonfinancial sector, and the Treasury term structure cause economically and statistically significant declines in real economic activity.

The second part of the paper uses fluctuations in the estimated financial bond premium as a proxy for exogenous disturbances to the efficiency of private financial intermediation within the CEE/SW dynamic stochastic general equilibrium (DSGE) model augmented with the BGG financial accelerator. We calibrate the key parameters of the model, so that the responses of macroeconomic aggregates to this "financial shock" match the corresponding impulse responses estimated using the actual data. Using this calibration, we then explore the extent to which observable fluctuations in the financial bond premium can account for macroeconomic dynamics during the 2007–09 crisis. The results indicate that the model can account well for the overall drop in consumption, investment, output, and hours worked that was observed during this period. The model also does well at matching the observed decline in inflation and nominal interest rates, as well as the sharp widening of nonfinancial credit spreads.

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both the monitoring effort and collateral; Van den Heuvel (2008) analyzes the welfare costs of regulatory capital requirements, which reduce the ability of banks to create liquidity; Dib (2009) and Gerali and others (2010) formulate DSGE models with monopolistically competitive banks in deposits and loan markets; and Gertler and Kiyotaki (2009) and Gertler and Karadi (2011) construct models in which an agency problem between depositors and financial intermediaries ties the availability of credit to intermediaries' capital position. An alternative approach, followed by Chen (2001), Meh and Moran (2004), and Hirakata, Sudo, and Ueda (2009), has been to incorporate the Holmstrom and Tirole (1997) framework into quantitative general equilibrium models.

Finally, we use this framework to analyze the potential benefits of an alternative monetary policy rule, a first-difference rule that allows for nominal interest rates to respond to changes in financial conditions as measured by fluctuations in credit spreads. The results suggest that by allowing the nominal interest rate to respond to credit spreads, as suggested recently by Taylor (2008), McCulley and Toloui (2008), and Meyer and Sack (2008), monetary policy can effectively dampen the negative consequences of financial disruptions on real economic activity, while experiencing only a modest increase in inflation.

The remainder of the paper is organized as follows. Section I briefly reviews the empirical methodology used to estimate the financial bond premium and relates our measure of financial stress to other commonly used indicators used to gauge strains in financial markets. Section II provides evidence that financial shocks—identified vis-à-vis orthogonalized disturbances to the financial bond premium in a standard monetary VAR framework—have significant adverse consequences for the real economy. Section III outlines the general equilibrium framework used to study the impact of financial disturbances on the macroeconomy and presents the corresponding results. Section IV concludes.

I. Financial Bond Premium as an Indicator of Financial Stress

Spurred by the extraordinary events of the 2007–09 financial crisis, an emergent theoretical literature is emphasizing the implications of the capital position of financial intermediaries for asset prices. For example, He and Krishnamurthy (2009 and 2010) show that adverse macroeconomic conditions, by depressing the capital base of financial intermediaries, can reduce the risk-bearing capacity of the marginal investor, causing a sharp increase in the conditional volatility and correlation of asset prices and a drop in risk-free interest rates. Relatedly, Acharya and Viswanathan (2010) develop a theoretical framework in which financial intermediaries—in response to a sufficiently severe aggregate shock—are forced to de-lever by selling their risky assets to better-capitalized firms, causing asset markets to clear only at "cash-in-the-market" prices (cf. Allen and Gale, 1994 and 1998). Brunnermeier and Pedersen (2009) and Garleanu and Pedersen (2009), in contrast, explore how margins or haircuts—the difference between the security's price and collateral value that must be financed with the trader's own capital—interact with liquidity shocks in determining asset price dynamics.

Empirical support for this type of mechanisms is provided by the recent work of Gilchrist and Zakrajšek (2011) (GZ hereafter), who employ a large panel of corporate bonds to decompose the associated credit spreads into two components: a default-risk component capturing the usual countercyclical movements in expected defaults, and a nondefault-risk component that captures the cyclical fluctuations in the relationship between default risk and credit spreads. According to their results, the majority of the information content of credit spreads for future economic activity is attributable to movements in this excess bond premium—that is, to deviations in the pricing of corporate debt claims relative to the expected default risk of the issuer. Moreover, shocks to this premium that are orthogonal to the current macroeconomic conditions are shown to cause economically and statistically significant declines in economic activity and inflation, as well as in risk-free rates and broad equity prices.

Importantly, GZ also show that fluctuations in their excess bond premium are closely related to the financial condition of broker-dealers, highly leveraged financial intermediaries that play a key role in most financial markets, according to Adrian and Shin (2010).[2] Taken together, the evidence presented by GZ supports the notion that deviations in the pricing of long-term corporate bonds relative to the expected default risk of the underlying issuer reflect shifts in the effective risk aversion of the financial sector. Increases in risk aversion, in turn, lead to a contraction in the supply of credit, both through the corporate bond market and the broader commercial banking sector.

Financial Intermediary Credit Spreads

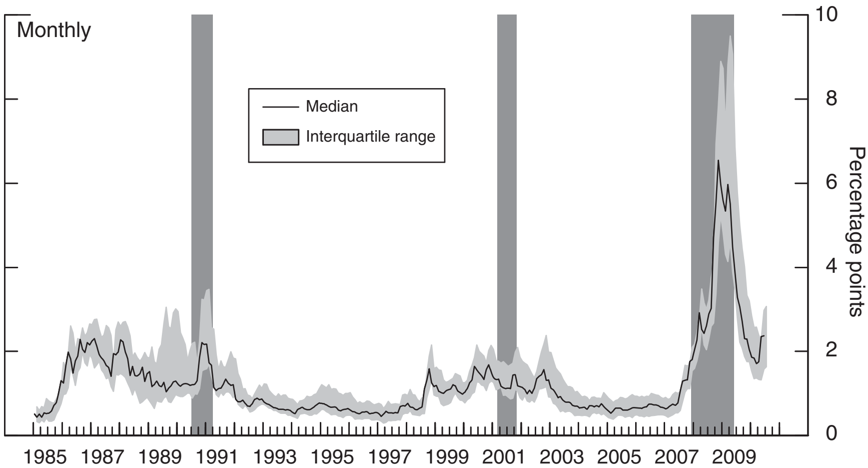
The origins of the 2007–09 crisis undoubtedly lie within the U.S. financial sector, which, after a massive buildup in leverage, a prolonged period of loose underwriting standards and mispricing of risk, underwent an abrupt de-leveraging process that sharply curtailed the availability of credit to businesses and households. To measure the cyclical fluctuations in the risk-bearing capacity of the financial sector, we apply the GZ methodology to credit spreads on bonds issued by a broad set of U.S. financial institutions. We then use the financial bond premium based on financial intermediary spreads as a summary statistic for shocks to the financial system.

The key information underlying our analysis comes from a sample of fixed income securities issued by U.S. financial corporations.[3] Specifically, for the period from January 1985 to June 2010, we extracted from the Lehman/Warga (LW) and Merrill Lynch (ML) databases month-end prices of outstanding financial corporate bonds that are actively traded in the

[2]Broker-dealers are financial institutions that buy and sell securities for a fee, hold an inventory of securities for resale, and differ from other types of institutional investors by their active procyclical management of leverage. As documented by Adrian and Shin (2010), expansions in broker-dealer assets are associated with increases in leverage as broker-dealers take advantage of greater balance sheet capacity; conversely, contractions in their assets are associated with de-leveraging of their balance sheets.

[3]The definition of the financial sector encompasses publicly traded financial firms in the following 3-digit NAICS codes: 522 (Credit Intermediation & Related Activities); 523 (Securities, Commodity Contracts & Other Financial Investments & Related Activities); 524 (Insurance Carriers & Related Activities); and 525 (Funds, Trusts & Other Financial Vehicles). Government-sponsored entities, such as Fannie Mae and Freddie Mac, are excluded from the sample.

Figure 1. Financial Intermediary Credit Spreads



Note: Sample period: Jan1985–Jun2010. The solid line depicts the median spread on senior unsecured bonds issued by 193 financial firms in our sample, and the shaded band depicts the corresponding interquartile range. The shaded vertical bars denote the NBER-dated recessions.

secondary market.[4] To guarantee that borrowing costs of different firms are measured at the same point in their capital structure, we restricted our sample to include only senior unsecured issues with a fixed coupon schedule. After eliminating extreme observations, we were left with an unbalanced panel of 886 individual securities, for a total of 42,880 bond/month observations. We matched these corporate securities with their issuer's quarterly income and balance sheet data from Compustat and daily data on equity valuations from CRSP, a procedure resulting in a sample of 193 firms. (Appendix describes the construction of credit spreads and contains the summary statistics for key characteristics of bonds in the sample.)

The paper focuses on the period from the mid-1980s onward, a period marked by a stable monetary policy regime and by significant deregulation of financial markets (for example, the repeal of Regulation Q (1986); the Riegle-Neal Act (1994); the Gramm-Leach-Bliley Act (1999)). In addition, rapid advances in information technology over the past quarter century have lowered the information and monitoring costs of investments in public securities, thereby increasing the tendency for corporate borrowing to take the form of negotiable securities issued directly in capital markets. By improving liquidity in both the primary and secondary markets, these

[4]These two data sources are used to construct benchmark corporate bond indices used by market participants. Specifically, they contain secondary market prices for a vast majority of dollar-denominated bonds publicly issued in the U.S. corporate cash market. The ML database is a proprietary data source of daily bond prices that starts in 1997. By contrast, the LW database of month-end bond prices has a somewhat broader coverage and is available from 1973 through mid-1998 (see Warga, 1991 for details).

changes in the financial landscape have facilitated more efficient price discovery and have likely improved the information content of credit spreads for future economic outcomes.[5]

Figure 1 depicts the time-series evolution of credit spreads for our sample of bonds. With the exception of the recent financial crisis, the median credit spread on bonds issued by financial institutions—although countercyclical—fluctuated in a relatively narrow range. In spite of focusing on a relatively narrow segment of the U.S. financial system—namely, the publicly traded financial corporations with senior unsecured debt trading in the secondary market—the interquartile range indicates a fair amount of dispersion in the price of debt across different institutions, information that is potentially useful for identifying shocks to the financial system.

The Financial Bond Premium

Before presenting our indicator of financial stress, we briefly outline the empirical methodology underlying the construction of the financial bond premium. (The reader is referred to Gilchrist and Zakrajšek (2011) for more thorough exposition and technical details.) The GZ decomposition of credit spreads is based on the regression model of the following type:

$$\ln S_{it}[k] = -\beta DD_{it} + \theta' X_{it}[k] + \varepsilon_{it}[k], \tag{1}$$

where $S_i[k]$ denotes the credit spread on bond k (issued by firm i); DD_{it} is the *distance-to-default* for firm i; $X_{it}[k]$ is a vector of bond-specific characteristics that controls for the optionality features embedded in most corporate securities as well as for potential term and liquidity premiums; and $\varepsilon_{it}[k]$ is a "pricing error."

The key feature of the GZ approach is that the firm-specific credit risk is captured by the distance-to-default (DD), a market-based indicator of default risk based on the option-theoretic framework developed in the seminal work of Merton (1974). In this contingent claims approach to corporate credit risk, it is assumed that a firm has just issued a single zero-coupon bond of face value F that matures at date T. Rational stockholders will default at date T only if the total value of the firm $V_T < F$; by assumption, the rights of the bondholders are activated only at the maturity date, as stockholders will maintain control of the firm even if the value of the firm $V_s < F$ for some $s < T$. Under the assumptions of the model, the probability of default—that is, $\Pr[V_T < F]$—depends on the DD, a volatility-adjusted measure of leverage inferred from equity valuations and the firm's observed capital structure.[6]

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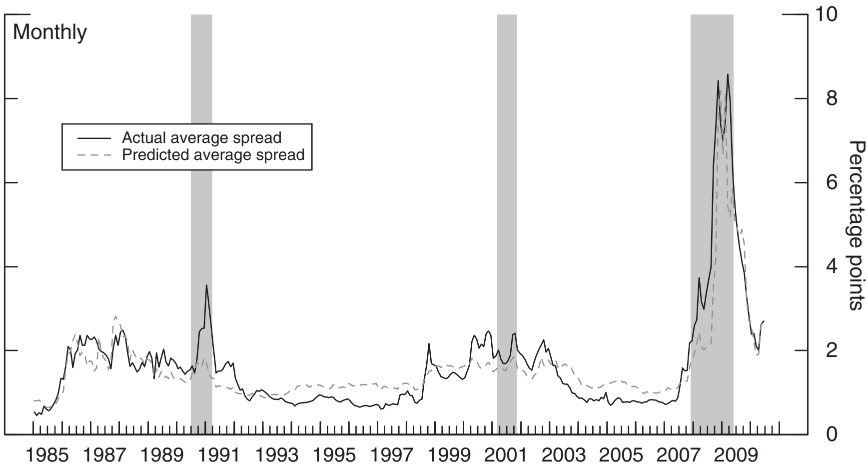
[5] The ability of corporate bond credit spreads to predict economic activity has been documented by Gertler and Lown (1999); King, Levin, and Perli (2007); Mueller (2009); Gilchrist, Yankov, and Zakrajšek (2009); Gilchrist and Zakrajšek (2011); and Faust and others (2011).

[6] Several other papers consider similar market-based indicators of default risk for financial institutions. For example, Gropp, Vesala, and Vulpes (2006) construct distance-to-default for a sample of large European banks and find that the DDs are unbiased indicators of banks'

Figure 2. Actual and Predicted Financial Intermediary Credit Spreads



Note: Sample period: Jan1985–Jun2010. The solid line depicts the average credit spread on senior unsecured bonds issued by financial firms in our sample. The dashed line depicts the predicted average credit spread using the methodology in Gilchrist and Zakrajšek (2011). The shaded vertical bars denote the NBER-dated recessions.

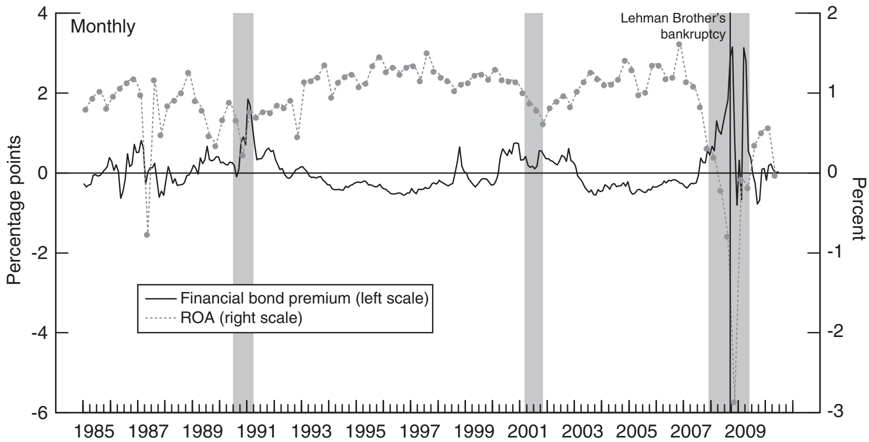
Using the estimated parameters of the credit spread model (1), we define the financial bond premium in month t by the following linear decomposition:

$$FBP_t = \bar{S}_t - \widehat{\bar{S}}_t,$$

where $\bar{S}_t$ denotes the average credit spread in month t and $\widehat{\bar{S}}_t$ is its predicted counterpart. As shown in Figure 2, the empirical credit spread model used by GZ explains a substantial portion of the cyclical fluctuations in financial intermediary credit spreads, a result indicating that the DD provides an accurate measure of default risk. Note also that the financial bond premium is, by construction, orthogonal to the observed measures of default risk, so that movements in the financial bond premium likely reflect variation in the price of default risk rather than change in the risk of default in the U.S. financial sector.

financial health and have substantial predictive power for subsequent rating changes; Basurto, Goodhart, and Hoffman (2006) analyze the effect of financial and real variables on the probabilities of default—derived from the Merton DD-framework—for banks in the sample of OECD countries; Chan-Lau and Sy (2007) introduce a "distance-to-capital," a market-based measure of default risk for the commercial banking sector that accounts for the fact that banks are typically closed well before the equity has been completely wiped out; and Carlson, King, and Lewis (2008) develop an indicator of financial distress based on the DDs for a sample of large U.S. financial institutions—including both commercial and investment banks—and find that the health of the financial sector has important implications for the real economy.

Figure 3. Financial Bond Premium and Financial Sector Profitability



Note: Sample period: Jan1985–Jun2010. The solid line depicts the estimated financial bond premium based on financial intermediary credit spreads. The solid dots depict the quarterly (annualized) return on assets (ROA) for the U.S. financial corporate sector, calculated using quarterly firm-level Compustat data. The shaded vertical bars denote the NBER-dated recessions.

The solid line in Figure 3 shows the estimated monthly financial bond premium—the difference between the solid and dotted lines in Figure 2—while the overlayed solid dots denote the quarterly (annualized) return on assets in the U.S. financial corporate sector. The high degree of negative comovement between this broad measure of profitability of the financial sector and the financial bond premium is consistent with the view that risk premiums in asset markets fluctuate closely in response to movements in capital and balance sheet conditions of financial intermediaries, a fact also emphasized by Adrian and Shin (2010) and Adrian, Moench, and Shin (2010a and 2010b).

Note that the financial bond premium appears to be a particularly timely indicator of strains in the financial system. The sharp run-up in the premium during the early 1990s, for example, is consistent with the view that capital pressures on commercial banks in the wake of the Basel I capital requirements significantly exacerbated the 1990–91 economic downturn by reducing the supply of bank-intermediated credit (Bernanke and Lown, 1991). In contrast, the robust health of the financial system at the start of the 2001 recession has been cited as an important factor for the absence of a "credit crunch," which, in turn, likely contributed to the fact that the downturn remained localized in certain troubled industries, particularly the high-tech sector (Stiroh and Metli, 2003).

In regard to the recent financial crisis, the intensifying downturn in the housing market and the emergence of significant strains in term funding markets in the United States and Europe during the summer of 2007 precipitated a sharp increase in the financial bond premium. At that time, banking institutions, in addition to their mounting concerns about actual and potential credit losses, recognized that they might need to take a large volume of assets onto their balance sheets, given their existing commitments to customers and the heightened reluctance of investors to purchasing an increasing number of securitized products. The recognition that the ongoing turmoil in financial markets could lead to substantially larger-than-anticipated calls on their funding capacity and investors' concerns about valuation practices for opaque assets were the primary factors behind the steady climb of the financial bond premium during the remainder of 2007 and over the subsequent year.

The full-fledged global nature of the crisis became apparent on September 15, 2008, when Lehman Brothers—with its borrowing capacity severely curtailed by a lack of collateral—filed for bankruptcy. Investor anxiety about financial institutions escalated sharply, and market participants became extraordinarily skittish and pulled back from risk taking even further. Amid cascading effects of these financial disruptions, which included a run on money market mutual funds, the government's rescue of AIG, and the failure of Washington Mutual (a large thrift), the financial bond premium shot up, reaching 315 basis points by October 2008.

Responding to the panic that was rapidly engulfing the entire global financial system, the Federal Reserve, at times acting in concert with foreign central banks, used its emergency and lending authorities to expand its existing liquidity facilities, while also announcing several additional initiatives aimed at restoring confidence in the financial system.[7] Concomitantly, the Treasury announced a temporary guarantee program for money market mutual funds and proposed the Troubled Asset Relief Program (TARP), under which government funds were to be used to help stabilize the banking system.[8] Lastly, the Federal Deposit Insurance Corporation (FDIC) provided a temporary guarantee for selected senior unsecured obligations of participating depository institutions and many of their parent holding companies, as well as for all balances in noninterest-bearing transaction deposit accounts at participating depository institutions—the so-called Temporary Liquidity Guarantee Program.

After unprecedented actions taken by the U.S. government during the September–October period and announcements of similar programs in a number of other countries, the panic abated and stresses in financial markets

[7]The new initiatives included the creation of the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF), the creation of the Commercial Paper Funding Facility (CPFF), and the creation of the Money Market Investor Funding facility (MMIFF). A detailed description of all the new policy tools used by the Federal Reserve to address the recent financial crisis can be found at www.federalreserve.gov/monetarypolicy/bst.htm.

[8]On October 3, 2008, the Congress approved and provided funding for TARP as part of the Emergency Economic Stabilization Act. Using funds from TARP, the Treasury established a voluntary capital purchase plan, under which the U.S. government was able to inject equity—in the form of preferred shares—into the banking system.

eased, as evidenced by the drop in the financial bond premium. Despite these improvements, investors remained greatly concerned about the soundness of financial institutions. As a result, pressures on already-strained balance sheets of financial institutions remained substantial and continued to threaten their viability, a situation that greatly impinged the flow of credit to businesses and households.[9] At the same time, the severity and persistence of financial strains and the significant tightening of aggregate credit conditions caused the downturn in economic activity that had been unfolding since late 2007 to accelerate noticeably. Reflecting these adverse macroeconomic developments, coupled with reports of very large losses in the fourth quarter of 2008, the pressure on financial firms intensified during the first few months of 2009, sending the financial bond premium back to its record level by March 2009.

The monetary authorities again responded forcefully to these adverse financial developments: The Federal Open Market Committee (FOMC) kept its target for the federal funds rate between 0 and 1/4 percent, expanded direct purchases of agency debt and mortgage-backed securities, and began direct purchases of longer-term Treasury securities. Partly as a result of these actions, conditions in financial markets, although remaining strained, began to show signs of improvements in the late spring of 2009. Substantially better-than-expected first-quarter earnings results for some large financial institutions contributed importantly to improved investor sentiment, and share prices of banks and insurance companies moved higher and their credit default swap premiums declined. The release of the findings of the Supervisory Capital Assessment Program (that is, the "stress test") in May further reduced uncertainty and restored confidence in the financial system, and banking organizations were able to issue significant amounts of equity and nonguaranteed debt during subsequent months.

Although the above narrative accords well with the recent U.S. financial history, there nevertheless exists a number of financial indicators that have been used extensively to gauge the degree of stress (or risk aversion) in financial markets. To examine whether fluctuations in commonly used indicators of financial market stress are informative about the subsequent movements in the financial bond premium, we estimate the following regression:

$$FBP_{t+1} = \alpha + \beta FBP_t + \gamma FS_t + \varepsilon_{t+1}, \tag{2}$$

where FS denotes one of the following indicators: (1) the option-implied volatility on the S&P 100 stock price futures (VXO)[10]; (2) the implied volatility

[9]In November 2008, Citigroup found itself under significant financial pressure. In response, the FDIC, the Treasury, and the Federal Reserve provided a package of loans and guarantees to bolster Citigroup's financial positions; a similar package was arranged for Bank of America in January 2009.

[10]We use the VXO, as opposed to the VIX, volatility index, because the VXO is available starting in January 1986, compared with January 1990, the starting date for the VIX. The correlation between these two indicators, however, is almost 0.99.

on 3-month Eurodollar futures; (3) the implied volatility on 30-year Treasury bond futures; (4) the difference between the 3-month London interbank offered rate (LIBOR) and the 3-month Treasury bill rate (the TED spread); (5) the difference between the 5-year swap rate and the 5-year Treasury yield; and (6) the yield spread between the off-the-run and on-the-run 10-year Treasury notes (the off/on-the-run spread).

According to the results reported in Table 1, stock market option-implied volatility—a popular measure of risk aversion in financial markets—has no predictive power for the financial bond premium, in either economic or statistical terms (column 1). The reverse (not reported) is also true—that is, taking into account past movements in the VXO, the financial bond premium has no marginal predictive power for the next month's stock market volatility. The two series, while clearly exhibiting a substantial amount of cyclical comovement, likely provide an assessment of the risk aversion in financial markets from two different vantage points—from the corporate bond market in the case of the financial bond premium and from the stock market in the case of the VXO index.[11]

Unlike the stock market, however, the corporate bond market is dominated by highly leveraged financial intermediaries that possess specialized knowledge about the market but also face either explicit or implicit capital requirements. A deterioration in the capital position of these marginal investors pricing corporate debt claims will cause a pullback from risk taking more broadly, resulting in a reduction in the supply of credit available to potential borrowers, both through the commercial banking system and through the market-based sources of external finance. Thus, fluctuations in the financial bond premium are likely to provide a more accurate indicator of changes in the supply of credit, thereby allowing for a better identification of credit supply shocks.

Note that a similar result holds for the option-implied volatility of both short- and long-term interest rates (columns 2–3). Neither indicator is helpful in forecasting the financial bond premium. All told, the results in columns 1–3 indicate that commonly used proxies for time-varying economic uncertainty do not predict subsequent movements in our measure of financial stress.

Fluctuations in the TED spread—the conventional measure of counterparty credit risk in interbank funding markets—also appear to be unrelated to subsequent movements in the financial bond premium (column 4). The direct effects of counterparty risks in the LIBOR market, however, are likely to be small, reflecting both the marking to market convention and collateralization requirements, as well as the generally high credit quality of

[11]As discussed by Bekaert, Hoerova, and Lo Duca (2010), volatility indices such as the VXO and VIX can be decomposed into an uncertainty component that captures the actual expected stock market volatility and the so-called variance risk premium, a component reflecting risk aversion and other nonlinear pricing effects. The link between the financial bond premium and the variance risk premium, while certainly intriguing, is beyond the scope of this paper and is left for future research.

Table 1. Indicators of Financial Stress and the Financial Bond Premium

Financial Stress Indicator	(1)[1]	(2)[2]	(3)	(4)	(5)[3]	(6)[4]
S&P100 volatility (VXO)	0.005 (0.004)	—	—	—	—	—
Eurodollar volatility (3m)	—	0.030 (0.017)	—	—	—	—
Treas. volatility (30y)	—	—	0.015 (0.011)	—	—	—
LIBOR–Treas. (3m)	—	—	—	0.078 (0.058)	—	—
Swap–Treas. (5y)	—	—	—	—	0.558 (0.220)	—
Off/On-the-run Treas. (10y)	—	—	—	—	—	−0.000 (0.005)
Adj. R^2	0.620	0.630	0.622	0.620	0.652	0.627
Obs.	293	257	305	305	259	268

Note: Sample period: Jan1985–Jun2010, unless noted otherwise. Dependent variable is FBP_{t+1}, the financial bond premium in month $t+1$. Entries in the table denote OLS estimates of γ, the coefficient associated with the financial stress indicator in month t (see equation (2)). Asymptotic standard errors reported in parentheses are computed according to Newey and West (1987), with the "lag truncation" parameter $L=12$.
[1]Sample period: Jan1986–Jun2010.
[2]Sample period: Jan1989–Jun2010.
[3]Sample period: Nov1988–Jun2010.
[4]Sample period: Feb1988–Jun2010.

market participants. As emphasized by Joslin and Singleton (2009), investor concerns about the possible deterioration in the credit quality of financial intermediaries, especially those that insure corporate bonds, often manifest themselves through higher risk premiums in the interest rate swap market. Indeed, the 5-year swap-Treasury spread has some marginal predictive power for the financial bond premium (column 5), although the improvement in the goodness-of-fit is rather modest ($\bar{R}^2=0.652$ vs. $\bar{R}^2=0.618\bar{R}^2$ from an AR(1) model).[12] Finally, the off/on-the-run Treasury spread—a gauge of investor liquidity preference (Krishnamurthy, 2002)—is also uninformative about the future movements in the financial bond premium (column 6).

II. The Financial Bond Premium and the Macroeconomy

To examine systematically the macroeconomic consequences of financial disturbances, we include the financial bond premium into an otherwise

[12]The swap-Treasury spread is a rough measure of the swap risk premium. As shown by Krishnamurthy and Vissing-Jorgensen (2010) private yield spreads measured relative to comparable-maturity Treasuries can be influenced importantly by the relative supply and demand pressures in the Treasury market. In addition, Treasury yields embody a substantial convenience premium. These factors, however, do not influence the level of swap yields. As a result, Joslin and Singleton (2009) advocate estimating swap risk premiums using a dynamic term structure model proposed by Joslin, Priebsch, and Singleton (2009).

standard VAR. The specification includes the following endogenous variables: (1) consumption growth as measured by the log-difference of real personal consumption expenditures on nondurable goods and services; (2) investment growth as measured by the log-difference of real private investment (residential and business) in fixed assets; (3) the log-difference of hours worked; (4) output growth as measured by the log-difference of real GDP; (5) inflation as measured by the log-difference of the GDP price deflator; (6) the growth of the market value of net worth in the nonfinancial (nonfarm) corporate sector; (7) the 10-year (nominal) Treasury yield; (8) the effective (nominal) federal funds rate; and (9) the financial bond premium.[13]

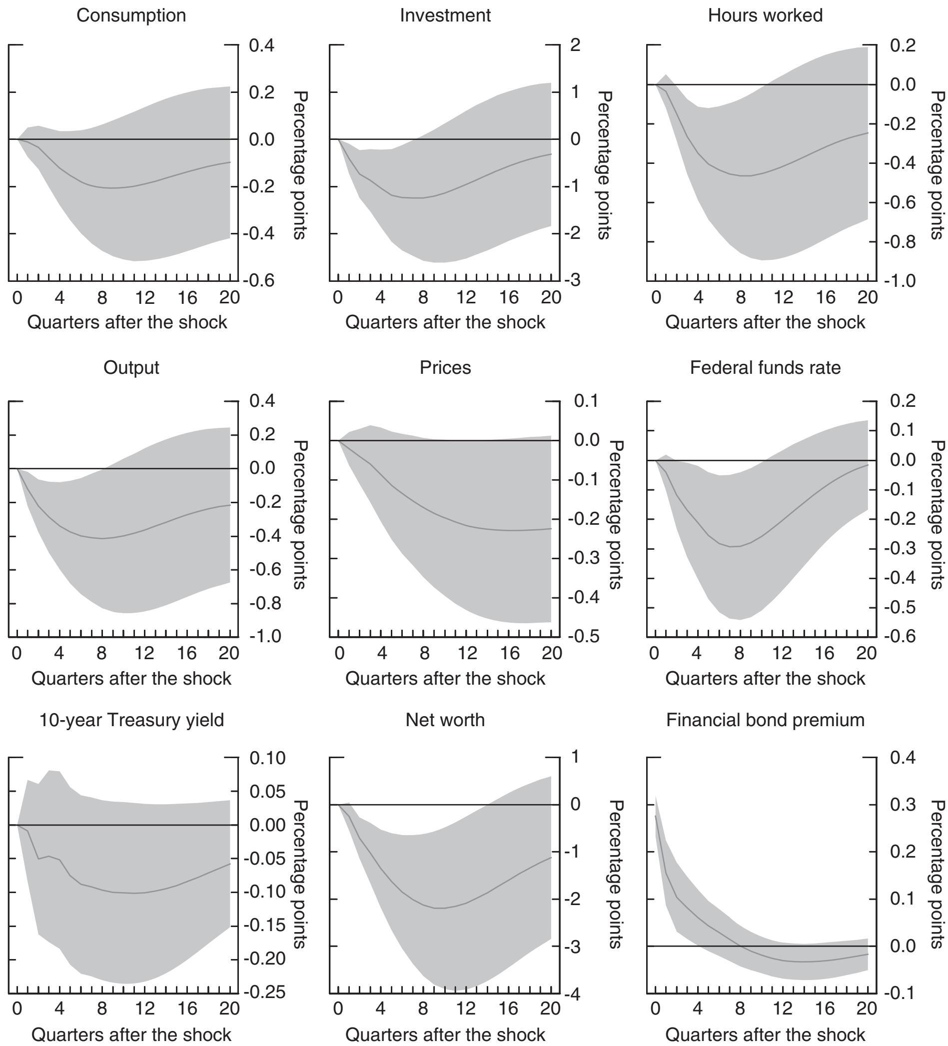
The choice of endogenous variables is motivated, in part, by the general equilibrium framework considered in the next section—a dynamic New Keynesian model augmented with the financial accelerator mechanism formulated by Bernanke, Gertler, and Gilchrist (1999)—which emphasizes credit constraints for nonfinancial borrowers and treats financial intermediaries largely as a veil. Although recent work by Gertler and Kiyotaki (2010), Gertler and Karadi (2011), and Cúrdia and Woodford (2009) has made important strides in incorporating a financial intermediary sector into a canonical macroeconomic framework, the highly stylized nature of the credit intermediation process in these models poses significant challenges for the quantitative evaluation of financial shocks. Our approach, by contrast, sidesteps these difficult calibration issues by assuming that fluctuations in the estimated financial bond premium provide an adequate description of the disruptions in the financial intermediation process.

The cost of this simplifying assumption is that it ignores the intricacies surrounding the significant dislocations—and their implications for asset prices, monetary and fiscal policy, financial stability, and the real economy—experienced by many asset markets during the 2007–09 crisis (cf. Brunnermeier, 2009 and Gorton, 2009). Also, by including only the net worth of the nonfinancial corporate sector, it abstracts from the massive de-leveraging in the household sector that occurred in the wake of the bursting of the housing bubble.[14] With these caveats in mind, we use the multivariate framework specified above to trace out the effect of a shock to the financial bond premium that is orthogonal to measures of economic activity and inflation, the balance sheet position of the nonfinancial sector, and the level of short- and long-term interest rates. The dynamic responses of key macroeconomic aggregates to an impact of such a financial shock will then provide a benchmark for the calibration of the DSGE model considered in the next section.

[13]Consumption and investment series are constructed from the underlying NIPA data using the chain-aggregation methods outlined in Whelan (2002). The market value of net worth is taken from the U.S. Flow of Funds Accounts.

[14]In a small nod to the importance of the housing market during the recent downturn, our measure of aggregate investment includes both residential and business fixed investment.

Figure 4. Macroeconomic Implications of a Financial Shock



Note: The figure depicts the impulse response functions from a 9-variable VAR(2) model to a 1 standard deviation orthogonalized shock to the financial bond premium (see text for details). Shaded bands denote 95-percent confidence intervals based on 1,000 bootstrap replications.

Figure 4 depicts the impulse responses of the nine endogenous variables to an orthogonalized shock to the financial bond premium, based on the VAR(2) model estimated over the 1985:Q1–2010:Q2 period. An unanticipated increase of one standard deviation in the financial bond premium—almost 30 basis points—causes a significant slowdown in economic activity. In economic terms, the implications of this financial disruption are substantial: Although the decline in consumption is relatively mild, total private fixed investment drops significantly, bottoming out a full percentage point below trend about five quarters after the shock; hours worked also decelerate markedly, and the output of the economy as a whole does not begin to recover until about a year and a half after the initial impact. The downturn in economic activity is amplified in part by the substantial drop in the net worth of nonfinancial firms, and the repair of corporate balance sheets is slow and protracted. The combination of the economic slack and appreciable disinflation in the wake of the financial shock elicits a significant easing of monetary policy, as evidenced by the decline in the federal funds rate.

III. General Equilibrium Framework

This section describes a New Keynesian general equilibrium model that allows for financial frictions along the lines of the financial accelerator mechanism formulated by Bernanke and Gertler (1989) and Bernanke, Gertler, and Gilchrist (1999). In absence of financial frictions, the model reduces to a standard New Keynesian framework of the type developed by Christiano, Eichenbaum, and Evans (2005) and analyzed subsequently by Smets and Wouters (2007) and Justiniano, Primiceri, and Tambalotti (2010). Key features of the CEE/SW framework include habit formation, higher-order adjustment costs to investment, fixed-costs of production and variable capacity utilization, and nominal rigidities due to a Calvo price-setting mechanism with indexation. Monetary policy is conducted via a Taylor-type rule that sets the nominal interest rate as a function of inflation, output growth, and lagged nominal rates.

The estimated versions of the CEE/SW framework, augmented with the BGG financial accelerator mechanism, can be found in the recent work by Christiano, Motto, and Rostagno (2009) and Gilchrist, Ortiz, and Zakrajšek (2009). These papers show that allowing for *unobservable* shocks to the efficiency of the credit intermediation process can account for a substantial fraction of the variability in investment and output in U.S. historical data. In contrast, this paper uses *observable* fluctuations in the financial bond premium as a proxy for such credit supply shocks, which, by boosting the cost of external finance for nonfinancial borrowers, cause a decline in spending and production.

In addition to augmenting the CEE/SW framework with the BGG financial accelerator mechanism, we also modify the preferences of the representative household to better match the dynamics of consumption over the course of the business cycle. Specifically, our modification nests standard household preferences—in which consumption and leisure are separable—with those proposed by Greenwood, Hercowitz, and Hoffman (1988) (GHH hereafter), a specification in which some fraction of labor disutility is quasi-linear in consumption and is, therefore, embedded in the household habit. It is well known that with preferences that are separable between consumption and leisure, financial shocks produce negative comovement between consumption and investment, a counterfactual response that is only partially mitigated by the model's New Keynesian features. With GHH preferences and habit, by contrast, financial shocks lead to positive comovement between consumption and investment.

The key parameters of the model are chosen heuristically so that the responses of macroeconomic aggregates to a financial shock roughly match the corresponding impulse responses shown in Figure 4. Using this calibration, we explore the extent to which observable fluctuations in the financial bond premium can account for the dynamics of the U.S. economy during the 2007–09 downturn. Our results imply that the model can fully account for the overall drop in consumption, investment, hours, and output that was observed during the crisis period. The model also does well at matching the observed decline in inflation and nominal interest rates, as well as the sharp widening of nonfinancial credit spreads. Lastly, we use this framework to analyze the potential benefits of an alternative monetary policy rule, a rule that allows for nominal interest rates to respond to changes in financial conditions as measured by movements in credit spreads.

The Agents

Households

The representative household maximizes the present discounted value of per-period utility:

$$E_0\left[\sum_{t=1}^{\infty} \beta^t U(Z_t, Z_{t-1}, L_t)\right],$$

where L_t denotes the labor supply, Z_t is the habit index, and preferences are assumed to satisfy:

$$U(Z_t, Z_{t-1}, L_t) = \ln(Z_t - \gamma Z_{t-1}) - (1-\omega)v(L_t);$$

$$0 < \gamma < 1; \quad 0 \leq \omega \leq 1,$$

with

$$Z_t = C_t - \omega v(L_t);$$

$$v(L) = \frac{\kappa}{1+\eta} L^{1+\eta}.$$

These preferences allow for internal habit formation in a manner that nests standard preferences—in which labor is separable from consumption and, therefore, the habit index Z_t depends only on past consumption (that is, $\omega = 0$)—with GHH preferences in which the habit index Z_t is a quasi-linear combination of consumption and labor; note that in the latter case, the labor supply decision is independent of the wealth effect, regardless of the degree of habit formation.

Households maximize their objective subject to an inter-temporal budget constraint:

$$C_t + b_t \frac{B_{t+1}}{P_t} = W_t L_t + \frac{B_t}{P_t} + DIV_t - T_t,$$

where P_t denotes the price level, b_t is the discount price of nominal bonds, W_t is the real wage, DIV_t denotes dividend income earned from imperfectly competitive retail firms, and T_t are the lump-sum taxes used to finance government spending and net transfers.

Letting

$$\lambda_t = \frac{1}{Z_t - \gamma Z_{t-1}} - \gamma\beta E_t\left[\frac{1}{Z_{t+1} - \gamma Z_t}\right] \quad \text{and} \quad R^n_{t+1} = \frac{1}{b_t}$$

denote the marginal utility of wealth and the (gross) nominal interest rate, respectively, household optimality conditions then imply the following inter-temporal savings condition:

$$\lambda_t = E_t\left[\beta\lambda_{t+1} R^n_{t+1} \frac{P_t}{P_{t+1}}\right];$$

and the following intra-temporal labor supply condition:

$$\lambda_t[W_t - \omega v'(L_t)] = (1-\omega)v'(L_t).$$

When $\omega = 0$, this reduces to the standard labor supply condition:

$$\lambda_t W_t = v'(L_t),$$

whereas when $\omega = 1$, we obtain the GHH specification, in which the labor supply is independent of the marginal utility of wealth:

$$W_t = v'(L_t).$$

Retail Firms

We assume the existence of a continuum of retail firms—indexed by τ—that supply, at a monopolistic price P_t^τ, a retail good Y_t^τ, produced using the homogeneous wholesale output Y_t^w that is purchased in a competitive market at price P_t^w. All retailers face a fixed cost of production and have access to a technology that allows them to transform wholesale goods into retail goods in a one-for-one manner. The final-good output is a Dixit-Stiglitz aggregate of the differentiated retail goods:

$$Y_t = \left(\int_0^1 Y_t^{\tau\frac{\varepsilon-1}{\varepsilon}} d\tau\right)^{\varepsilon/(\varepsilon-1)};$$

and the price level is given by

$$P_t = \left(\int_0^1 P_t^{\tau(1-\varepsilon)} d\tau \right)^{1/(1-\varepsilon)};$$

the individual retail demand satisfies

$$Y_t^\tau = \left(\frac{P_t^\tau}{P_t} \right)^{-\varepsilon} P_t;$$

where ε determines the elasticity of demand.

Retail firms face nominal price rigidities that evolve according to a standard Calvo price-setting process, in which prices can be adjusted with constant probability $\theta > 0$ in each period. In periods when prices are not adjusted, we assume that the nominal price is fully indexed to past inflation. The price reset in period t—denoted by P_t^*—is given by

$$P_t^* = \left[\frac{\varepsilon}{\varepsilon - 1} \right] \frac{E_t \sum_{i=0}^{\infty} \theta^i \beta^i \left(\frac{\lambda_{t+i}}{\lambda_t} \right)^{-1} P_t^w Y_{t+i} \left(\frac{1}{P_{t+i}} \right)^{\varepsilon}}{E_t \sum_{i=0}^{\infty} \theta^i \beta^i \left(\frac{\lambda_{t+i}}{\lambda_t} \right)^{-1} Y_{t+i} \left(\frac{1}{P_{t+i}} \right)^{\varepsilon}}.$$

The price level in period t depends on both the price level in the previous period indexed to lagged inflation and on the newly set price P_t^*:

$$P_t = \left[\theta((1 + \pi_{t-1}) P_{t-1})^{1-\varepsilon} + (1 - \theta)(P_t^*)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}.$$

Entrepreneurs

As in BGG, entrepreneurs are long-lived, risk-neutral agents that purchase capital and produce wholesale goods that are sold to retail firms. Entrepreneurs purchase capital K_t at time $t-1$ in a competitive market at the relative price Q_{t-1}, and they make labor and capital utilization decisions at time t to maximize profits. Purchases of capital goods are financed using a combination of entrepreneurial net worth and debt issued to the household sector. The presence of financial frictions in the process of issuing debt implies that entrepreneurs must pay a premium on external funds raised from households. This premium is an increasing function of the leverage of the entrepreneurial sector. Because entrepreneurs are long-lived, the net worth of the entrepreneurial sector is a state variable of the economy.

Entrepreneurs are also assumed to "die" with constant exogenous probability in each period, in which case they are replaced within the period by new entrepreneurs. As a result, entrepreneurs discount the future more heavily than households and withhold from consuming until they die. These assumptions imply that entrepreneurs will not, on average, accumulate enough savings to fully finance their investment opportunities. We assume that upon death, entrepreneurial consumption is fully taxed and rebated in a lump-sum to the household sector. New entrepreneurs are given (negligible) start-up funds to begin operation; these funds are assumed to be provided via a lump-sum tax on households.

Entrepreneurs choose labor L_t and capital utilization u_t to maximize profits

$$\left(\frac{P_t^w}{P_t}\right) Y_t^w - W_t L_t - \psi(u_t) K_t,$$

subject to the Cobb-Douglas production function:

$$Y_t^w = A_t \left(K_t^s\right)^\alpha L_t^{1-\alpha},$$

where $K_t^s = u_t K_t$ denotes capital services and $\psi(u_t)K_t$ is the resource cost of increasing the rate of capital utilization. Letting P_t^k denote the entrepreneur's marginal profitability of capital, then cost minimization implies

$$\frac{W_t L_t}{P_t^k K_t^s} = \frac{1-\alpha}{\alpha},$$

where

$$P_t^k = \psi'(u_t).$$

The entrepreneur's marginal cost of production is given by:

$$MC_t = \frac{P_t^W}{P_t} = \frac{1}{A_t} W_t^{1-\alpha} \left(P_t^k\right)^\alpha \left(\alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}\right).$$

Because capital goods are resold at time $t+1$, the real rate of return on capital—denoted by R_{t+1}^k—is the sum of the marginal profitability of capital and the capital gain:

$$R_{t+1}^k = \frac{\left[u_{t+1} P_{t+1}^k - \psi(u_{t+1}) + (1-\delta) Q_{t+1}\right]}{Q_t},$$

where $0 < \delta < 1$ is the rate of capital depreciation.

Closing the Model

The External Finance Premium

The external finance premium—denoted by s_t—is defined as the ratio of the expected real rate of return on capital (which, in equilibrium, is equal to the cost of external funds) to the expected real rate of return on a riskless bond, which is interpreted as the cost of internal funds:

$$s_t \equiv \frac{E_t R_{t+1}^k}{E_t\left[R_{t+1}^n \frac{P_t}{P_{t+1}}\right]}.$$

In order to focus on the primary distortion associated with financial frictions—namely, the introduction of a time-varying countercyclical wedge between the rate of return on capital and the rate of return on the riskless bond held by households—we adopt a number of simplifications with respect to the original BGG formulation. Specifically, imperfections in private financial intermediation imply that the external finance premium increases in response to an increase in borrowers' leverage:

$$s_t = \exp(\sigma_t)\left(\frac{Q_t K_{t+1}}{N_{t+1}}\right)^{\chi}, \tag{3}$$

where $0 < \chi < 1$ is the parameter governing the strength of this response and σ_t denotes a shock to the efficiency of the financial intermediation process. The possibility of disruptions to the efficiency of financial intermediation is taken as exogenous by assuming that σ_t evolves according to an AR(1) process of the form:

$$\sigma_t = (1 - \rho_\sigma)\sigma + \rho_\sigma \sigma_{t-1} + \varepsilon_t.$$

In this context, an increase in σ_t raises the cost of external finance for a given amount of leverage, implying an increase in the effective cost of financial intermediation.[15]

Net worth at the beginning of period $t+1$ is the return on capital less the repayment of the loan made at the beginning of period t:

$$N_{t+1} = \mu\left[R_t^k Q_{t-1} K_t - s_{t-1} E_{t-1}\left[R_t^n \frac{P_{t-1}}{P_t}\right](Q_{t-1}K_t - N_t)\right] + (1-\mu) W^E.$$

where $0 < \mu < 1$ is the parameter reflecting the depletion of net worth owing to the death rate of entrepreneurs; W^E is the lump-sum transfer from households to new entrepreneurs; and $s_{t-1}E_{t-1}[R_t^n (P_{t-1})/(P_t)]$ is the equilibrium (gross) interest rate on risky debt.

Capital Goods Production

We assume the existence of a competitive capital-goods-producing sector that produces new capital goods according to an adjustment technology that is increasing in the rate of investment. Aggregate capital accumulation evolves

[15]Christiano, Motto, and Rostagno (2009) interpret such a shock as an increase in the idiosyncratic variance of firm-level project returns in the entrepreneurial sector. Such a shock raises the cost of external finance because in the Costly-State Verification (CSV) framework adopted by BGG, an increase in idiosyncratic uncertainty implies an increase in the cost of debt finance; see also Gilchrist, Sim, and Zakrajšek (2010). Such a shock may also be interpreted as an increase in the cost of default in the CSV framework.

according to

$$K_{t+1} = (1-\delta)K_t + \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right]I_t,$$

where $S(\cdot)$ is the capital adjustment cost function. The optimality condition for capital goods producers implies the following relationship between the price of capital and the investment rate:

$$Q_t\left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] = Q_t S'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}} - E_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}Q_{t+1}S'\left(\frac{I_{t+1}}{I_t}\right)\frac{I_{t+1}}{I_t}\right].$$

Aggregate Resource Constraint

Let G denote government spending, which is financed through lump-sum taxes of households. The resource constraint implies that final output Y_t satisfies

$$Y_t = C_t + I_t + \psi(u_t)K_t + G + \Xi,$$

where Ξ denotes the aggregate resource loss because of the presence of fixed production cost in the retail sector.

Monetary Policy

For our baseline case, we assume that the policy interest rate depends on its own lag, inflation, and output growth. In letting the short-term interest rate respond to output growth—as opposed to the output gap—the monetary authority is assumed to follow a robust first-difference rule of the type proposed by Orphanides (2003). Moreover, as shown by Orphanides and Williams (2006), such first-difference rules are highly successful in stabilizing economic activity in the presence of imperfect information regarding the structure of the economy.[16]

Prompted by the observation that the behavior of key private interests rates during the recent crisis diverged markedly from their usual comovement with the federal funds rate, a number of prominent observers have suggested that credit spreads should be given independent weight in monetary policy decisions. Most notably, Taylor (2008) has argued that the intercept term of his famous rule should be adjusted downward in proportion to observed movements in the spread of term LIBOR over rates on comparable-maturity

[16]According to the simulations reported by Orphanides and Williams (2006), such a robust monetary policy rule yields outcomes for the federal funds rate that are very close to those seen in the actual data, especially for the period since the mid-1980s.

overnight index swaps (OIS).[17] Others have suggested that monetary policy should pay close attention to the balance sheets of financial intermediaries. Christiano and others (2007), for example, develop a model in which financial shocks are an important source of economic fluctuations and where a Taylor rule modified to include a response to aggregate credit delivers superior macroeconomic outcomes.

In our framework, shocks to the efficiency of financial intermediation are the sole source of cyclical fluctuations. To assess the degree to which this type of modification of our baseline policy rule would improve macroeconomic stability, we consider a policy rule in which monetary authorities also respond to movements in the external finance premium, according to

$$\ln R^n_{t+1} = \ln R^n + \phi_r \ln R^n_t + \phi_\pi \ln \Pi_t + \phi_{\Delta y} \Delta \ln Y_t + \phi_s \ln s_t, \qquad (4)$$

where $0 < \phi_r < 1$ is the parameter governing the degree of interest rate smoothing, while $\phi_\pi > 0$, $\phi_{\Delta y} > 0$, and $\phi_s < 0$ determine the response of the policy interest rate to inflation, output growth, and the external finance premium, respectively. Note that this adjustment implies that the policy rate be reduced—relative to what our baseline first-difference rule would prescribe—when credit spreads are higher than normal; conversely, the policy rate should be raised in response to an unusual easing of financial conditions.[18]

Calibration

As noted above, we employ a somewhat heuristic approach to calibrate the model. Most parameters, including those that determine the model's steady-state (that is, the household's labor supply elasticity and the degree of habit formation), are fixed at values commonly used in the literature. Parameters that govern the behavior of monetary policy and the financial shock process are directly estimated from the data. We then choose the key elasticities that determine the dynamics of inflation, investment, consumption, and output in order to match the model's impulse response function to those estimated using our VAR framework.

[17]The LIBOR-OIS spread is a conventional measure of counterparty credit risk in interbank funding markets; see, for example, Taylor and Williams (2009).

[18]The view that the central bank should raise short-term interest rates to "prick" asset bubbles is widely rejected by today's profession, because monetary policy is too blunt of a tool to allow the type of surgical intervention required to deflate a bubble without plunging the economy into a recession. Nevertheless, modifications of simple policy rules to include a measure(s) of economy-wide financial conditions have been proposed by the advocates of the "leaning against the wind" principle, which argues that the central banks should cautiously raise interest rates beyond the level necessary to maintain price stability over the short to medium run, when a potentially detrimental asset price boom has been identified (cf. Borio and Lowe, 2002 and 2006). Importantly, the proponents of this view stress the nonlinear nature of the policy response, as positive and negative asset price shocks have asymmetric macroeconomic effects, as well as the strong informational requirements concerning the properties of the emerging bubble.

Specifically, a period in the model is a quarter. We set the discount factor $\beta = 0.984$; the labor share of income $1-\alpha = 2/3$; the labor supply elasticity is $1/\eta = 3$ and the degree of habit formation $\gamma = 0.75$. The depreciation rate $\delta = 0.025$. The steady-state markup is $\varepsilon/(\varepsilon-1) = 1.1$. Government spending, as a share of output, is set to 0.2 in the steady state.

The parameters of the monetary policy rule are chosen to match the parameters from a regression of the nominal federal funds rate on its own lag, GDP price inflation, and real output growth, estimated over the period 1985:Q1–2010:Q2. This regression yields $\phi_r = 0.92$, $\phi_\pi = 0.15$, and $\phi_{\Delta y} = 0.11$. Similarly, we choose the autoregressive coefficient for the financial shock to match an AR(1) regression coefficient of the financial bond premium over our sample period—that is, $\rho_\sigma = 0.75$, implying a half-life of financial disturbances of about 2.5 quarters.

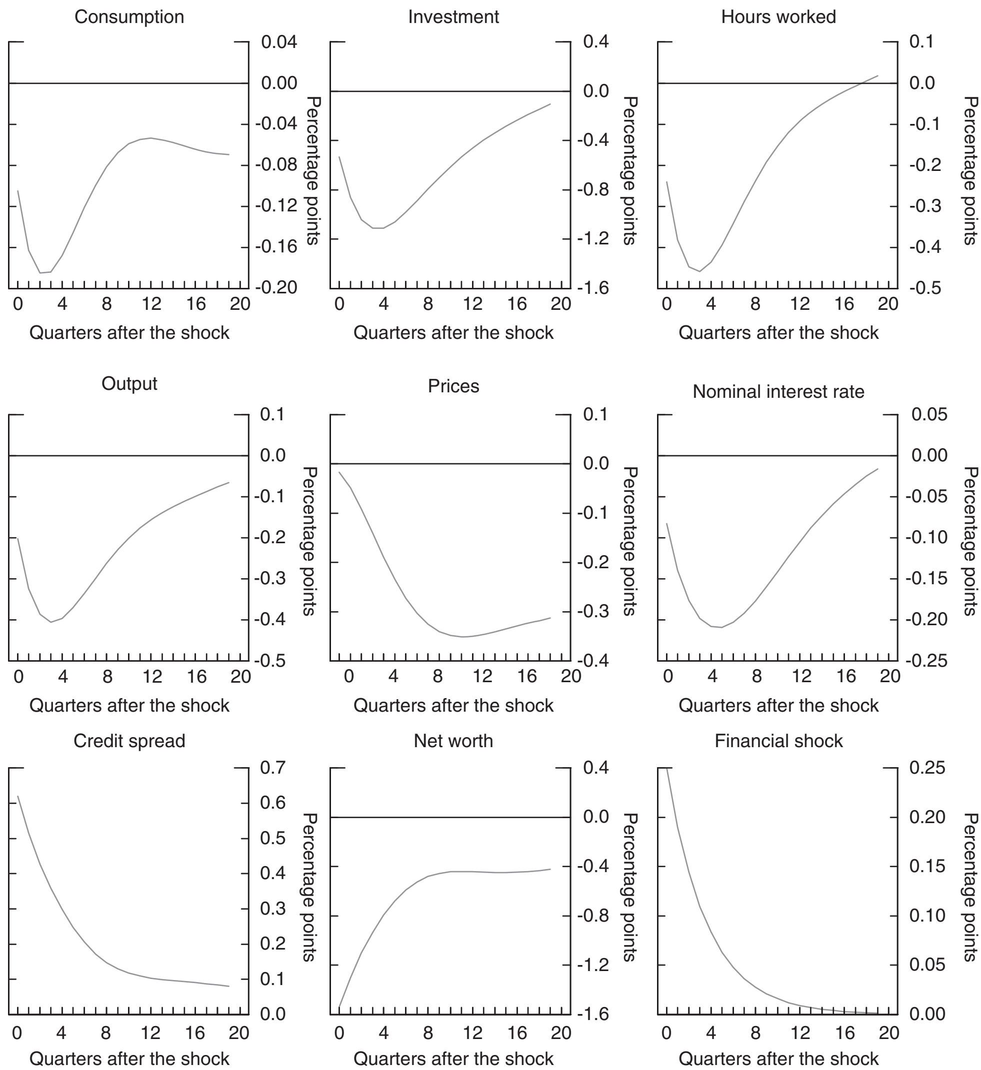
The log-linearized model implies that there are two key financial parameters to choose: the steady-state leverage ratio and the elasticity of the external finance premium with respect to leverage, the parameter χ that governs the strength of the financial accelerator mechanism, with bigger values of χ leading to larger declines in investment and output in response to a financial shock.[19] In addition, there are three more parameters that need to be calibrated: ω the share of labor disutility that enters the habit index Z_t; $\Lambda_I \equiv -S''(I_t/I_{t-1})/S'(I_t/I_{t-1})$, the elasticity of asset prices with respect to the investment-capital ratio; and θ, the parameter determining the frequency of price resets. Larger values of ω induce a greater comovement between consumption, employment, and output in response to a financial shock, while increasing Λ_I strengthens the hump-shaped response of investment to such disturbances.

The steady-state ratio of the real value of the capital stock to the entrepreneur's net worth is chosen so that the steady-state leverage ratio is 100 percent, or $(QK-N)/N = 1$, which implies $K/N = 2$ (note that $Q = 1$ in steady state). We choose ω, Λ_I, θ, and χ so that the model's impulse responses to a financial disturbance match the size of the decline in consumption, investment, output, and inflation in response to a shock to the financial bond premium documented in Section II. This implies the following values for the four elasticities: $\omega = 0.4$; $\Lambda_I = 3.0$; $\theta = 0.8$; and $\chi = 0.1$.

The investment elasticity Λ_I and the Calvo price setting parameter θ are within the range of standard estimates in the literature. In contrast, the choice of $\chi = 0.1$, about twice as large as the calibration adopted by BGG, is somewhat higher than that suggested by the recent estimates. Although there are no prior estimates of ω, we note that if $\omega = 1$, the model implies perfect comovement between consumption, investment, and output; in contrast, $\omega = 0$ implies no decline in consumption in response to financial shocks. Our choice of $\omega = 0.4$ implies that the model can closely replicate the fact that consumption drops by roughly one half of the amount of output in response to a financial disturbance.

[19]In the case of no financial market frictions, $\chi = 0$. In this case, balance sheet conditions of entrepreneurs are irrelevant for the cost of external funds and thus for their capital expenditure decisions.

Figure 5. Model-Based Impulse Responses to a Financial Shock (*Baseline Monetary Policy Rule*)



Note: The panels of the figure depict the model-based impulse response functions of selected variables to a 1 standard deviation financial shock for the baseline specification of the monetary policy rule, a case in which the monetary authority does not respond to credit spreads (see text for details). All variables are expressed in percentage-point deviations from their respective steady-state values.

Baseline Results

Figure 5 plots the impulse responses of the selected macroeconomic variables implied by the model in response to a financial shock, assuming the baseline specification of the monetary policy rule. The model captures remarkably well the shape of the corresponding impulse response functions shown in Figure 4. Consumption, investment, hours, and output all exhibit significant declines, with the peak response of each variable closely matching its empirical counterpart. Although the model delivers hump-shaped dynamics for each of those variables that are consistent with those observed in the data, the model dynamics imply a peak response several quarters earlier than the peak response observed in Figure 4.

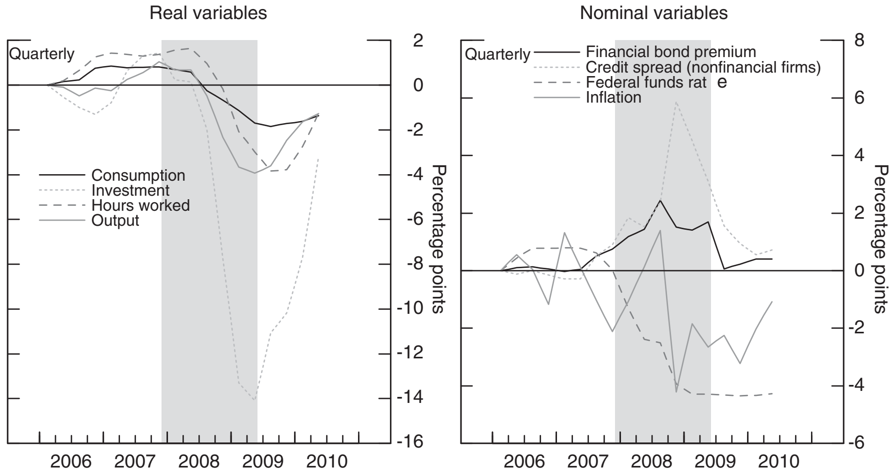
The decline in the price level implied by the model also matches that seen in the data. Furthermore, given the estimated policy rule, the model-implied dynamics for inflation and output generate a path for the nominal interest rate that is broadly in line with the estimated response of the federal funds rate to an orthogonalized shock to the financial bond premium.

We now consider the ability of the model to explain the 2007–09 economic downturn as a response of the macroeconomy to a sequence of adverse financial shocks. To do so, we initialize the model to be in steady state as of the end of 2005 and feed in, as shocks to σ_t, the realized values of innovations—based on the AR(1) model—to the financial bond premium over the 2006:Q1–2010:Q2 period. Figure 6 shows the evolution of the key macroeconomic variables of the U.S. economy over this period, while Figure 7 shows the corresponding path for the model-implied variables. According to the model, investment falls 14 percent in response to the realized shocks to the financial bond premium, a drop that is exactly in line with that observed in the data. The model-implied declines in hours and output are about 5 percent, which is slightly more than their empirical counterparts. Consistent with the data, the model also produces a modest—about 2 percent—but protracted decline in consumption.

Apart from its effects on the real economy, the model also implies that the realized sequence of disturbances originating in the financial sector reduces inflation about 2 percentage points and causes a drop in the nominal interest rate of more than 200 basis points. The response of inflation implied by the model is clearly smoother than that observed in the data, though their respective magnitudes are quite comparable. The actual response of the short-term nominal interest rate, however, is considerably stronger: The actual policy rate falls about 400 basis points, before leveling off at the zero lower bound. This divergence from the simple first-difference rule likely reflects the Federal Reserve's response to persistent credit market turmoil, as the FOMC aggressively reduced its target for the federal funds rate between late 2007 and early 2008, even though official statistics did not yet indicate that real GDP was contracting, while inflation, if anything, was still rising.[20]

[20]See Mishkin (2008) for a detailed discussion of the FOMC's decisions during that period. The divergence of the actual policy from the simple rules during that time was also noted by many observers. To account for the difference, Meyer and Sack (2008), for example, proposed a modified Taylor rule in which the intercept—representing the Federal Reserve's view of the "equilibrium real funds rate"—had been adjusted downward in response to

Figure 6. The U.S. Economy During the 2007–09 Financial Crisis



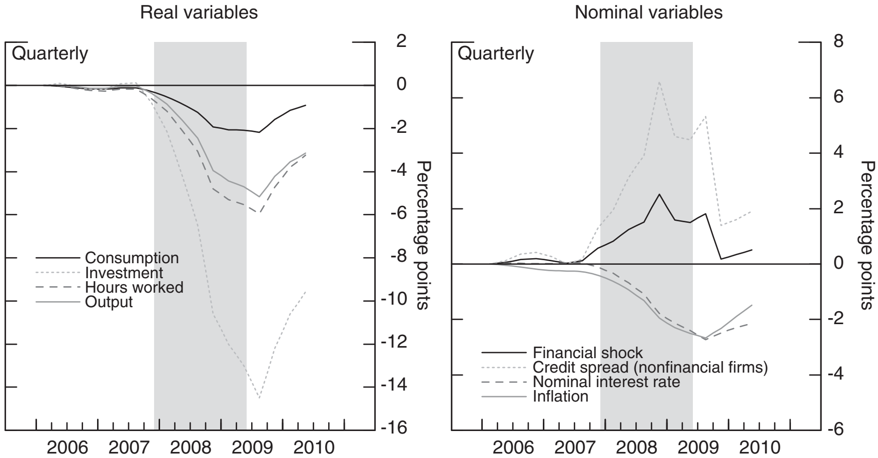
Note: The two panels of the figure depict the behavior of selected macroeconomic variables in the period surrounding the 2007–09 financial crisis. Consumption, investment, hours worked, and output have been detrended using the Hodrick-Prescott filter. All series are indexed to equal zero in 2006:Q1. The shaded vertical bar denotes the NBER-dated recession.

An important aspect of the recent crisis—alluded above, but one that is omitted from our analysis—is the fact that since December 2008, the FOMC has maintained a target range for the federal funds rate of 0 to 1/4 percent—that is, monetary policy has been effectively constrained by the presence of a zero lower bound (ZLB) on nominal interest rates. Although our empirical results are qualitatively and quantitatively robust to the exclusion of that period from our sample, the binding ZLB constraint raises important questions for the conduct of monetary policy in any model used to analyze the macroeconomic and financial developments over this period. As emphasized by Eggertsson and Woodford (2003) and Nakov (2008), forward guidance regarding the anticipated future path of short-term nominal interest rates provides a very effective way to stabilize the output gap and inflation within the New Keynesian framework. By announcing that the policy rate will be kept low during the initial phase of economic recovery, such a commitment provides stimulus to the economy by lowering expected future real interest rates, thereby avoiding deflation in the near term, while producing only mildly elevated rates of inflation once the economy has fully recovered.

However, as shown by Levin and others (2010), when the economy is hit by a large and persistent natural rate shock—the kind experienced during the recent crisis—forward guidance alone delivers relatively poor macroeconomic outcomes. According to their simulations, a combination of

persistent strains in the financial markets, with the magnitude of the adjustment calibrated to the increase in credit spreads in interbank funding markets in early 2008.

Figure 7. Model-Based Simulation of a Financial Shock (*Baseline Monetary Policy Rule*)



Note: The two panels of the figure depict the model-implied path of selected macroeconomic variables in response to the estimated financial shocks for the baseline specification of the monetary policy rule, a case in which the monetary authority does not respond to credit spreads (see text for details). All variables are expressed in percentage-point deviations from their respective steady-state values. The shaded vertical bar denotes the NBER-dated recession.

forward guidance and other policy measures—such as large-scale asset purchases, for example—is needed to deliver a sufficient macroeconomic stimulus in situations where the economy experiences a "Great Recession"-style shock and the near-term path of the policy rate is constrained by the zero lower bound. Although incorporating the ZLB and unconventional monetary policy actions into the analysis lies beyond the scope of our paper, our next set of simulation results would suggest that an aggressive and timely response of monetary policy to changes in financial conditions—in our context measured by movements in credit spreads—may reduce the likelihood of interest rate policy being subsequently constrained by the zero lower bound.

The Spread-Augmented Monetary Policy Rule

To recap briefly, our baseline simulations imply that shocks to the financial intermediation process, as measured by movements in the financial bond premium, can account quite well for the collapse in employment, consumption, investment and output during the 2007–09 financial crisis. Because the actual monetary policy response was clearly stronger than that implied by the model, it is likely that the model is underestimating the full economic impact of financial disruptions during this period. Nevertheless, the model dynamics are sufficiently close to the actual economic outcomes to provide a useful guide for alternative policy rules that may be used to stabilize the economy in the wake of disruptions in financial markets.

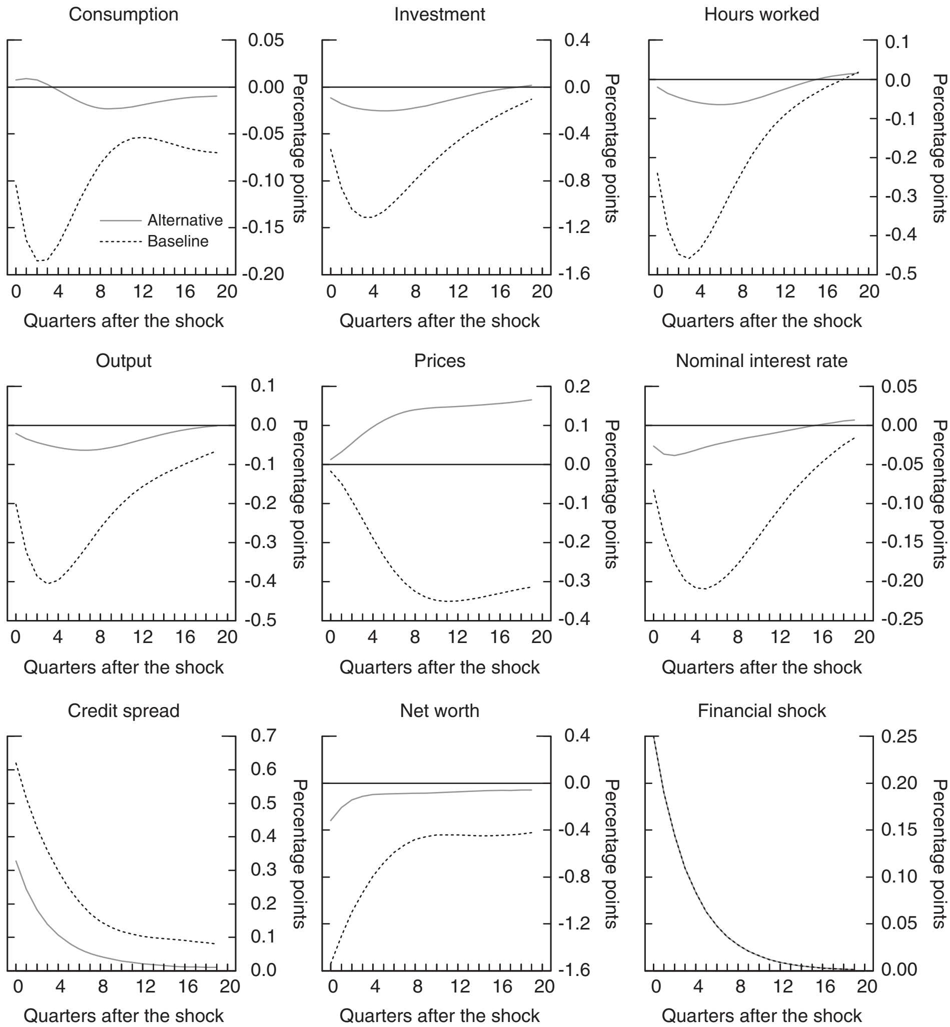
In this section, we consider one such rule proposed in the literature: the adjustment to the first-difference rule so that monetary policy responds to financial developments as measured by movements in credit spreads (cf. Cúrdia and Woodford, 2010). Specifically, we augment the baseline first-difference rule by allowing for a direct response of the policy rate to the measured credit spread (see equation (4)). The coefficient on the spread is set equal to minus one, so that the nominal rate offsets the increase (or decrease) in financial stress on a one-for-one basis. It is important to note this rule is not derived formally from a welfare-maximization problem.[21] Rather, our aim is to evaluate whether adding a response to credit spreads, as proposed by Taylor (2008) and McCulley and Toloui (2008) can improve equilibrium responses of the macroeconomy to shocks emanating from the financial sector.

The solid lines in Figure 8 depict the model impulse responses to a financial shock under the spread-augmented monetary policy rule, while the dotted lines denote the corresponding responses under the baseline first-difference rule (that is, $\phi_s = 0$), replicated, for comparison purposes, from Figure 5. The comparison of responses reveals that including the credit spread in the policy rule successfully stabilizes the real side of the economy. Importantly, the price level, in response to a financial shock, increases 0.2 percentage points, rather than falling 0.3 percentage points, as in the baseline case. Because of rising inflation, the nominal interest rate actually declines only 4 basis points under the spread-augmented rule, compared with the decline of 20 basis points in the baseline case. Effectively, the rise in inflation implies a reduction in the real rate of interest with very little movement in the nominal rate. This reduction in real rates leads to an offsetting increase in asset values and a much smaller decline in net worth than one sees in the baseline scenario. As a result, the response of the credit spread under the alternative policy basically mimics the response of the financial shock, resulting in very little additional amplification through the financial accelerator mechanism.

Although asset prices are forward looking, they influence the balance sheets of firms, and hence the strength of the financial accelerator, immediately. Consequently, a reduction in expected future real interest rates can be very effective in offsetting an emerging disruption in credit markets. (We return to this issue below, when considering policy responses in environments where financial disruptions are anticipated in advance.) This point is made explicit in Figure 9, which shows the model-implied path of the key macroeconomic aggregates during the 2006:Q1–2010:Q2 period under the

[21]In the case in which credit spreads are endogenous, both financial and nonfinancial shocks will cause credit spreads to fluctuate, and the magnitude of spread adjustment to the policy rate will have important implications for the economy's response to various types of disturbances; see Cúrdia and Woodford (2010) for detailed analysis and discussion.

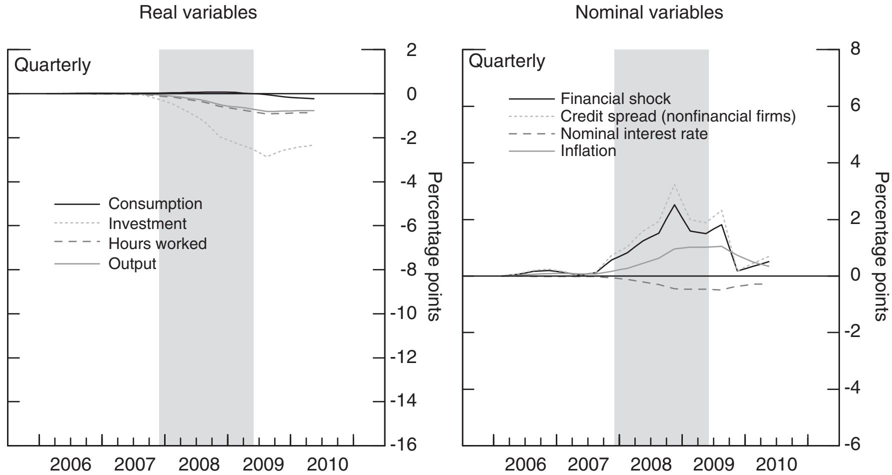
Figure 8. Model-Based Impulse Responses to a Financial Shock (*Baseline vs. Spread-Augmented Monetary Policy Rule*)



Note: The solid lines in each panel of the figure depict the model-based impulse response functions of selected variables to a 1 standard deviation financial shock for the alternative specification of the monetary policy rule, a case in which the monetary authority responds to credit spreads; the dotted lines in each panel correspond to impulse responses under the baseline specification of the monetary policy rule (see text for details). All variables are expressed in percentage-point deviations from their respective steady-state values.

spread-augmented policy rule. Consistent with the results presented in Figure 8, such a rule fully stabilizes the response of output and hours and implies only a modest reduction in investment—about 2 percentage points—which is offset by a slight increase in consumption. Again the response of the nominal interest rate is close to zero—the slight easing of monetary policy

Figure 9. Model-Based Simulation of a Financial Shock (*Spread-Augmented Monetary Policy Rule*)



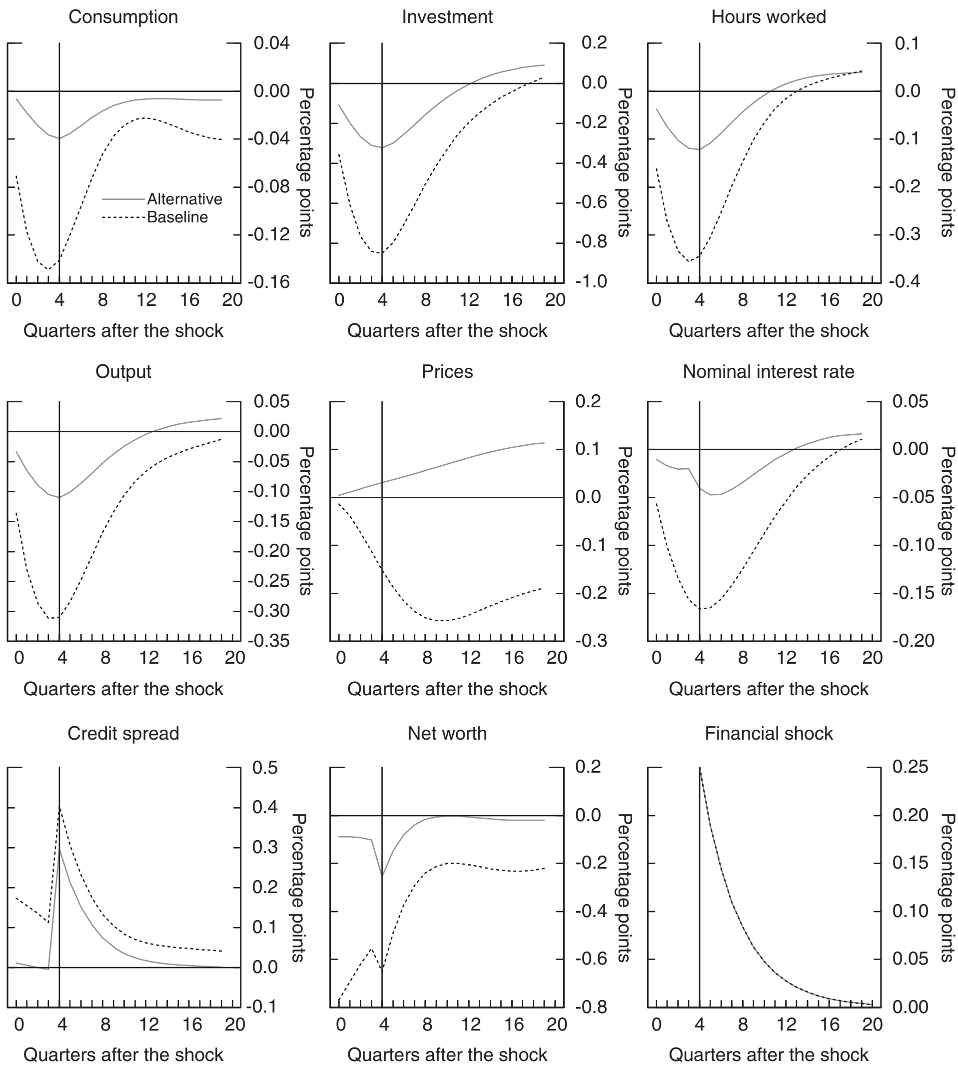
Note: The two panels of the figure depict the model-implied path of selected macroeconomic variables in response to the estimated financial shocks for the alternative specification of the monetary policy rule, a case in which the monetary authority responds to credit spreads (see text for details). All variables are expressed in percentage-point deviations from their respective steady-state values. The shaded vertical bar denotes the NBER-dated recession.

leads to an increase in inflation and a reduction in the real interest rate. These developments, in turn, boost asset values, counteracting the adverse consequences of financial shocks.

To be sure, the disruptions in financial markets during the recent financial crisis are far more complex than simple shocks to the credit spread modelled in our framework. Nevertheless, the above results suggest that a monetary policy regime that is committed, in advance, to fully offset shocks to the financial system through active interest rate policy can be quite beneficial in mitigating the deleterious consequences of financial market disruptions. In the above examples, financial shocks are surprise events that imply an immediate jump in credit spreads. Because the output response is sluggish relative to the response of the credit spread, it is difficult to distinguish whether the benefits of responding to movements in credit spreads are due to the fact that the widening of spreads signals a future decline in economic activity or that the agents in the economy anticipate the response and asset prices adjust accordingly.

To analyze this issue, we consider a shock to σ_t that is known four periods in advance. Thus, agents and the monetary authorities are able to anticipate future disruptions in credit markets. We again analyze the potential stabilization benefits of allowing the nominal interest rate to respond to realized movements in the credit spread. Figure 10 depicts the impulse responses to this anticipated financial shock under both the baseline

Figure 10. Model-Based Impulse Responses to an Anticipated Future Financial Shock (*Baseline vs. Spread-Augmented Monetary Policy Rule*)



Note: The solid lines in each panel of the figure depict the model-based impulse response functions of selected variables to an anticipated 4-quarter-ahead 1 standard deviation financial shock for the alternative specification of the monetary policy rule, a case in which the monetary authority responds to credit spreads; the dotted lines in each panel correspond to impulse responses under the baseline specification of the monetary policy rule (see text for details). All variables are expressed in percentage-point deviations from their respective steady-state values.

(the dotted lines) and the spread-augmented policy rules (the solid lines). Under the baseline rule, the anticipated financial shock causes an immediate reduction in asset prices and entrepreneurial net worth and a decline in economic activity that occurs before the actual disruption in credit markets (that is, period 4). The magnitude of these effects is only slightly less than that reported in response to an unanticipated shock in Figure 5.

In contrast, under the spread-augmented rule, the anticipated disruption to the credit intermediation process causes a slight initial decrease in the net worth of entrepreneurs, followed by an additional modest decline upon the actual impact. The realized spread, however, reacts strongly once the shock occurs. In this case, the decline in output precedes the spike in credit spreads. Hence, the stabilizing effects of the spread-augmented rule cannot be attributed to the fact that credit spreads provide a timely indicator of future cyclical downturns. Under this alternative policy, the decline in output is quite modest, relative to the case where policy does not respond to financial stress indicators. In addition, the announced policy of actively responding to credit spreads results in very little actual movement in the nominal interest rate. These results confirm the intuition suggested above that agents' expectations that the monetary authority will respond to financial disruptions when they occur can have a powerful stabilizing effects on economic activity.

IV. Conclusion

This paper examined the extent to which the workhorse DSGE model with financial frictions is able to account for the extraordinary macroeconomic dynamics of the 2007–09 period. We showed that by carefully constructing a sequence of financial shocks using financial intermediary credit spreads, a reasonably calibrated version of the CEE/SW framework augmented with the BGG financial accelerator can fully account for the overall drop in consumption, investment, hours, and output that was observed during the crisis period. The model also does well at matching the observed decline in inflation and nominal interest rates, as well as the sharp widening of nonfinancial credit spreads.

Although the model is relatively simple compared with the recent work in this area, our findings nonetheless provide considerable insight into the importance of financial factors in business cycle fluctuations. In particular, the results suggest that by allowing the nominal interest rate to respond to credit spreads—a primary measure of financial stress in our framework—monetary policy can effectively dampen the negative consequences of financial market shocks on real economic activity, while experiencing only a modest increase in inflation.

In reality, of course, monetary authorities would have to take into account many credit spreads, rather than just one. Moreover, the central bank would face a difficult judgment call of whether a rise in credit spreads indicates disruptions in the financial sector or represent an endogenous response of financial conditions to developments elsewhere in the economy. As underscored by the recent crisis, the complex circumstances associated with financial market disruptions would suggest that a superior approach is likely to involve the central bank using its entire arsenal of tools, rather than a simple proportional response to any single measure of financial conditions.

APPENDIX

Financial Intermediary Bonds

As discussed by Gilchrist and Zakrajšek (2011), the micro-level aspect of our data allows us to construct credit spreads that are not biased by the maturity/duration mismatch, a problem that plagues credit spread indices constructed with aggregated data. In particular, for each individual bond issue in our sample, we construct a theoretical risk-free security that replicates exactly the promised cash-flows of the corresponding corporate debt instrument. For example, consider a corporate bond k issued by firm i that at time t is promising a sequence of cash-flows $\{C(s): s = 1, 2, \ldots, S\}$, consisting of the regular coupon payments and the repayment of the principle at maturity. The price of this bond in period t is given by

$$P_{it}[k] = \sum_{s=1}^{S} C(s)\, D(t_s),$$

where $D(t) = e^{-r_t t}$ is the discount function in period t. To calculate the price of a corresponding risk-free security—denoted by $P_t^f[k]$—we discount the promised cash-flow sequence $\{C(s): s = 1, 2, \ldots, S\}$ using continuously compounded zero-coupon Treasury yields in period t, obtained from the daily estimates of the U.S. Treasury yield curve reported by Gürkaynak, Sack, and Wright (2007). The resulting price $P_t^f[k]$ can then be used to calculate the yield—denoted by $y_t^f[k]$—of a hypothetical Treasury security with exactly the same cash-flows as the underlying corporate bond. The credit spread $S_{it}[k] = y_{it}[k] - y_t^f[k]$, where $y_{it}[k]$ denotes the yield of the corporate bond k, is thus free of the "duration mismatch" that would occur were the spreads computed simply by matching the corporate yield to the estimated yield of a zero-coupon Treasury security of the same maturity.

To ensure that the results are not driven by a small number of extreme observations, we eliminated all observations with credit spreads below 5 basis points and with spreads greater than 3,500 basis points. In addition, we dropped from our sample all observations with a remaining term-to-maturity of less than one year or more than 30 years, because calculating spreads for maturities of less than one year and more than 30 years would involve extrapolating the Treasury yield curve beyond its support.

Table A1 contains summary statistics for the key characteristics of bonds in our sample. Note that a typical financial firm may have a few senior unsecured issues outstanding at any point in time—the median firm, for example, has two such issues trading in any given month. This distribution, however, exhibits a significant positive skew, as some firms can have as many as 43 different issues trading in the market at a point in time. The distribution of the real market values of these issues is similarly skewed, with the range running from \$9.2 million to more than \$4.3 billion. Not surprisingly, the maturity of these debt instruments is fairly long, with the average maturity at issue of about 10 years. Because these securities tend to generate significant cash flows in the form of regular coupon payments, their average effective duration is only about 6.5 years.

According to the S&P's credit-rating scale, our sample spans a wide spectrum of credit quality, from "double C" to "triple A." At "A2," however, the median bond is well within the investment-grade category, an indication of the generally high creditworthiness of financial firms, at least as perceived by one of the major rating agencies. Turning to returns, the (nominal) coupon rate on these bonds averaged 6.89 percent during our sample period, while the average expected total return, as measured by the nominal

Table A1. Summary Statistics of Corporate Bond Characteristics

Variable	Mean	SD	Min	P50	Max
No. of bonds per firm/month	3.00	3.46	1.00	2.00	26.0
Mkt. value of issue[1] ($mil.)	466.9	552.6	9.1	264.0	4,350
Maturity at issue (years)	10.4	8.0	2.0	10.0	40.0
Term to maturity (years)	8.6	7.7	1.0	5.9	30.0
Duration (years)	6.47	3.15	0.90	4.79	15.3
Credit rating (S&P)	—	—	CC	A2	AAA
Coupon rate (pct.)	6.89	1.94	2.25	6.63	15.75
Nominal effective yield (pct.)	6.78	2.77	1.01	6.43	41.2
Credit spread (bps.)	172	253	5	106	3,495

Note: Sample period: Jan1985–Jun2010; Obs. = 42,880; No. of bonds = 886; No. of firms = 193. Sample statistics are based on trimmed data (see text for details).

[1]Market value of the outstanding issue deflated by the CPI (1982–84 = 100).

effective yield, was 6.78 percent per annum. Relative to Treasuries, an average bond in our sample has an expected return of about 172 basis points above the comparable risk-free rate, with the standard deviation of 253 basis points.

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