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Credit risk dynamics in response to changes in the federal funds target: The implication for firm short-term debt

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ABSTRACT

The recent credit crisis has raised a number of interesting questions regarding the role of the Federal Reserve Bank and the effectiveness of its expected and unexpected interventions in financial markets, especially during the crisis, given its mandate. This paper reviews and evaluates the impact of expected and unexpected changes in the federal funds rate target on credit risk premia. The paper's main innovation is the use of an ACH-VAR (autoregressive conditional hazard VAR) model to generate the Fed's expected and unexpected monetary policy shocks which are then used to determine the effects of a Federal Reserve policy change on counterparty credit risk and more importantly short-term firm debt financing. The findings answer a longstanding question sought by researchers on the effect of policy makers' announcements on firm debt financing. The results clearly show that the Federal Reserve influences short-term debt financing through the credit channel for both expansionary and contractionary monetary policies. In particular, we find that the growth in counterparty risk appears less responsive to anticipated responses in the Fed funds rate that fail to materialize than to an unanticipated increase in the federal funds rate. Finally, we also document that the results appear to validate the Feds interventions in financial markets to stem counterparty risk and to make liquidity more readily available to firms.

1. Introduction

In this paper we examine the impact of changes in the federal funds rate target on firms' short-term credit risk dynamics and the subsequent implications for short-term debt financing. The extreme credit climate of 2007/2008 forced financial markets to reassess and limit counterparty credit risk,[2] thereby making it difficult for a number of highly leveraged firms to raise operational capital (Silipo, 2011). Concerns about credit risk first arose in early 2008 with the collapse of Bear Stearns and skyrocketed later in that year when Lehman Brothers defaulted on its debt obligations. In fact, fears of systemic defaults were so extreme in the aftermath of the Lehman bankruptcy that Euro-denominated Credit Default Swap (CDS) contracts on the U.S. Treasury were quoted at spreads as high as 100 basis points.

There is a longstanding widespread claim that credit default swaps[3] work to lower the cost of firms' debt financing because they create a new source of credit risk transfer for corporate bonds.[4] Recently, Ashcraft and Santos (2007) challenged this viewpoint arguing that there is no evidence that the CDS actually lowers the interest rates on corporate debt. We believe that Ashcraft and Santos' reliance on time series analysis to evaluate this phenomenon yielded statically significant but shallow results, so we will use an autoregressive conditional hazard VAR procedure that should provide insights that are deep, subjective and dynamic. The academic literature suggests that the credit risk transfer mechanism is itself sensitive to changes in the short-term rate (Dunbar 2008; Houweling & Vorst, 2005; Jarrow & Turnbull, 1995) and as such any action by the Federal Reserve Bank on its lending rate should influence the debt financing and short-term cash-flow financing needs of firms.

While central banks are generally less concerned with the effects of financial market bubbles, during the financial market crisis the

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[2] This is the risk that an investor may lose part or all of his investment because of an issuer's insolvency or inability to pay the interest and principal. The greater the credit risk, the more interest the issuer has to pay to sell bonds.

[3] A rise in the growth of a firm's credit risk premia indicates rising perception that the firm will be unable to meet future bond payments. This will reduce the firm's ability to access external financing to meet current cash flow needs or new investment opportunities.

[4] This informational role of the CDS market could lead to a reduction in the cost of debt by reducing, for example, the information premium investors' demand on firms' bonds.

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U.S. Federal Reserve Bank aggressively cut its benchmark lending rate to make capital more easily available to the productive sector and prevent negative spillovers to the real economy, see Appendix B. The central bank's unexpected interventions to stem the systematic effects of the credit shock provide the motivation of this study. Did the efforts of the Federal Reserve Bank to use the credit channel to ease liquidity concerns and make capital more readily available to firms reduce the cost of short-term corporate debt? More specifically we will attempt to determine (i) the credit risk transfer mechanism's reaction to an unanticipated monetary policy shock given an extreme macroeconomic event that pushes credit risk temporarily away from its long run equilibrium growth path, (ii) the effect of this unexpected Federal Reserve monetary policy change on firms of different credit qualities and ultimately (iii) the implications for short-term debt financing.

Despite the apparent significance of credit risk in financial markets, there has been relatively little empirical research about how it affects the price of short-term debt financing in which counterparties may default. Appendix A illustrates the credit risk spreads of investment grade debt, high yield debt and their reaction to both expected and unexpected Fed policy responses. The chart plots the time series of the “on-the-run” spreads of the CDX.NA.IG (Investment grade) and the CDX.NA.HY (High yield) indexes. The behavior of the index spreads over the sample period can be divided into two phases. In the phase prior to the credit crisis, the spreads were relatively low in magnitude, while in the second phase starting about June 2007 the spreads became highly volatile. The indexes however retreat before the September 18th 2007 FOMC meeting. On December 31st 2007 both indexes jumped sharply, only to retreat again before the March 18th 2008 meeting.

To better understand the short-term dynamics of changes in the federal funds rate on CDS and the effect of the changes in the CDS on the short-term debt financing of the firm we turn to papers by Hamilton and Jorda (2002) and Tsai (2011) for empirical motivation. Both papers formulate a measure of monetary policy shocks based on the ACH/VAR (autoregressive conditional hazard VAR) methodology for the federal funds rate target. A key feature in these models is that they allow for the analysis of two sources of unexpected changes in the federal funds target. Where, the unexpected increase can be due to either an increase in the federal funds rate target when it was expected to remain constant, or an expected increase in the federal funds rate target that fails to occur. These two events in the ACH-VAR model give rise to completely different information on the expected future federal funds rate.

The remainder of this paper is organized as follows. Section 2 provides a review of the existing literature Section 3 describes the econometric model which is based on the Hamilton and Jorda's ACH and ordered-probit models that is used to model the federal funds rate target, and the ACH-VAR. Section 4 describes the data for ACH, the ordered-probit model, and the ACH-VAR model respectively, while Section 5 contains our empirical results for the ACH and ordered-probit models. Section 5 also discusses the effect of an unanticipated increase in the federal funds rate target on stock returns in the ACH-VAR model. We conclude the paper in Section 6.

2. Review of the literature

There is a large and growing literature on the valuation of the credit risk transfer mechanism (CDS),[5] within which two distinct approaches dominate. One approach (Merton, 1974) explicitly relates a credit event to the value of the firm's assets. The firm is assumed to default on its obligations when the firm value falls below some threshold (Das, 1995; Pierides, 1997). These types of models are called structural models because the link to some underlying economic fundamentals is explicit. The second approach, which finds its origins in the modeling of the risk-free term structure is referred to as the reduced form approach because the relationship with underlying variables such as the firm value is not explicitly modeled (Dunbar, 2008; Duffie & Singleton, 1999; Houweling & Vorst, 2005; Hull & White, 2000; Jarrow, Lando, & Turnbull, 1997; Jarrow & Turnbull, 1995). Regardless of the approach used, the short-term rate is used to reflect the Federal Reserves' policy response, which is also a predictor of credit risk. In fact, a number of prior studies have indicated that an increase in the short-term risk-free rate could mean a contractionary monetary policy, which usually increases credit risk, while an expansionary monetary policy reduces credit risk.

Since capital markets are imperfect, information asymmetries are expected to lead to a wedge between the cost of internal and external funds. Jaffee and Russell (1976) and Stigitz and Weiss (1981) both find agency problems in an imperfect capital market makes external financing costly. Many in the academic and practitioner literature claim that credit default swaps lower the cost of borrowing because they provide new hedging opportunities and information on firms. Almeida and Campello (2007) and Hahn and Lee (2009) both provide evidence that a firm's ability to obtain external financing significantly affects corporate investment and ultimately firm value.

To isolate and estimate investor reactions to monetary policy changes, a preponderance of papers has employed the Vector Auto Regression (VAR) technique (Cook & Hahn, 1989). Thorbecke (1997) measures the effects of monetary policy changes in the federal funds rate on asset prices, and finds that an expansionary monetary policy has had a significant positive effect on asset returns. Ewing, Forbes, and Payne (2003) employ VAR to identify the different responses of five sector-specific S&P 500 stock returns to monetary shocks. Cassola and Morana (2004) use a cointegrated VAR to investigate the effects of monetary policy on the Euro stock market, and also find that a contractionary monetary shock has a positive effect on stock prices. In all these cases, the general consensus was that monetary policy shocks significantly influence the movements of asset prices.

However, a shortcoming with most of these earlier studies is the inability to decompose the Federal Reserve's policy change into components that could be used to isolate the effects of the Fed's actions. This is because ample evidence exists to suggest that financial markets do not respond to anticipated monetary policy changes (Andersen, Bollersev, Diebold, & Vega, 2007; Bernanke & Kuttner, 2005; Chulia, Martens, & Dijk, 2010; Guo, 2004; Gurkaynak, Sack, & Swanson, 2005; Wongswan, 2009). In fact, Bernanke and Kuttner (2005) addressed this issue with the use of an innovative policy decomposition procedure introduced in Kuttner (2001), which isolates the unexpected (surprise) policy change which might plausibly generate market (credit risk) responses. This does not mean that credit risk respond to monetary policy only when the Fed surprises the markets. Naturally, credit risk will also respond to expectations about future policy, which in turn may be driven by news about changing economic conditions.

Bernanke and Kuttner (2005) argued that estimating the response of financial markets to monetary policy actions is complicated by the fact that the market is unlikely to respond to policy actions that were already anticipated. Kuttner's (2001) event study methodology decomposes the surprise and expected change in the federal funds target rate and the corresponding Fed funds futures rate on the day of the FOMC announcements. Kuttner (2001) then used the surprise and anticipated decomposition to estimate the impact of the monetary policy event on asset prices. However a weakness in the event study methodology is the fact that it can only estimate the immediate effect of an unanticipated monetary policy on markets. Hence it is not

[5] A credit default swap is a contingent claim that allows the trading of default risk separately from other sources of uncertainty. This instrument is essentially an insurance contract against the default of an underlying entity.

able to estimate the dynamic response of the markets to an unanticipated monetary policy stimulus. Thus, this limitation of the event study methodology motivates us to investigate the dynamic effects of credit risk premia based on the unanticipated shock of the target change.

The traditional linear VAR measures of monetary policy fail to allow us to separately estimate the dynamic effects of unanticipated monetary shocks from anticipated shocks, since the usual VAR impulse–response analysis is estimated only by a monetary policy shock measured as the difference between the federal funds rate and the rate that one would have predicted. Such a monetary shock makes no distinction between a forecast error that arises because of an anticipated change in the target or a surprise change in the target. This weakness led Bernanke and Kuttner (2005) to adopt the Campbell–Ammer framework by relating the proxies for expectations to the surprise news regarding the path of monetary policy embodied in the surprises derived from Federal funds futures (proposed by Campbell, 1991; Campbell & Ammer, 1993), where the federal funds surprise was introduced in the VAR model as an exogenous variable. This approach effectively break the VAR's one-month-ahead forecast error into a component having to do with the surprise news regarding monetary policy, and the component incorporating a rational forecast made at time t.

Work by Hamilton and Jorda (2002) further decomposed the unanticipated policy change into one where there was an unexpected increase (decrease) in the funds rate target and another where there was an expectation of an increase (decrease) which failed to materialize. This characteristic is of particular importance to counterparty risk analysis. As we discussed earlier, central banks manage monetary policy so as to foster economic growth. They are less concerned with avoiding asset price bubbles. However the central bank may or may not react after such bubbles deflate, so as to minimize possible damages to the real economy. This is where both types of an unexpected change in the ACH framework become meaningful. Hence to better understand the short term dynamics of CDS on short term debt financing and firm value we turn to this autoregressive conditional hazard VAR (ACH-VAR) approach first proposed by Hamilton and Jorda to estimate monetary policy surprises; this model explicitly considers the discrete nature of the federal funds rate target, and is able to capture the serial dependence in such a series. The ACH-VAR approach decomposes the unexpected federal funds rate target changes into a forecast error that arises because the Fed unexpectedly raised the target and one in which a drop in the target was anticipated but failed to materialize. These two events in the ACH-VAR framework has been shown by Hamilton and Jorda (2002) and Tsai (2011) to contain completely different statistical information on the expected future federal funds rate, and therefore should have quite different responses from credit risk and subsequently short-term firm debt and firm value.

3. Methodology

3.1. The autoregressive conditional hazard model

The paper develops an autoregressive conditional hazard (ACH) and ordered probit framework as described in Hamilton and Jorda (2002) to predict the probability and magnitude of a change in the federal funds rate conditional on historical information. The ACH results are subsequently used jointly with the VAR model to determine impulse response dynamics. This ACH model which uses calendar time is a variant of Engle and Russell's (1998) autoregressive conditional duration (ACD) model which uses an event index to model the average length of time until the next change in the funds rate occur. This modification allows the new information since the previous target change to be most relevant in predicting the next target change. The ACH framework is particularly useful to model processes that change in discrete intervals. In our case, a given change in federal funds rate typically occurs in discrete time interval. Let $\varphi_{N(t)}$ be the expectation of the length of time denoted as $u_{N(t)}$ between the nth and the $(n+1)$th time the Fed changed the target rate conditional on $u_{N(t-1)}, u_{N(t-2)}$. Formally the ACH model can thus be represented as:

$$\varphi_{N(t)} = \sum_{j=1}^{m}\alpha_j u_{N(t)-j} + \sum_{j=1}^{r}\beta_j\,\varphi_{N(t)-j} \tag{1}$$

where the $\varphi_{N(t)}$ or average length of time is clearly a function of time and expression (1) will change only when there is a change in the target rate. Now if we define h_t as the conditional probability of a change in the target based on the information set available at time $t-1$ defined as $\aleph_{t-1}$. Then the expected length of time until the next change in the target will be:

$$\frac{1}{h_t} = \sum_{j=1}^{\infty} j(1-h_t)^{j-1}h_t \tag{2}$$

where the hazard rate implied by the ACH model in Eq. (1) would be then:

$$h_t = \frac{1}{\varphi_{N(t-1)}}. \tag{3}$$

Now if we denote z_{t-1} as a vector of exogenous variables known at time $t-1$, Eq. (3) can be generalized as:

$$h_t = \frac{1}{\varphi_{N(t-1)} + \delta Z'_{t-1}}. \tag{4}$$

The above generalized hazard function requires that h_t do not take values outside (0, 1) or $\varphi>1$ to ensure convergence in the numerical search. One way to satisfy this condition will be to use a smooth transition function, that is $\gamma[\tau]$, hence Eq. (4) is updated as:

$$h_t = \frac{1}{\gamma\left[\varphi_{N(t-1)} + \delta Z'_{t-1}\right]}. \tag{5}$$

This hazard rate can then be used to estimate the log likelihood function. If we assume $x_t=1$ for a change in target rate during the week t and zero otherwise, then the probability of observing x_t given $\aleph_{t-1}$ is:

$$g(x_t|\aleph_{t-1},\theta_1) = (h_t)^{x_t}(1-h_t)^{1-x_t} \tag{6}$$

where the conditional log-likelihood function given the parameter vector $\theta_1 = (\delta', \alpha', \beta')$ is:

$$L_1(\theta_1) = \sum_{t=1}^{T}[x_t\log(h_t) + (1-x_t)\log(1-x_t)]. \tag{7}$$

Here the MLE estimates obtained by maximizing Eq. (7) require the additional constraints $\alpha_j\geq 0, \beta_j\geq 0$ and $0\leq\beta_1+\beta_2+\ldots+\beta_r\leq 1$.

3.2. The ordered probit model

An ordered probit model is used to analyze how much the target will change if the Fed decides to change the target. If y_t is the size of the change in fed rate, then there exists a latent variable y_t^* such that

$$y_t^* = w_{t-1}\pi' + \epsilon_t. \tag{8}$$

Where $\boldsymbol{w}_{t-1}$ is a vector of exogenous variables observed at $t-1$ with residuals that are i.i.d. N (0, 1). Now assume the fed changes its target rate by discrete intervals of $s_1, s_2, s_3 \ldots\ldots s_k$ (where $s_1<s_2<s_3<\ldots\ldots<s_k$). Conditional on a change in the funds rate, it is hypothesized that the

observed discrete target change, y_t, is related to latent continuous variable y_t^* in the following way:

$$y_t = \begin{cases} s_1 & if\ \ y_t^* \in (-\infty, c_1] \\ s_2 & if\ \ y_t^* \in (c_1, c_2] \\ \quad . \\ \quad . \\ \quad . \\ s_k & if\ \ y_t^* \in (c_{k-1}, \infty) \end{cases} \tag{9}$$

where $c_1 < c_2 < c_3 \ldots\ldots\ldots < c_k$ and where the probability that the target will change by s_j is given by

$$\Pr\left(y_t = s_j | w_{t-1}, x_t = 1\right) = \Pr\left(c_{t-1} < w'_{t-1}\pi + \varepsilon_t \le c_t\right) \tag{10}$$

given $j=1,2, \ldots, k$, with $c_0 = -\infty$ and $c_t = \infty$. The cumulative density function is

$$\Pr\left(y_t = s_j | \mathbf{w}_{t-1}, x_t = 1\right) = \begin{cases} \Phi\left(c_1 - \mathbf{w}'_{t-1}\pi\right) & \text{for } j = 1 \\ \Phi\left(c_j - \mathbf{w}'_{t-1}\pi\right) - \Phi\left(c_{j-1} - \mathbf{w}'_{t-1}\pi\right) & \text{for } j = 2, 3, \ldots\ldots k-1 \\ 1 - \Phi\left(c_{k-1} - \mathbf{w}'_{t-1}\pi\right) & \text{for } j = k \end{cases} \tag{11}$$

where $\Phi(z)$ is the CDF of a standard normal distribution. Let $l(y_t|w_{t-1},\theta_2)$ be the log of probability of observing y_t conditional on $\boldsymbol{w}_{t-1}$ and $x_t = 1$, then,

$$l(y_t | w_{t-1}, \theta_2) = \begin{cases} \log\left[\Phi\left(c_1 - w'_{t-1}\pi\right)\right] & \text{if } y_t = s_1 \\ \log\left[\Phi\left(c_j - \mathbf{w}'_{t-1}\pi\right) - \Phi\left(c_{j-1} - \mathbf{w}'_{t-1}\pi\right)\right] & \text{if } y_t = s_2, s_3 \ldots\ldots s_{k-1} \\ \log\left[1 - \Phi\left(c_{k-1} - w'_{t-1}\pi\right)\ \right] & \text{if } y_t = s_k \end{cases} \tag{12}$$

where the parameter vector $\theta_2 = \left(\acute{\pi},\ c_1, c_2, \ldots' \ldots . c_{k-1}\right)$ and the conditional likelihood function is:

$$L_2(\theta_2) = \textstyle\sum_{t=1}^{T} x_t l(y_t | w_{t-1}, \theta_2). \tag{13}$$

The MLE estimates from Eq. (13) is obtained under the condition that $c_j > c_{j-1}$ for $j=1, 2, \ldots, k-1$.

3.3. The ACH-VAR model

The Vector Autoregressive Model (VAR) model is used to evaluate the impact of a change in federal funds rate on counterparty credit risk. This paper follows Thorbecke's (1997) methodology with a modification, allowing for two different surprises in the federal funds rate target. Assume Y_t a vector of the data in month t consists of the growth rate of employment (*EM*), the inflation rate (*P*), market liquidity (*LIQ*), the federal funds rate (*f*), the log of broad money (*M2*), the log of investment grade credit risk (*CDXi*) and high yield grade counterparty credit risk (*CDXh*). We also denote $Y_{1,t} = (EM_t, P_t, LIQ_t)$ as those variables that come before the federal funds rate f_t and $Y_{2,t} = (M2_t, CDXi_t, CDXh_t)$ are variables that come after. In VAR, we estimate the effect of monetary policy shock based on a Cholesky decomposition of the residual variance–covariance matrix:

$$\frac{\partial E\left(Y_{t+s} | f_t, Y_{1,t}, Y_{t-1}, Y_{t-2}, \ldots\right)}{\partial f_t}. \tag{14}$$

Eq. (14) also measures the effect of an orthogonalized shock of f_t on Y_{t+1}, where the orthogonalized shock is defined as $u_t^f = f_t - E(f_t | Y_{(1,t)}, Y_{(t-1)}, Y_{(t-2)}, \ldots)$.. Equivalently we can also write:

$$u_t^f = f_t - f_{t-1} - \left[E\left(f_t | Y_{1,t}, Y_{t-1}, Y_{t-2}, \ldots\right) - f_{t-1}\right]. \tag{15}$$

A positive value of u_t^f can come from two sources: *i)* the Fed could have change the target ($f_t - f_{t-1} > 0$) when no change was expected $[E(f_t|Y_{1,t}, Y_{t-1}, Y_{t-2}, \ldots) - f_{t-1} = 0]$; *ii)* the Fed may not have changed the target ($f_t - f_{t-1} = 0$) even though a drop of $[E(f_t|Y_{1,t}, Y_{t-1}, Y_{t-2}, \ldots) - f_{t-1} < 0]$ was expected. In the usual linear VAR setup these two events would likely produce the same result. But in the case of the *ACH*, these two events are not forced to have the same effects.[6] Here we find that a major innovation of this methodology is the separation of different effects of the federal funds rate on counterparty credit risk.

A perennial issue with the VAR impulse framework discussed in Tsai (2011) surrounds the ordering of the variables. To address the "ordering" issue related with estimation of the impulse response function, we turn to existing literature mainly Bernanke and Blinder (1992), Christiano, Eichenbaum, and Evans (1996), Thorbecke (1997), and Croushore and Evans (2006). The ordering of variables in our VAR specification is the growth rate of employment (*EM*), the inflation rate (*P*), market liquidity (*LIQ*), the federal funds rate (*f*), the log of broad money (*M2*) and specific to this study, the log of investment grade credit risk (*CDXi*) and high yield grade counterparty credit risk (*CDXh*).[7] Consistent with the earlier literature, it is assumed that Fed responds to the growth of employment, the inflation rate, and the liquidity conditions in financial markets.

4. Data source

4.1. Data for ACH and ordered probit-models

Our paper investigates how both anticipated and unanticipated changes in the Fed target affected credit risk premia and debt financing. The study uses data covering the period March 2003 to September 2008. A complete set of CDX data is available only from March 2003 which sets up the beginning of the sample period. In addition, due to the 2007/2008 financial crisis, the Federal Open Market Committee (Henceforth FOMC) on October 8th 2008 decided to institute a target range for the federal funds rate of 50 to 150 basis points. Such a low target range is not appropriate for the estimation of the ACH model that's why we limit our estimation to September 2008. The raw data in our study also includes the dates and sizes of the federal funds target changes for 2003–2008 as reported by the Federal Reserve Banks of New York and St. Louis.

Appendix B includes the dates and size of federal funds target changes and Appendix C reports meeting dates of FOMC. The FOMC directives almost always implement the target change immediately, and target changes typically occur in discrete increments of 25 basis points, with the exception of 2008 when the Feds took the unusual step to make a few isolated 50 and 75 basis points cuts.

To be able to predict the timing of changes in the target (vector z_{t-1} in Eq. (4)) we follow the earlier work by Hamilton and Jorda. Despite the extensive literature relating Fed policy to a number of macroeconomic variables, Hamilton and Jorda found that for the specific task of predicting whether the Fed is going to change the target during any given week, institutional factors and simple time series appear to be far more useful. Hence, the variables considered to be included in the vector z_{t-1} in Eq. (4) for predicting the timing of changes in the target can be divided into 3 categories: (i) macroeconomic variables

[6] A detailed description on ACH-VAR model can be obtained from Hamilton and Jorda (2002).

[7] Data on credit risk premia is obtained from Markit Financial Information Services.

that may influence the Fed's policy objectives within the context of the Taylor rule; (ii) monetary and financial aggregate variables, for example the absolute value of the spread between the effective federal funds rate and the six-month Treasury bill rate ($|SP6_t|$); (iii) and variables consisting of the dates of the FOMC meetings, the size of the previous target change and the number of weeks since the previous change. See Appendix D for a list of the data variables and sources.

4.2. Data for the ACH-VAR model

One of the main inputs of our VAR specification is the credit risk premia. The CDX North American Investment Grade index (**CDX.NA.IG**) is a US Benchmark for tradable 5 year and 10 year index products. The index consists of 125 North American investment-grade companies and was first issued in 2003. On the other hand, the CDX North American High Yield Index (**CDX.NA.HY**) is comprised of 100 North American High Yield grade companies. Data on the CDX was obtained from Markit Financial Information Services. Data on market liquidity, Inflation, Employment, M2, the Fed funds target, the Effective Funds rate, the 6 month Treasury bill rate (TB6) was obtained from the Federal Reserve Bank of St Louis.

5. Empirical results of the ACH, ordered-probit and ACH-VAR models

5.1. Empirical results for the ACH model

Table 1 presents the maximum likelihood estimates for the model covering the sample period March 2003 to September 2008 for the ACH (0, 1) model. We achieve convergence by setting the coefficient on $\varphi_{N(t-1)}$ to zero and adding the $FOMC_t$ and $|SP6_{t-1}|$.

The results in Table 1 indicate that both $FOMC_t$ and $|SP6_{t-1}|$ are significant in predicting the next target change. Since 1994, the Fed has tended to implement target changes during the week of the FOMC meeting rather than the week after, and consistent with Tsai (2011) we find $FOMC_t$ is significant in predicting the likelihood of the next target change during the period 2003–2008. The average absolute spread $SP6_{t-1}$ is another important variable that influences the change of target. If the six-month Treasury bill rate is far away from the federal funds rate, then we can expect the Fed to change the target. The average absolute spread over this period is 0.311, and the mean duration $\bar{u}$ is 14.47. To understand the effect of the FOMC meeting we first estimate the hazard rate of a target change for our sample period:

$$\frac{1}{61.268+0.077\times 14.47+3.204\times 0.311}=\frac{1}{63.379}=0.0158.$$

There is only a 1.58% chance that Fed will change the target next week if no FOMC meeting is scheduled. In contrast, due to a statistically significant and large negative coefficient on $FOMC_t$ the probability of a target change increases to

$$\frac{1}{63.379-61.921}=0.686$$

That is, if there is an FOMC meeting in week t, a change in the target is more likely to happen.

Table 1
Parameter estimates for the ACH (0, 1) model for 2003–2008. ACH (0, 1) model

$$h_t=\frac{\varphi_{N(t)}=\alpha\, u_{N(t)-1}\quad 1}{\gamma\left[\varphi_{N(t-1)}+\delta_1 constant+\delta_2 FOMC_t+\delta_3|SP6_{t-1}|\right]}.$$

Parameters	Variables	Estimates	Standard error
α	$u_{N(t)-1}$	0.77**	0.047
δ_1	*Constant*	61.268**	31.839
δ_2	$FOMC_t$	−61.921**	31.848
δ_3	$SP6_{t-1}$	3.204**	2.015
Log likelihood	−49.203		

The variable $FOMC_t$ is a dummy variable that takes the value of one if in week 't' there is an FOMC meeting and zero otherwise. $SP6_{t-1}$ is the absolute value of the spread between the 6-month Treasury bill rate (TB6) and the federal funds rate. The federal funds rate used is an average of the daily effective federal funds rate for the week ending on Wednesday. The TB6 is an average of the 6-month Treasury rate on the secondary market for the week ending Wednesday. To ensure the convergence the model uses a smooth transition function $\gamma[\tau]$. In addition, $\varphi_{N(t)}$ denotes the expectation of the length of time denoted as $u_{N(t)}$ between the nth and the (n+1)th time the Fed changed the target rate and h_t represents the conditional probability of a change in the target.

Table 2
Parameter estimates for the ordered probit model for 2003–2008. ACH-ordered probit model

$$\Pr\left(y_t=s_j|w_{t-1},x_t=1\right)=\Pr\left(c_{t-1}<\pi_1 y_{t,N(t)-1}+\pi_2 SP6_{t-1}+\varepsilon_t\le c_t\right).$$

Parameters	Variables	Estimates	Standard error
π_1	$y_{t,N(t)-1}$	5.912***	1.085
π_2	$SP6_{t-1}$	2.376***	0.583
c_1		−2.979***	0.55
c_2		−2.003***	0.389
c_3		1.263***	0.24
c_4		3.559***	0.552
–Log likelihood	−34.163		

$y_{t,N(t)-1}$which represents the magnitude of the last federal funds target change as of the date $t-1$. $SP6_{t-1}$ is the value of the spread between the 6-month Treasury bill rate and the federal Funds rate. The federal funds rate used is an average of the daily effective federal funds rate for the week ending on Wednesday. ***, **, and * are the levels of significance of the coefficients at the 1%, 5% and 10% levels of significance.

5.2. Empirical results for the ordered-probit model

The empirical estimates of the ordered probit model are presented in Table 2.[8] The ordered probit model estimates the size of federal target changes when they occur.

From Appendix B, we can see that since January 1991 the changes in targets have been in increments of 25.0 basis points. We follow Hamilton and Jorda's (2002) empirical estimates of the ordered-probit model for the sizes of Fed target changes when they occur. We consolidate the data into 5 possible categories for changes in the target (along with the three changes of 75 basis points in 2008) as follows. With y_t^* denoting the actual change in the target value according to Appendix B, the data used in the analysis is defined as y_t[9]

$$y_t=\begin{cases}-0.5 & if -\infty\le y_t^*\le -0.4375\\ -0.25 & if -0.4375\le y_t^*\le -0.125\\ 0.00 & if -0.125\le y_t^*\le 0.125\\ 0.25 & if\ 0.125\le y_t^*\le 0.4375\\ 0.50 & if\ 0.4375\le y_t^*\le \infty.\end{cases}$$

Table 2 reports the empirical estimates of threshold parameters and exogenous variables. The coefficients of lagged target change ($y_{t,N(t-1)}$) and the difference between the 6-month Treasure bill and

[8] Several of the ACH explanatory variables were found to be insignificant in explaining the magnitude of the target change and were therefore dropped from the analysis.
[9] Where −0.4375, −0.125, 0.125 and 0.4375 are all multiples of 25 basis points.

federal funds target rate ($SP6_{t-1}$) are statistically significant in explaining the sizes of the target changes. A significantly positive coefficient on $y_{t,N(t-1)}$ implies if the previous change raised the target rate then there is a higher probability that Fed will increase the funds rate this week. Further, a positive and significant coefficient on $SP6_{t-1}$ implies that if the six-month Treasury bill rate is above the federal funds rate, then we can expect the Fed to raise the target and vice-versa. In addition, the estimated cutoff points are also found to be statistically significant.

5.3. Discussion of the ACH-VAR empirical results

We estimated both (a) linear and (b) ACH-VAR models which include our macro variables plus the variables measuring credit risk growth for each debt category discussed earlier. Figs. 1 and 2 present the results of the impulse–response functions for the growth of employment, the inflation rate, liquidity, the federal funds rate, broad money (M2) and credit risk premia. Fig. 1 (Fig. 2) presents the results of a positive (negative) policy shock to the federal funds rate target and the corresponding responses of the macro variables and credit risk premia.

As discussed in Section 3, the ACH-VAR model decomposes the effects of an unanticipated monetary policy shock on credit risk into two components. The dashed line in Fig. 1 (Fig. 2) records the average values over all the dates (τ) in our sample and answers the question as to what happens when the Federal Reserve deliberately and unexpectedly increases (decreases) its target for the federal funds rate (see Eq. (E.1) in Appendix E). The dotted line in Fig. 1 (Fig. 2) answers the question as to what happens if investors predict that the Fed will decrease (increase) its target for the federal funds rate, but in fact the target remains unchanged. The results are completely different and suggest that the Fed's decision not to increase (lower) the target typically has few lasting consequences.

In Fig. 1, the dashed line suggests that when the Federal Reserve deliberately but unexpectedly raises its target for the effective federal funds rate, the effect of this surprise monetary policy shock results in an initial decline in the growth of the credit risk premia for both the investment grade (−0.4%) and high yield debt (−0.8%). Consistent with the established literature, the results also show that the growth in money supply decreases by 0.2% and liquidity growth picks up over the first month as money supply growth picks up with the decay of the initial policy shock. In fact, as the shock to the federal funds rate target decays and normalizes after the first month, the growth in credit risk premia of high risk debt which overshoots in the first month declines, while stabilizing for investment grade debt over the next 8 months. As our results indicate, if the Fed unexpectedly raises the target, it may cause the average investor to revise his/her forecast to reveal a possible substantial increase in the federal funds rate in the future. Consequently, this unexpected funds rate increase leads to an initial

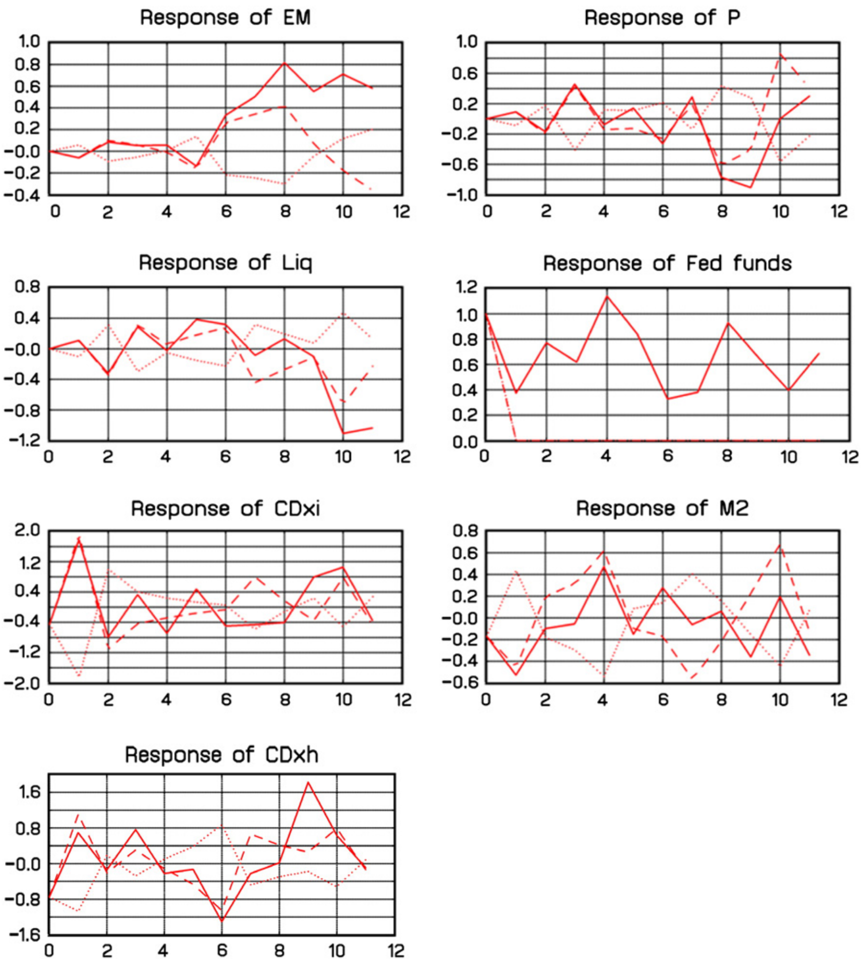


Fig. 1. The effect of y_{t+j} for $j=0,1,2,\ldots,11$ of different definitions of an innovation in the Fed funds rate. Impulse responses of a 100-basis-point increase in f_τ on the CDX.NA.IG and the CDX.NA.HY credit risk premium growth under different definitions of an innovation. The unit for each variable on the vertical axis is percent. The horizontal axis is the lag horizon in months. Solid line: innovation refers to a forecast error in the VAR (Traditional VAR). Dashed line: innovation means that the Fed deliberately raised the federal funds target. Dotted line: innovation refers to the case where the Fed was expected to lower the target fed funds rate but this never materialized.

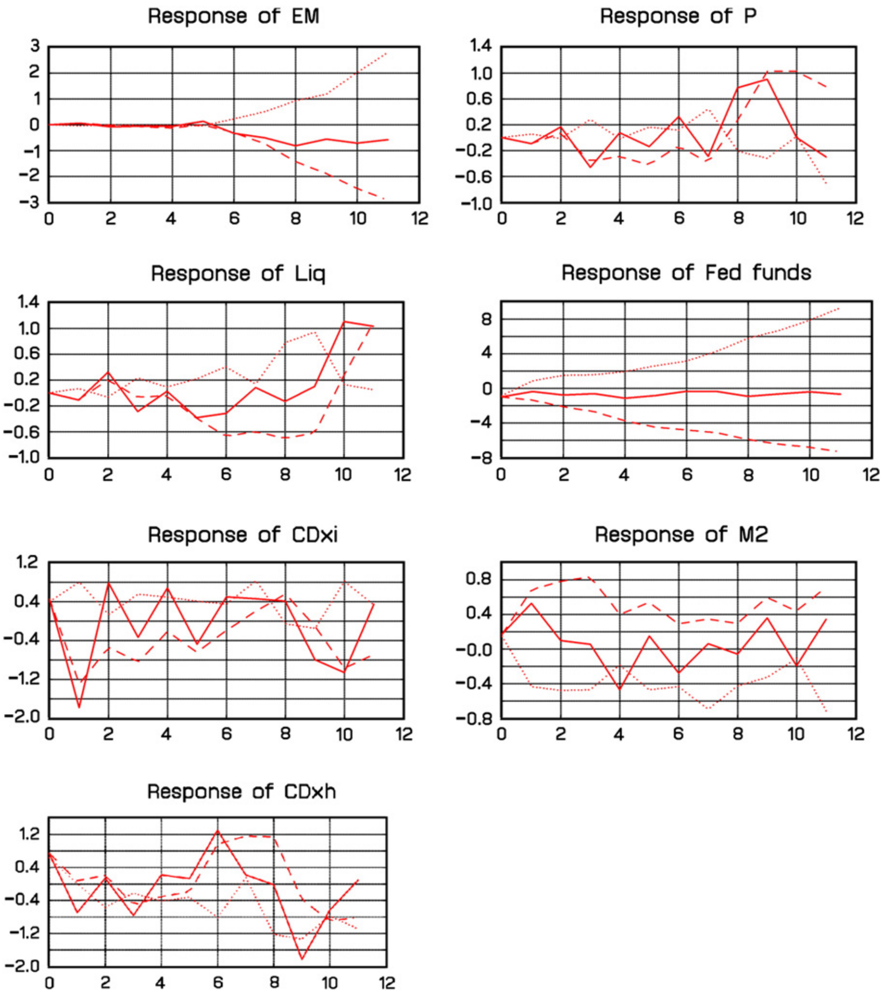


Fig. 2. The effect of y_{t+j} for $j=0,1,2,\ldots,11$ of different definitions of an innovation in the Fed funds rate. Impulse responses of a 100-basis-point decrease in f_T on the CDX.NA.IG and the CDX.NA.HY credit risk premium growth under different definitions of an innovation. The unit for each variable on the vertical axis is percent. The horizontal axis is the lag horizon in months. Solid line: innovation refers to a forecast error in the VAR (Traditional VAR). Dashed line: innovation means that the Fed decreased the federal funds target. Dotted line: innovation refers to the case where the Fed was expected to increase the target fed funds rate but this never materialized.

decline in credit risk premia because of a rise in the future expected interest rates used to discount firm value.

The dotted line in Fig. 1 denotes the response of investors predicting a decline in the federal funds rate target that fails to materialize. These results are different from those earlier findings in which the Federal Reserve deliberately but unexpectedly changes its target for the federal funds rate. This shock leads to less volatility in the growth of employment, inflation, the federal funds rate and market liquidity. It indicates, as is well known, the Fed's deliberate decision not to change the target has few lasting effects on these macroeconomic variables compared to the Federal Reserve deliberate decision to change its target. In addition, the dotted line in the second panel on the right of Fig. 1 shows that this negative monetary policy shock causes the federal funds rate to decline initially (−1.5% for investment grade and −0.9% for high yield bonds) but normalizing around the target rate by the second month.

In the case of the traditional linear VAR impulse–response function (solid line), which describes the effects of a 100-basis-point increase in f_T (the effective federal funds rate) on each of the other variables, the second-left graph of Fig. 1 shows that a monetary policy shock initially has no effect on market liquidity which subsequently rises 0.1% as the initial impulse declines, reaching a maximum after the fifth month. Similarly to the findings of Hamilton and Jorda (2002) the growth in M2 initially declines (−0.2%) but recovers and overshoots (0.4%) within the next 4 months.

In Fig. 2 we examine the effects of an unexpected 100 basis point cut in the federal funds rate target on the credit risk transfer mechanism. The results indicate that when the Federal Reserve unexpectedly cuts its target for the effective federal funds rate, the effect of this surprise monetary policy shock (the dashed line) is an initial jump in the growth of the credit risk premia for both investment grade (0.4%) and high yield (1.0%) debt. Interestingly, the growth of high yield credit risk premia declines sharply during the first month (−0.6%) and stays relatively low over the next 5 months. Similarly, the growth in investment grade debt falls by 1.2% during the first month, after which it gradually rises to 0.4% in the 8th month. The results also show that the growth in money supply jumps by 0.4% and liquidity growth picking up by the second month as the federal funds rate stabilizes.

These results suggest that the Fed's unexpected monetary policy expansion is initially helpful to both types of debt in particular the highly risky debt. In fact, the results also indicate that if the Fed unexpectedly lowers the target rate, this may lead the average investor to revise his forecast to reveal a substantial decrease in the future federal funds rate, leading to a decline in the future expected interest rates used to discount firm value, which may be one reason why an unexpected negative shock leads to an initial increase in credit risk premia. On the other hand, the dotted line suggests that if it is expected that the Fed will lower the target but it does not, this new information might cause the future federal funds rate to initially discount firm debt at the same rate as the prior innovation, but typically having few lasting consequences on short-term firm debt while continuing to discount investment grade debt far less than high yield debt.

In summary our results presented in Figs. 1 and 2 indicate that policy responses lead to market responses which may have significant implications for short-term debt financing. In fact an unexpected increases the target rate results in a surprise monetary shock leading to an initial decline in the credit risk premia on bonds, which is more profound on high risk bonds. Conversely, a decline in the federal funds rate target results in an initial increase in credit risk which declines over the first month and appears less volatile for high risk relative to investment grade debt over the next 5 months.

In addition, it is well known that if the firm's credit riskiness suddenly increases (as seen in the jump in the growth in CDS prices), then its cost of capital and its required rate of return will also increase. A further important implication of these results is the short term response by firms to the unexpected change in the Fed's policy which suggests that a change in policy has positive short-term effects on corporate debt contrary to the findings in Ashcraft and Santos (2007).

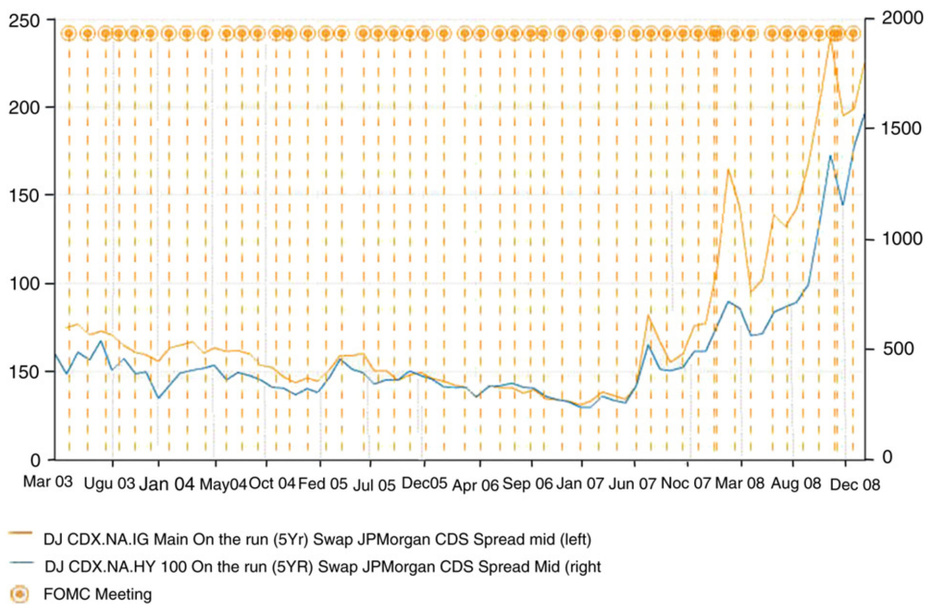
6. Conclusion

This paper investigates how an unexpected policy shock in the federal funds rate target influences the growth in credit risk and evaluates the implications for short-term debt financing in which counterparties may default. We use an ACH-VAR model that allows us to distinguish between two types of innovations; (i) the effects of an unanticipated monetary policy shock arising from a surprise change in the funds rate target, and (ii) an expected target change in the federal funds rate that failed to materialize.

The findings answer a longstanding question sought by researchers on the effect of policy makers' announcements on firm debt. The results from the ACH-VAR model indicate that an unexpected policy shock leads to short-term market responses that appear positive for firm debt financing, particularly for firms of poor credit quality, which is initially very responsive. We also find that the growth in counterparty risk appears less responsive to anticipated responses in the Fed funds rate that fail to materialize than an unanticipated increase in the federal funds rate. For instance, during contractionary periods counterparty risk responds more favorably when the Federal Reserve unexpectedly lowers its target than when they do nothing when investors were expecting some action on the Fed funds rate.

Interestingly, we find that both sets of innovations generated by the ACH-VAR model contain completely different information on the expected future federal funds rate, and thus have quite different impacts on credit risk. The results clearly show the Federal Reserve's influence of firm debt financing through the credit channel for both an expansionary and contractionary monetary policies. It also demonstrates that the Central bank has managed to stem the systematic counterparty credit risk fears in financial markets through this channel. Finally, the results appear to validate the Feds unexpected intervention in financial markets to help make liquidity more readily available to firms through the credit channel.

Appendix A



Appendix A. Graphical illustration of CDS response to Fed policy from 2003–2008. Appendix A presents the credit risk spreads of investment grade debt, high yield debt and their reaction to possible Fed policy responses. The chart plots the time series of the "on-the-run" spreads of the CDX.NA.IG (investment grade) and the CDX.NA.HY (high yield) indexes. The behavior of the index spreads over the sample period can be divided into two phases. In the phase prior to the credit crisis, the spreads were relatively low in magnitude, while in the second phase starting about June 2007 the spreads become highly volatile. The indexes however retreat ahead of the September 18th 2007 FOMC meeting. On December 31st 2007 both indexes jumped sharply, only to retreat ahead of the March 18th 2008 meeting. Source: JPMorgan.

Appendix B. Sizes of FOMC federal funds target changes 1984–2008

Date of change	Target value	Target change	Duration in days	Day of the week
1-Mar-84	9.5	na		Thursday
15-Mar-84	9.875	0.375	14	Thursday
22-Mar-84	10	0.125	7	Thursday
29-Mar-84	10.25	0.25	7	Thursday
5-Apr-84	10.5	0.25	7	Thursday
14-Jan-84	10.625	0.125	70	Thursday
21-Jun-84	11	0.375	7	Thursday
19-Jul-84	11.25	0.25	28	Thursday
9-Aug-84	11.5625	0.3125	21	Thursday
30-Aug-84	11.4375	−0.125	21	Thursday
20-Sep-84	11.25	−0.1875	21	Thursday
27-Sep-84	11	−0.25	7	Thursday
4-Oct-84	10.5625	−0.4375	7	Thursday
11-Oct-84	10.5	−0.0625	7	Thursday
18-Oct-84	10	−0.5	7	Thursday
8-Nov-84	9.5	−0.5	21	Thursday
23-Nov-84	9	−0.5	15	Friday
6-Dec-84	8.75	−0.25	13	Thursday
20-Dec-84	8.5	−0.25	14	Thursday
27-Dec-84	8.125	−0.375	7	Thursday
24-Jan-85	8.25	0.125	28	Thursday
14-Feb-85	8.375	0.125	21	Thursday
21-Feb-85	8.5	0.125	7	Thursday
21-Mar-85	8.625	0.125	28	Thursday
28-Mar-85	8.5	−0.125	7	Thursday
18-Apr-85	8.375	−0.125	21	Thursday
25-Apr-85	8.25	−0.125	7	Thursday
16-May-85	8.125	−0.125	21	Thursday
20-May-85	7.75	−0.375	4	Monday
11-Jul-85	7.6875	1.0625	52	Thursday
25-Jul-85	7.75	0.625	14	Thursday
22-Aug-85	7.8125	0.625	28	Thursday
29-Aug-85	7.875	0.625	7	Thursday
6-Sep-85	8	0.125	8	Friday
18-Dec-85	7.75	−0.25	103	Wednesday
1-Mar-86	7.25	−0.5	79	Friday
10-Apr-86	7.125	1.125	34	Thursday
17-Apr-86	7	−0.125	7	Thursday
24-Apr-86	6.75	−0.25	7	Thursday
11-Jul-86	6.375	−0.5	36	Friday
14-Aug-86	6.3125	−0.0625	34	Thursday
21-Aug-86	5.875	−0.4375	7	Thursday
4-Dec-86	6	0.125	105	Thursday
30-Apr-87	6.5	0.5	147	Thursday
21-May-87	6.75	0.25	147	Thursday
2-Jul-87	6.625	−0.125	21	Thursday
27-Aug-87	6.75	0.125	56	Thursday
3-Sep-87	6.875	0.125	7	Thursday
4-Sep-87	7.25	0.375	1	Friday
24-Sep-87	7.3125	0.0625	20	Thursday
21-Oct-87	7.1.25	−0.1875	28	Thursday
28-Oct-87	7	−0.125	6	Wednesday
4-Nov-87	6.8125	−0.1875	7	Wednesday
28-Jan-88	6.625	−0.1875	85	Thursday
11-Feb-88	6.5	−0.125	14	Thursday
30-Mar-88	6.75	0.25	48	Wednesday
9-May-88	7	0.25	40	Monday
25-May-88	7.25	0.25	16	Wednesday
22-Jun-88	7.5	0.25	28	Wednesday
19-Jul-88	7.6875	0.1875	27	Tuesday
8-Aug-88	7.75	0.0625	20	Monday
9-Aug-88	8.125	0.375	1	Tuesday
20-Oct-88	8.25	0.125	72	Thursday
17-Nov-88	8.3125	0.0625	28	Thursday
22-Nov-88	8.375	0.0625	5	Thursday
15-Dec-88	8.6875	0.3125	23	Thursday
29-Dec-88	8.75	0.0625	14	Thursday
5-Jan-89	9	0.25	7	Thursday
9-Feb-89	9.0625	0.0625	35	Thursday
14-Feb-89	9.3125	0.25	5	Tuesday
23-Feb-89	9.5625	0.25	9	Thursday
24-Feb-89	9.75	0.1875	1	Friday
4-May-89	9.8125	0.0625	69	Thursday
6-Jun-89	9.5625	−0.25	33	Tuesday

Appendix B (*continued*)

Date of change	Target value	Target change	Duration in days	Day of the week
7-Ju-89	9.3125	−0.25	31	Friday
27-Jul-89	9.0625	−0.25	20	Thursday
10-Aug-89	9	−0.0625	14	Thursday
18-Oct-89	8.75	−0.25	69	Wednesday
22-May-86	6.8125	0.0625	28	Thursday
5-Jun-86	6.875	0.0625	14	Thursday
13-Jul-90	8	−0.25	205	Friday
29-Oct-90	7.75	−0.25	108	Monday
14-Nov-90	7.5	−0.25	16	Wednesday
7-Dec-90	7.25	−0.25	23	Friday
19-Dec-90	7	−0.25	12	Wednesday
9-Jan-91	6.75	−0.25	21	Wednesday
1-Feb-91	6.25	−0.25	23	Friday
8-Mar-91	6	−0.25	35	Friday
30-Apr-91	5.75	−0.25	53	Tuesday
6-Aug-91	5.5	−0.25	98	Tuesday
13-Sep-91	5.25	−0.25	38	Friday
31-Oct-91	5	−0.25	48	Thursday
6-Nov-91	4.75	−0.25	6	Wednesday
6-Dec-91	4.5	−0.25	30	Friday
20-Dec-91	4	−0.5	14	Friday
9-Apr-92	3.75	−0.25	111	Thursday
2-Jul-92	3.25	−0.5	84	Thursday
4-Sep-92	3	−0.25	64	Friday
4-Feb-94	3.25	0.25	518	Friday
22-Mar-94	3.5	0.25	46	Tuesday
18-Apr-94	3.75	0.25	27	Monday
17-May-94	4.25	0.5	29	Tuesday
16-Aug-94	4.75	0.5	91	Tuesday
15-Nov-94	5.5	0.75	91	Tuesday
1-Feb-95	6	0.5	78	Wednesday
6-Jul-95	5.75	−0.25	155	Thursday
19-Dec-95	5.5	−0.25	166	Tuesday
31-Jan-96	5.25	−0.25	43	Wednesday
25-Mar-97	5.5	−0.25	419	Tuesday
29-Sep-98	5.25	−0.25	553	Tuesday
15-Oct-98	5	−0.25	16	Thursday
17-Nov-98	4.75	−0.25	33	Tuesday
30-Jun-99	5	0.25	225	Tuesday
24-Aug-99	5.25	0.25	55	Tuesday
16-Nov-99	5.5	0.25	84	Tuesday
2-Feb-00	5.75	0.25	78	Wednesday
21-Mar-00	6	0.25	48	Tuesday
16-May-00	6.5	0.5	56	Tuesday
3-Jan-01	6	−0.5	232	Wednesday
6-Nov-89	8.5	−0.25	19	Monday
20-Dec-89	8.25	−0.25	44	Wednesday
31-Jan-01	5.5	−0.25	28	Wednesday
20-Mar-01	5	−0.5	48	Tuesday
18-Apr-01	4.5	−0.5	29	Wednesday
15-May-01	5	−0.5	27	Tuesday
27-Jun-01	3.75	−0.25	43	Wednesday
21-Aug-01	3.5	−0.25	55	Tuesday
17-Sep-01	3	−0.5	27	Monday
2-Oct-01	2.5	−0.5	15	Tuesday
6-Nov-01	5	−0.5	35	Tuesday
11-Dec-01	1.75	−0.25	35	Tuesday
6-Nov-02	1.25	−0.25	330	Wednesday
26-Jun-03	1	0.25	232	Thursday
30-Jun-04	1.25	0.25	370	Wednesday
10-Aug-04	1.5	0.25	41	Tuesday
21-Sep-04	1.75	0.25	42	Tuesday
10-Nov-04	2	0.25	50	Wednesday
14-Dec-04	2.25	0.25	34	Thursday
2-Feb-05	2.5	0.25	50	Wednesday
22-Mar-05	2.75	0.25	48	Thursday
3-May-05	3	0.25	42	Tuesday
30-Jun-05	1.25	0.25	58	Tuesday
9-Aug-05	3.5	0.25	40	Tuesday
20-Sep-05	3.75	0.25	42	Tuesday
1-Nov-05	4	0.25	42	Tuesday
13-Dec-05	4.25	0.25	42	Tuesday
31-Jan-06	4.5	0.25	49	Tuesday
28-Mar-06	4.75	0.25	56	Tuesday
10-May-06	5	0.25	43	Wednesday
29-Jun-06	5.25	0.25	50	Thursday

(continued on next page)

Appendix B (*continued*)

Date of change	Target value	Target change	Duration in days	Day of the week
18-Sep-07	4.75	−0.5	446	Tuesday
31-Oct-07	4.5	−0.25	43	Wednesday
11-Dec-07	4.25	−0.25	41	Tuesday
22-Jan-08	3.5	−0.75	42	Tuesday
30-Jan-08	3	−0.5	8	Wednesday
18-May-08	2.25	−0.75	48	Tuesday
30-Apr-08	2	−0.25	43	Wednesday
8-Oct-08	1.5	−0.5	160	Friday
29-Oct-08	1	−0.5	21	Friday

Source: Federal Reserve Bank of St. Louis.

Appendix C. Dates of FOMC federal funds target changes—1984–2008

Year	FOMC dates
1984	January 30–31
	March 26–27
	May 21–22
	July 16–17
	August 21
	October 2nd
	November 7th
	December 17–18
1985	February 12–13
	March 26th
	May 21st
	July 9–10
	August 20th
	October 1st
	November 4–5
	December 16–17
1986	February 11–12
	April 1st
	May 20th
	July 8–9
	August 19th
	September 23rd
	November 5th
	December 15–16
1987	February 10–11
	March 31st
	May 19th
	July 7th
	August 18th
	September 22nd
	November 3rd
	December 15–16
1988	February 9–10
	March 29th
	May 17th
	June 29–30
	August 16th
	September 30th
	November 1st
	December 13–14
1989	February 6–7
	March 28th
	May 16th
	July 5–6
	August 22nd
	October 3rd
	November 14th
	December 18–19
1990	February 6–7
	March 27th
	May 15th
	July 2–3

Appendix C (*continued*)

Year	FOMC dates
	August 21st
	October 2nd
	November 13th
	December 17–18
1991	February 5–6
	March 26th
	May 14th
	July 2–3
	August 20th
	October 1st
	November 5th
	December 17–18
1992	February 4–5
	March 31st
	May 19th
	June 30–31
	August 18th
	October 16th
	November 17th
	December 22nd
1993	February 2–3
	March 23rd
	May 18th
	July 6–7
	August 17th
	September 21st
	November 16th
	December 21st
1994	February 3–4
	March 22nd
	May 17th
	July 5–6
	August 16th
	September 27th
	November 15th
	December 20th
1995	January 31–1
	March 28th
	May 23rd
	July 5–6
	August 22nd
	September 26th
	November 15th
	December 19th
1996	January 30–31
	March 26th
	May 21st
	July 2–3
	August 20th
	September 24th
	November 13th
	December 17th
1997	February 4–5
	March 25th
	May 20th
	July 1–2
	August 19th
	September 30th
	November 12th
	December 16th
1998	February 3–4
	March 31st
	May 19th
	June/July 301
	August 18th
	September 29th
	November 17th
	December 22nd
1999	February 3–4
	March 30th
	May 18th
	June 29–30
	August 24th
	October 5th
	November 16th
	December 21th
2000	February 1–2

Appendix C (*continued*)

Year	FOMC dates
	March 21st
	May 16th
	June 27–28
	August 22nd
	October 3rd
	November 15th
	December 19th
2001	January 30–31
	March 20th
	May 15th
	June 26–27
	August 21st
	October 2nd
	November 6th
	December 11th
2002	January 29–30
	March 19th
	May 7th
	June 25–26
	August 13th
	September 24th
	November 6th
	December 10th
2003	January 28–29
	March 18th
	May 6th
	June 24–25
	August 12th
	September 16th
	October 28th
	December 9th
2004	January 27–28
	March 16th
	May 4th
	June 29–30
	August 10th
	September 21st
	November 10th
	December 14th
2005	February 1–2
	March 22nd
	May 3rd
	June 29–30
	August 9th
	September 20th
	November 1st
	December 13th
2006	January 31st
	March 27–28
	June 28–29
	August 8th
	September 20th
	October 24–25
	December 12th
2007	January 30–31
	March 20–21
	May 9th
	June 27–28
	August 7, 10, 16
	September 18th
	October 30–31
	December 6, 11
2008	January 9, 21, 29–30
	March 10, 18
	April 29–30
	June 24–25
	July 24th
	August 5th

Source: Federal Reserve Bank of St. Louis

Appendix D. Data variables for sample period March 2003 to September 2008

Variables	Data source
Federal funds target (*f*) magnitude and date of change.	Federal Reserve Bank New York
Federal Open Market Committee (*FQMC*) meeting dates.	Federal Reserve Bank New York
Spread between effective federal funds rate and six meeting dates.	Federal Reserve Bank St. Louis
Growth of employment (*EM*).	Federal Reserve Bank St. Louis
Inflation rate (*P*).	Federal Reserve Bank St. Louis
Market liquidity (*LIQ*-difference between 3-month T bill and 3-month Eurodollar rate).	Federal Reserve Bank St. Louis.
Log of broad money (*M2*).	Federal Reserve Bank St. Louis
Log of investment grade credit risk (CDXI)—125 investment grade companies.	Markit Financial Services
Log of high yield credit risk (CDXh)—100 high yield grade companies.	Markit Financial Services

Appendix E

We calculate the impulse response function for credit premia growth responding to changes in the first term on the right-hand side of Eq. (15) as follows. Given the historical values for ($Y_{1,\tau}$,$Y_{\tau-1}$, $Y_{\tau-2}$,…), we use the ACH model to calculate the impact if the Fed raises the target by, say, 25 basis points during month τ (so that$i_\tau = i_{\tau-1} + 0.25$) compared to keeping the target constant ($i_\tau = i_{\tau-1}$). For this calculation, we assume that the second term on the right-hand side of Eq. (15) is zero, so that expectations are for no change in the federal funds rate target. The difference is normalized in units of a derivative, as follows:

$$(0.25)^{-1}\left[\tilde{\mathbf{y}}_{\mathrm{r+j|r}}(\mathbf{i}_{\mathrm{r}})|i_r = i_{r-1} + 0.25 - \tilde{\mathbf{y}}_{\mathrm{r+j|r}}(\mathbf{i}_{\mathrm{r}})|i_r = i_{r-1}\right] \qquad \text{E.1}$$

where $\bar{Y}_{\tau+j|\tau}(i_\tau)$ summarizes the dynamic consequences of the forecast time path for $\{i_{\tau+j}\}_{j=0,\infty}$ as calculated by the ACH model.

We also investigate the consequences of changes in the second term in Eq. (15), the impact if investors predict a change in the target but none occurs. Let $\hat{i}_{\tau|\tau-1}$ denote the forecast for the target in month τ based on historical information available in month $\tau-1$. Then we calculate the consequences as follows:

$$\omega_r\left[\tilde{\mathbf{y}}_{\mathrm{r+j|r}}(\mathbf{i}_{\mathrm{r}})|i_r = i_{r-1} - \tilde{\mathbf{y}}_{\mathrm{r+j|r}}(\mathbf{i}_{\mathrm{r}})|i_r = i_{r|r-1}\right] \qquad \text{E.2}$$

where

$$\omega_r = \begin{cases} \left(i_{r-1} - \hat{i}_{r|r-1}\right)^{-1} & \text{if} \quad \left|i_{r-1} - \hat{i}_{r|r-1}\right| > 0.05 \\ 0 & \text{otherwise} \end{cases}.$$

The effect of the weight w_t in Eq. (E.2) is to ignore observations for which no change was expected and to rescale positive or negative forecast errors into units comparable to Eq. (E.1).

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