Using interest rate uncertainty to predict the paper-bill spread and real output

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Abstract

Using daily data and GARCH modeling, I show that the rapid rise in the paper-bill spread during the Fall of 1998 was driven primarily by interest rate uncertainty, rather than Fed policy or default risk. The Fed’s surprise cut in mid-October was especially effective in reversing the rapid rise in uncertainty and therefore the paper-bill spread. I then consider, using a kitchen-sink approach, interest rate uncertainty as a predictor of real output. The results indicate that interest rate uncertainty does embody useful (predictive) information over and above that contained in the index of leading economic indicators, the National Association of Purchasers Managers index (NAPM), a measure of default risk, as well as other financial variables. © 2002 Elsevier Science Inc. All rights reserved.

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1. Introduction

The commercial paper-bill spread (henceforth spread) has received considerable attention in the literature primarily for its role in predicting future economic activity. Friedman and Kuttner (1992, 1993, 1998) have been active in this area and conclude that the spread was a good predictor of US recessions except for the most recent 1990 recession. Friedman and Kuttner (1998) argue that factors unrelated to the business cycle drove the spread during this period.¹

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Emery (1996) argues that Friedman and Kuttner’s results are sensitive to two outliers and once these are accounted for, the spread loses its ability to predict real output.\(^2\)

A related line of research focuses on the substitutability of commercial paper and US T-bills. Ferderer, Vogt, and Chahil (1998) provide evidence, via an asset supply-asset demand model, that the substitutability between commercial paper and bills increased during the 1980s. According to their model, increased substitutability weakens the ability of the spread to embody important information regarding real economic variables, consistent with the failure of the spread to predict the 1990 recession.

This paper contributes to the existing literature in two ways. First, I show that interest rate uncertainty, as quantified from a GARCH (1, 1) model of the US T-bill, played a critical role in explaining the spread during the ‘credit crunch’ of 1998. In particular, I show that the rise in the spread beginning in August was due primarily to increases in interest rate uncertainty resulting from the Russian default and devaluation during August 1998. It is argued that the Fed contributed to the increased uncertainty (and thus increased the spread) by lowering the targeted Fed funds rate by less than expected after the FOMC meeting in late September. The FOMCs inter-meeting (surprise) cut, however, was remarkably effective in lowering uncertainty and thus the spread. The tight relationship between interest rate uncertainty and the spread appears to be exclusive to the fall of 1998. Prior to and shortly following this period, the relationship between interest rate uncertainty and the spread was very weak, consistent with Ferderer et al. (1998). The results indicate that liquidity in the commercial paper market is a product of two components: (1) a long run factor that has caused liquidity in the paper market to rise over time and (2) a short-term ‘financial crisis’ factor that temporarily reverses this process (the credit crunch of 1998).

Second, I investigate whether or not interest rate uncertainty embodies information in terms of predicting the growth rate of industrial production. I explore various Friedman–Kuttner type specifications and establish a baseline model that contains lagged industrial production, the official index of leading economic indicators, and the National Association of Purchasing Managers index (NAPM).\(^3\) I then add a variety of financial variables to the baseline model and evaluate each model based on two in sample criteria and two out of sample criteria. In total, 12 models were considered and then ranked according to these four criteria. The results indicate that interest rate uncertainty out performs all of the financial variables examined. The model that ‘fit’ best includes the three variables above (baseline model), a measure of default risk, and interest rate uncertainty.

Together, the results may shed light on the debate between Emery (1996) and Thoma and Gray (1998) on the one hand and Bernanke (1990), Bernanke and Blinder (1992), and Friedman and Kuttner (1992, 1993, 1998) on the other. For example, when the spread became recognized as the ‘best’ predictor of real output, various theories arose to explain the spread’s success. Bernanke (1990), among others, suggested that the spread performs well since it may more accurately reflect monetary policy actions than the other financial variables typically examined, including the first difference of the federal funds rate. Another popular argument is that a rise in the spread reflects increased demand for short-term funds to finance inventories, consistent with a higher spread preceding weaker economic activity. The results in this paper suggest another channel in which the spread may influence economic activity. In particular, the results during the fall of 1998 clearly indicate that increases in the spread may, at times, reflect reduced liquidity.
and higher uncertainty, both of which may lead to reduced economic activity. The results also indicate that the relationship between the spread and interest rate uncertainty only occurs during financial crises and in non-crisis periods, this relationship is non-existent, consistent with the fragility of the spread in terms of predicting real output (Emery, 1996; Thoma & Gray, 1998). The implication is that when modeling changes in real output or the spread itself, researchers should consider adding an uncertainty measure to their existing set of explanatory variables. The experience during the fall of 1998 in US credit markets provides us with a clear example as to the important role played by interest rate uncertainty (i.e., it would be hard to imagine modeling the spread without an uncertainty measure).

The paper is organized as follows. Section 1 provides an overview of the credit crunch during 1998 and provides the rationale for using the measure of uncertainty as an explanatory variable. Section 2 provides the empirical results prior to and during the credit crunch of 1998. Section 3 provides the empirical results associated with adding interest rate uncertainty to a variety of Friedman–Kuttner type regressions used to predict real output. Section 4 concludes.

2. Overview of the credit crunch of 1998

The US economy, by virtually every measure, weathered the Asian Financial Crisis better than expected. By the summer of 1998 people were accustomed to unemployment rates below 5%, healthy economic growth, low and steady inflation, and remarkable gains on Wall Street. Consumers were confident and the wealth effect was in full force. Politicians were debating how to spend the government budget surplus. Credit was abundant, so abundant that Alan Greenspan warned banks that they “might be being” too lenient in their lending practices. Interest rates, at least nominal rates, were low and relatively stable. The spread had been relatively low and stable since the end of the Gulf War (February 1991).

In mid-August, 1998, Russia declared a debt moratorium and let the Russian ruble float. The following excerpt reflects the chaos in financial markets during this time (Wall Street Journal, September 2, 1998)

“This time, it isn’t some ill-starred military adventure. Instead, the world is blaming Russia for the chaos sweeping through financial markets over the past month. Russia’s abrupt decision in mid-August to let the ruble’s value fall and default on part of its debt is widely viewed as the reason for widespread selling in everything from Brazilian bonds to US stocks.”

Given that credit markets were locking up (i.e., firms had a difficult time selling paper and bonds) and that inflation had been tame for years, the FOMC announced on September 30 that they were lowering their target for the Fed funds rate by 25 basis points to 5.25%. From the Wall Street Journal Interactive edition (September 30, 1998)

“The Federal Reserve cut interest rates for the first time since January 1996 in a pre-emptive strike against recession that reflects a sudden reversal in the central bank’s outlook for the economy and new worries about a credit crunch.”

The rate cut had little effect as credit markets got tighter and tighter. Five days after the cut, William McDonough, president of the New York Federal Reserve Bank, stated in an appearance
before the Institute of International Bankers: “I believe that we are in the most serious financial crisis since World War II—and one that has a propensity to get worse rather than better.”

Alan Greenspan reacted and shocked financial markets with his “surprise” inter-meeting cut on October 15, 1998. As will be shown shortly, this cut was very effective in easing the credit crunch, almost across the board. Given that lower grade issuers were still being punished, the FOMC cut the target for the Fed funds rate by another 25 basis points on November 18, 1998.

Fig. 1 depicts three key economic variables associated with the credit crunch. The vertical bars denote the Russian default and the three cuts by the Fed, respectively.

The top panel shows the rally (flight to quality) in the US T-bill market shortly after the Russian default. As is clear from the top two panels, the Fed’s first cut was ineffective with regard to mitigating the flight to quality and lowering commercial paper spreads. Conversely,
the second cut was very effective. The final cut appears to have been effective in lowering the low grade spread. Note that the corporate bond spread did not react significantly to any of the Fed cuts.

2.1. Rationale for using interest rate uncertainty

Holding liquid assets allows investors the flexibility to readjust their portfolios quickly and at low costs when new information arrives. In an uncertain environment, investors tend to increase their appetite for liquidity given the higher probability of new information arriving. If bills are more liquid than paper, then paper should embody a liquidity premium that rises with uncertainty. The spread will be influenced by uncertainty in the following way: higher uncertainty, given a more liquid bill market, causes investors to substitute away from paper towards bills, raising the price of bills and lowering the price of paper, resulting in a higher spread.

Kamara (1994) makes the same argument when investigating the spread between US notes and bills. In particular, his theoretical model reveals that the liquidity risk of an asset is a product of two factors: equilibrium price volatility and the expected length of time required to complete a transaction at a "reasonable" price (p. 406). Given that bills are more liquid than notes, his empirical results indicate that the spread (yield on notes minus the yield on bills) rises with interest rate uncertainty.6

To my knowledge, the only paper that incorporates interest rate uncertainty directly into a model of the spread was the aforementioned paper by Ferderer et al. (1998). According to their fixed parameter results, the coefficient on interest rate uncertainty is positive and significant. They refer to this finding as novel with the implication that the spread includes a ‘liquidity’ premium that rises with interest rate uncertainty (p. 368). Closer investigation, via rolling regressions, reveals that the relationship between uncertainty and the spread has weakened and for all intents and purposes, is non-existent by the beginning of the 1990s, consistent with the development of a highly active and liquid secondary market for commercial paper. The results that follow suggest that prior to and shortly after the crisis, the relationship between the spread and interest rate uncertainty is non-existent, consistent with the results of Ferderer et al. (1998). However, during the 1998 crisis, a very tight relationship between the spread and interest rate uncertainty appeared suggesting that during this time, investors preferred bills relative to paper.7

I employ two distinct specifications to measure interest rate uncertainty, both using the conditional variance from a GARCH (1, 1) model of the US T-bill (TB). Specification 1 can be characterized as follows:

Specification 1—CVMEAN

\[
\begin{align*}
TB_t &= c + u_t \\
u_t &= \varepsilon_t, \quad \varepsilon_t | I_{t-1} \sim N(0, \sigma^2_t) \\
\sigma^2_t &= \omega_0 + \omega_1 \varepsilon^2_{t-1} + \omega_2 \sigma^2_{t-1}.
\end{align*}
\]

The resulting conditional variance (Eq. (3)) is labeled CVMEAN with the mean equation estimated with a constant and no regressors. This specification follows Ferderer et al. (1998). Specification 2 models the T-bill as an ARIMA (1, 1, 1) process and is characterized below.
Specification 2—CV ARIMA

\[ TB_t = c + u_t, \]
\[ (1 - \rho_1 L)u_t = (1 + \theta_1 L)\epsilon_t, \quad \epsilon_t | I_{t-1} \sim N(0, \sigma_t^2) \]
\[ \sigma_t^2 = \omega_0 + \omega_1 \epsilon_{t-1}^2 + \omega_2 \sigma_{t-1}^2. \]

The resulting conditional variance (Eq. (6)) is labeled CVARIMA. The residuals from the ARIMA specification are well behaved according to Ljung-Box Q statistics, a desirable quality emphasized by Brenner, Harjes, and Kronner (1996). The results, with regard to the crisis, are robust to either specification, as well as a variety of ARMA models of the T-bill.

The uncertainty that prevailed during this period was referred to by Alan Greenspan in his semi-annual Humphrey–Hawkins testimony (February 23, 1999)

“In the wake of the Russian crisis and subsequent difficulties in other emerging-market economies, investors perceived that the uncertainties in financial markets had broadened appreciably and as a consequence they became decidedly more risk averse.”

In what follows, I show that during the credit crunch of 1998, the spread and both measures of interest rate uncertainty (CVMEAN, CVARIMA) shared a close and tight (positive) relationship. Given Ferderer et al.’s interpretation, the positive and significant coefficient on interest rate uncertainty indicates a return of a liquidity premium on paper, that is, paper during this time was less liquid than bills. This interpretation is consistent with the press accounts during this time as well as testimony from Federal Reserve officials.


Table 1 provides the definitions of the variables used in modeling the paper-bill spread. All data are daily and are from the Federal Reserve Board.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low grade spread</td>
<td>The 90-day rate on A2/P2 non-commercial paper minus the rate on 3-month US T-bills (secondary market)</td>
</tr>
<tr>
<td>High grade spread</td>
<td>The 90-day rate on AA financial commercial paper minus the rate on 3-month US T-bills (secondary market)</td>
</tr>
<tr>
<td>CVMEAN</td>
<td>The conditional variance of the daily 3-month US T-bill (secondary market). Mean equation with no regressors</td>
</tr>
<tr>
<td>CVARIMA</td>
<td>The conditional variance of the daily 3-month US T-bill (secondary market). T-bill modeled as an ARIMA (1, 1) in the mean equation</td>
</tr>
<tr>
<td>DDEFAULT</td>
<td>The first difference of the spread between aaa and baa corporate bonds</td>
</tr>
<tr>
<td>POLICY</td>
<td>The spread between the Fed funds rate and the yield on the 30-year US treasury (constant maturity)</td>
</tr>
</tbody>
</table>
All variables are stationary in levels except for DEFAULT, which was difference stationary (DDEFAULT). The regression results using CVMEAN as the measure of interest rate uncertainty are provided in Table 2.

The results in Table 2 are extremely consistent with the narrative above. Prior to the crisis, the coefficients on CVMEAN are insignificant for the low grade and high grade spreads, consistent with Ferderer et al.’s observation that increased liquidity in the commercial paper market weakens the relationship between the spread and interest rate uncertainty. The insignificant coefficients on DDEFAULT in all regressions are consistent with the results of Bernanke (1990) and Ferderer et al. (1998) as well as Fig. 1. The POLICY coefficient is significant in all regressions implying that both spreads rise with tighter monetary policy, consistent with Bernanke (1990) and Ferderer et al. (1998).

During the crisis, the coefficient on CVMEAN becomes significant at the 1% level in both regressions, arguably capturing the notion that the withdrawal of liquidity provision was not uniform across the paper and bill markets. Put differently, differences in liquidity during this period resulted in a significant relationship between interest rate uncertainty and the spread, consistent with Kamara (1994). Additional evidence as to the importance of interest rate uncertainty during this period is given in the bottom two rows in Table 2. Prior to the crisis, the fit of each model as measured by adjusted $R^2$ values, is not affected by the inclusion of CVMEAN. Conversely, the inclusion of CVMEAN during the crisis dramatically improves the fit of each model. For example, the inclusion of CVMEAN during the crisis raises the adjusted $R^2$ for the low grade spread from 0.02 to 0.39 and from 0.14 to 0.60 for the high grade spread. Fig. 2 illustrates the influence that CVMEAN has in terms of predicting the high grade spread during the crisis.

The top panel of Fig. 2 shows how poorly the model without CVMEAN performed during the crisis. The bottom panel shows that the inclusion of CVMEAN dramatically improves the fit and captures the dramatic rise in the spread shortly after the 25 basis point cut by the Fed on September 30, 1998. Interestingly, the improved fit of the model with CVMEAN appears to end in the beginning of November, when the spread returned to its pre-crisis levels. Empirical results confirm this notion. I arbitrarily split the crisis sample at November 1, 1998 and ran two separate regressions. The adjusted $R^2$ from August 17, 1998 to November 1, 1998 rose to 0.70 with CVMEAN remaining highly significant. After November 1, the adjusted $R^2$ falls to 0.10 with the coefficient on CVMEAN becoming negative and insignificant. The results are similar if the low grade spread is employed rather than the high grade spread.

3.1. Results with CVARIMA

Table 3 provides the results using CVARIMA as the measure of interest rate uncertainty.

The results in Table 3 are similar to the results provided in Table 2 given the important role played by CVARIMA during the crisis. The adjusted $R^2$ rises dramatically with the inclusion of CVARIMA during the crisis and the fit of each model during the crisis is much better than the fit prior to the crisis. For example, during the crisis for the low-grade spread the adjusted $R^2$ was 0.02 without CVARIMA and 0.44 with. A graph similar to Fig. 2 reveals that the inclusion of CVARIMA results in the model picking up the dramatic rise in the spread during the crisis. Interestingly, CVARIMA is significant for each sample period and each spread. The negative
<table>
<thead>
<tr>
<th>Variable</th>
<th>Low grade spread</th>
<th></th>
<th></th>
<th>High grade spread</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prior to crisis</td>
<td>During crisis</td>
<td>Full sample</td>
<td>Prior to crisis</td>
<td>During crisis</td>
<td>Full sample</td>
</tr>
<tr>
<td>Constant</td>
<td>0.699&lt;sup&gt;a&lt;/sup&gt; (0.019)</td>
<td>0.858&lt;sup&gt;a&lt;/sup&gt; (0.054)</td>
<td>0.755&lt;sup&gt;b&lt;/sup&gt; (0.019)</td>
<td>0.552&lt;sup&gt;b&lt;/sup&gt; (0.016)</td>
<td>0.550&lt;sup&gt;b&lt;/sup&gt; (0.021)</td>
<td>0.539&lt;sup&gt;b&lt;/sup&gt; (0.014)</td>
</tr>
<tr>
<td>CVMEAN</td>
<td>0.213 (1.630)</td>
<td>0.650&lt;sup&gt;a&lt;/sup&gt; (0.050)</td>
<td>0.785&lt;sup&gt;b&lt;/sup&gt; (0.065)</td>
<td>0.321 (0.735)</td>
<td>0.439&lt;sup&gt;b&lt;/sup&gt; (0.050)</td>
<td>0.417&lt;sup&gt;b&lt;/sup&gt; (0.055)</td>
</tr>
<tr>
<td>DDEFAULT</td>
<td>0.375 (0.597)</td>
<td>2.988 (2.400)</td>
<td>2.541 (1.683)</td>
<td>0.292 (0.299)</td>
<td>0.639 (1.206)</td>
<td>0.517 (0.371)</td>
</tr>
<tr>
<td>POLICY</td>
<td>0.071&lt;sup&gt;b&lt;/sup&gt; (0.035)</td>
<td>0.159 (0.105)</td>
<td>0.157&lt;sup&gt;b&lt;/sup&gt; (0.068)</td>
<td>0.074&lt;sup&gt;b&lt;/sup&gt; (0.022)</td>
<td>0.246&lt;sup&gt;b&lt;/sup&gt; (0.042)</td>
<td>0.097&lt;sup&gt;b&lt;/sup&gt; (0.019)</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.02</td>
<td>0.39</td>
<td>0.60</td>
<td>0.12</td>
<td>0.60</td>
<td>0.54</td>
</tr>
<tr>
<td>$R^2$ w/o CVMEAN</td>
<td>0.03</td>
<td>0.02</td>
<td>0.06</td>
<td>0.12</td>
<td>0.14</td>
<td>0.24</td>
</tr>
</tbody>
</table>

<sup>a</sup> Significance at the 5% level.

<sup>b</sup> Significance at the 1% level.
coefficient on CVARIMA prior to the crisis on the low-grade spread is counterintuitive and suggests that lower levels of interest rate uncertainty results in a higher spread. The results prior to the crisis for the high grade spread are opposite and suggest that high levels of interest rate uncertainty results in a higher spread. In either case however, the fit of each model is relatively weak relative to the crisis period, suggesting that the influence of interest rate uncertainty on the spread prior to the crisis is also (relatively) weak. This latter argument is supported by the full sample results for the low-grade spread where the coefficient on CVARIMA is positive and significant even though prior to the crisis, the coefficient was negative.

Fig. 3 depicts the constructed interest rate uncertainty variable CVMEAN, along with the low and high grade spreads. Recall that the vertical bars represent the Russian default and the three Fed cuts, respectively.

Fig. 3 reveals a remarkably close relationship between interest rate uncertainty and both of the spreads. The first cut appears to have exacerbated interest rate uncertainty, consistent with the market being disappointed with the size of the Fed’s cut. The surprise cut (October 15) was
Table 3
Equation estimated: \( \text{CPSPREAD} = \alpha_0 + \alpha_1 \text{CVARIMA}_{t-1} + \alpha_2 \text{DDEFAULT}_{t-1} + \alpha_3 \text{POLICY}_{t-1} \)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Low grade spread</th>
<th></th>
<th></th>
<th>High grade spread</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prior to crisis</td>
<td>During crisis</td>
<td>Full sample</td>
<td>Prior to crisis</td>
<td>During crisis</td>
<td>Full sample</td>
</tr>
<tr>
<td>Constant</td>
<td>0.779(^a) (0.021)</td>
<td>0.946(^b) (0.064)</td>
<td>0.764(^b) (0.042)</td>
<td>0.478(^b) (0.020)</td>
<td>0.636(^b) (0.033)</td>
<td>0.541(^b) (0.021)</td>
</tr>
<tr>
<td>CVARIMA</td>
<td>-48.125(^b) (9.945)</td>
<td>35.225(^b) (7.294)</td>
<td>43.422(^b) (8.380)</td>
<td>27.296(^b) (7.485)</td>
<td>19.004(^b) (3.269)</td>
<td>23.644(^b) (4.108)</td>
</tr>
<tr>
<td>DDEFAULT</td>
<td>0.370 (0.600)</td>
<td>1.849 (2.079)</td>
<td>2.237 (1.676)</td>
<td>0.294 (0.284)</td>
<td>-0.044 (1.814)</td>
<td>0.404 (0.361)</td>
</tr>
<tr>
<td>POLICY</td>
<td>0.062(^a) (0.0212)</td>
<td>0.062 (0.099)</td>
<td>0.129 (0.084)</td>
<td>0.076(^b) (0.019)</td>
<td>0.191(^b) (0.048)</td>
<td>0.123(^b) (0.021)</td>
</tr>
<tr>
<td>Adjusted (R^2)</td>
<td>0.18</td>
<td>0.44</td>
<td>0.47</td>
<td>0.22</td>
<td>0.47</td>
<td>0.50</td>
</tr>
<tr>
<td>(R^2) w/o CVARIMA</td>
<td>0.03</td>
<td>0.02</td>
<td>0.06</td>
<td>0.12</td>
<td>0.14</td>
<td>0.24</td>
</tr>
</tbody>
</table>

\(^a\) Significance at the 5% level.  
\(^b\) Significance at the 1% level.
remarkably successful in decreasing the amount of uncertainty and thus was extremely effective in bringing the spread back down to ‘reasonable’ levels. This result is interesting given that a priori, surprises should exacerbate uncertainty, especially in the context of GARCH models.\textsuperscript{13} The third cut had minimal effect on interest rate uncertainty but did appear to have the desired effects of decreasing the lower grade spread.\textsuperscript{14}

An article in the WSJ by David Wessel (November 17, 1998) titled “How the Fed Fumbled and then Recovered in Making Policy Shift” sheds light on these incidents. Regarding the first cut in September, Fed officials figured that simply changing direction would make a big enough splash. From Wessel: “They had hoped their first cut in nearly three years would reassure financial markets that the world’s most powerful central bank was prepared to do what was needed to avoid a global economic meltdown.” Mr. Boehne, the Philadelphia Fed’s president stated: “I thought the amount was irrelevant.” Mr. Boehne went on to address the possibility of a 50 basis point cut: “The problem with 50 basis points was that people could have inferred that we knew more bad things than we did.” Mr. Greenspan made the same argument internally. According to Wessel, the 25 basis point cut was the fumble. The recovery of course was the surprise cut in mid-October. Again the Fed faced the same dilemma. The surprise cut, by its very nature, may have resulted in an adverse reaction in financial markets if, to coin Mr. Boehne, “people inferred that we knew more bad things than we did.” The opposite occurred. From Wessel, “On their TV sets and computer screens, Fed officials watched the instant analysis with a bit of trepidation. But the reaction was almost universally favorable and the intended message received: the Fed was prepared to do what was necessary. “Yes!” one Fed official said late that

Fig. 3. Commercial paper spreads and interest rate uncertainty.
afternoon after listening to a Wall Street pundit on CNBC, the business cable channel: “They got it right.”

In sum, both measures of interest rate uncertainty seem to capture the dramatic rise in the spread during the crisis. Note that interest rate uncertainty appears to have reached a new and higher mean since the third cut. This observation is particularly relevant given that Alan Greenspan had been warning investors about irrational exuberance since December 1996. In fact, interest rate uncertainty was low and stable since the beginning of the sample (January 1, 1997) until August 1998.15 Could it be that the Fed has effectively managed uncertainty to a new and higher level, consistent with the Fed’s perception of an optimal amount of risk aversion?

4. Interest rate uncertainty as a predictor of real economic activity

Given the results of the previous section, it is reasonable to investigate whether or not interest rate uncertainty helps predict real economic activity. Previous work in this area focuses on the role of interest rate uncertainty on investment expenditures (Bernanke, 1983; Ferderer, 1993; Ingersoll & Ross, 1992; Leahy & Whited, 1996). The theoretical implications in this line of research are ambiguous. Leahy and Whited (1996), point out that there are two opposing forces operating that result in the ambiguity. On one hand, an increasingly uncertain environment increases the value of waiting since new information is arguably more valuable in an uncertain environment, particularly if investment is irreversible. This effect, referred to as the option value of waiting, implies that interest rate uncertainty and investment are negatively related. The opposing effect relies on the expected value of the firm being a convex function with respect to interest rates. Higher (mean preserving) interest rate volatility increases the likelihood there will be extremely low and extremely high interest rates in the future. Given a convex function, the benefits of lower rates exceed the costs of higher rates with the result that increased interest rate uncertainty tends to increase investment.

Empirically, the results are mixed as well. Evans (1983) finds a negative relationship between interest rate uncertainty and aggregate output. Ferderer (1993) uses the risk premium on long-term bonds as his measure of uncertainty and finds a significant negative relationship between uncertainty and investment. Many other papers offer mixed results. As Leahy and Whited (1996) summarize: “the empirical evidence on the issue is far too scanty to assert with confidence that we can sign the investment-uncertainty relationship (p. 67).”

In what follows, I investigate whether or not interest rate uncertainty embodies useful information in terms of predicting the growth rate of industrial production that is not included in a variety of other financial and non-financial economic variables.

I conduct exclusion tests on numerous specifications with the growth rate of industrial production as the dependent variable. I also consider out of sample forecasts and evaluate each model based on the lowest root mean squared error criterion. Table 4 defines the variables employed in this section.16

Two indexes, the first difference of the official index of leading economic indicators (DLEAD) and the National Association of Purchasing Management’s index (NAPM) were included, along with the lagged dependent variable, to form what I refer to as the baseline model.17
Table 4

Variable definitions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>DLIND</td>
<td>Log difference of industrial production</td>
</tr>
<tr>
<td>DLEAD</td>
<td>First difference of the official index of leading economic indicators. The index was first differenced to achieve stationarity</td>
</tr>
<tr>
<td>NAPM</td>
<td>The National Association of Purchasing Management’s index</td>
</tr>
<tr>
<td>PPIINF</td>
<td>Inflation as measured by the producer price index</td>
</tr>
<tr>
<td>M2GROW</td>
<td>Growth rate of M2</td>
</tr>
<tr>
<td>SPREAD</td>
<td>Yield on 6-month commercial paper minus the yield on the 6-month US T-bill</td>
</tr>
<tr>
<td>FF</td>
<td>The federal funds rate. According to unit root tests, the null hypothesis of a unit root cannot be rejected</td>
</tr>
<tr>
<td>DFF</td>
<td>The first difference of the federal funds rate</td>
</tr>
<tr>
<td>POLICY</td>
<td>The spread between the Fed funds rate and the yield on the 30-year US treasury (constant maturity)</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>The spread between baa and aaa rated corporate bond yields</td>
</tr>
<tr>
<td>CVMEAN</td>
<td>The conditional variance from a GARCH (1, 1) specification of the US 3-month T-bill. The mean equation included only a constant</td>
</tr>
<tr>
<td>CVARIMA</td>
<td>The conditional variance from a GARCH (1, 1) specification of the US 3-month T-bill. The mean equation modeled the US T-bill as an ARIMA (1, 1) process</td>
</tr>
</tbody>
</table>

4.1. Baseline model

\[ \Delta IP_t = \alpha + \sum_{i=1}^{T} \beta_i \Delta IP_{t-1} + \sum_{i=1}^{T} \delta_i \text{DLEAD}_{t-1} + \sum_{i=1}^{T} \psi_i \text{NAPM}_{t-1} + \varepsilon_t \]

I then add the financial variables contained in Table 4, one by one, and report the results from testing the joint (null) hypothesis that all the coefficients of each variable equal zero. F-tests (F) and results from log likelihood ratio tests (LR) are reported (see Table 5).\(^{18}\)

Casual observation of Table 5 reveals that both indexes, DLEAD and NAPM (columns 3 and 4), are good predictors of output given that we can reject the null hypothesis (at the 1% level) that the respective coefficients jointly equal zero. The results of Models 1–3 suggest that producer price inflation (PPIINF), the growth rate of M2 (M2GROW), and the commercial paper-bill spread (SPREAD) do not add any explanatory power to the baseline model. Put differently, these three variables do not contain any additional information in terms of predicting real output that is not contained in the three variables that comprise the baseline model.\(^{19}\) The same can be said for the spread between the federal funds rate and the 30-year US Treasury Bond (POLICY) (Model 6).\(^{20}\)

Models 4 and 5 suggest that the federal funds rate (FF) and the first difference of the federal funds rate (DFF) do embody useful information in terms of predicting real output that is not contained in the baseline model, consistent with Bernanke and Blinder (1992). The results regarding the significance of FF should be treated with caution since the null hypothesis of a unit root in FF cannot be rejected. Model 7 reveals that DEFAULT, the spread between baa and aaa rated corporate bonds, does add to the explanatory power of the baseline model and is significant at the 5% level according to the F and log-likelihood ratio test statistics.
Table 5
The F-statistics and log likelihood ratio tests—various models: January 1983 to December 1998

<table>
<thead>
<tr>
<th>Model</th>
<th>Variables</th>
<th>F-statistic</th>
<th>LR-statistic</th>
<th>Adj. R^2</th>
<th>AIC</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>DLIND: F: 0.034^b, LR: 0.020^c</td>
<td>F: 0.000^c</td>
<td>LR: 0.001^c</td>
<td>0.3299</td>
<td>−7.825</td>
<td>(1) 0.004627</td>
</tr>
<tr>
<td>Model 1 (PPIINF)</td>
<td>DLEAD: F: 0.012^b, LR: 0.005^c</td>
<td>F: 0.000^c</td>
<td>LR: 0.001^c, LPM: F: 0.152</td>
<td>0.3434</td>
<td>−7.818</td>
<td>(1) 0.004866</td>
</tr>
<tr>
<td>Model 2 (M2GROW)</td>
<td>NAPM: F: 0.018^b, LR: 0.008^c</td>
<td>F: 0.000^c</td>
<td>LR: 0.001^c, M2GROW: F: 0.453</td>
<td>0.3291</td>
<td>−7.796</td>
<td>(1) 0.004806</td>
</tr>
<tr>
<td>Model 3 (SPREAD)</td>
<td>DLEAD: F: 0.139, LR: 0.085^c</td>
<td>F: 0.000^c</td>
<td>LR: 0.001^c, SPREAD: F: 0.598</td>
<td>0.3481</td>
<td>−7.800</td>
<td>(1) 0.04735</td>
</tr>
<tr>
<td>Model 4 (FF)</td>
<td>DLEAD: F: 0.004^c, LR: 0.001^c</td>
<td>F: 0.000^c</td>
<td>LR: 0.001^c, FF: F: 0.047^b</td>
<td>0.356</td>
<td>−7.838</td>
<td>(1) 0.004580</td>
</tr>
<tr>
<td>Model 5 (DIFF)</td>
<td>DLEAD: F: 0.009^c, LR: 0.003^c</td>
<td>F: 0.002^c, NAPM: F: 0.003^c</td>
<td>0.349</td>
<td>−7.826</td>
<td>(1) 0.004572</td>
<td></td>
</tr>
<tr>
<td>Model 6 (POLICY)</td>
<td>DLEAD: F: 0.043^b, LR: 0.022^c</td>
<td>F: 0.000^c, NAPM: F: 0.004^c, POLICY: F: 0.475</td>
<td>0.328</td>
<td>−7.795</td>
<td>(1) 0.004720</td>
<td></td>
</tr>
<tr>
<td>Model 7 (DEFAULT)</td>
<td>DLEAD: F: 0.025^b, LR: 0.012^b</td>
<td>F: 0.000^c, NAPM: F: 0.004^c, DEFAULT: F: 0.029^b</td>
<td>0.361</td>
<td>−7.850</td>
<td>(1) 0.004537</td>
<td></td>
</tr>
<tr>
<td>Model 8 (CVMEAN)</td>
<td>DLEAD: F: 0.013^b, LR: 0.006^c</td>
<td>F: 0.000^c, NAPM: F: 0.000^c, CVMEAN: F: 0.015^b</td>
<td>0.367</td>
<td>−7.855</td>
<td>(1) 0.004511</td>
<td></td>
</tr>
<tr>
<td>Model 9 (CVARIMA)</td>
<td>DLEAD: F: 0.085^b, LR: 0.050^b</td>
<td>F: 0.000^c, NAPM: F: 0.000^c, CVARIMA: F: 0.044^b</td>
<td>0.357</td>
<td>−7.839</td>
<td>(1) 0.004552</td>
<td></td>
</tr>
</tbody>
</table>

^a Significance at the 10% level.
^b Significance at the 5% level.
^c Significance at the 1% level.

The results from Models 8 and 9 show that both measures of interest rate uncertainty (CVMEAN and CVARIMA) contain useful information, in terms of predicting real output, that is not contained in the variables that comprise the baseline model. Both measures of interest rate uncertainty are significant at the 5% level. For purposes of goodness of fit, two criteria, the adjusted R^2 and the Akaike information criterion (AIC) are reported in the columns 6 and 7, respectively. According to these criteria, Model 8 (CVMEAN) fits the data the best, followed by Model 7 (DEFAULT) and Model 9 (CVARIMA). Given these results, I add DEFAULT and CVMEAN to the baseline model (Model 10). I also report results of a similar model using
Table 6
The $F$-statistics and log likelihood ratio tests: January 1983 to December 1998

<table>
<thead>
<tr>
<th>Model 10</th>
<th>DLIND</th>
<th>DLEAD</th>
<th>NAPM</th>
<th>DEFAULT</th>
<th>CVMEAN</th>
<th>Adj. $R^2$</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F$: 0.001$^c$</td>
<td>$F$: 0.000$^c$</td>
<td>$F$: 0.001$^c$</td>
<td>$F$: 0.003$^c$</td>
<td>$F$: 0.001$^c$</td>
<td>$F$: 0.000$^c$</td>
<td>0.4190</td>
<td>(1) 0.004330</td>
</tr>
<tr>
<td>LR: 0.000$^c$</td>
<td>LR: 0.000$^c$</td>
<td>LR: 0.000$^c$</td>
<td>LR: 0.001$^c$</td>
<td>LR: 0.000$^c$</td>
<td>LR: 0.000$^c$</td>
<td>$-7.914$</td>
<td>(6) 0.004195</td>
</tr>
</tbody>
</table>

Omitted variable tests on Model 10
| FF | DFF | SPREAD | M2GROW | PPIINF |
| $F$: 0.860 | $F$: 0.845 | $F$: 0.501 | $F$: 0.768 | $F$: 0.131 |
| LR: 0.791 | LR: 0.770 | LR: 0.354 | LR: 0.669 | LR: 0.061$^a$ |

Model 11
<table>
<thead>
<tr>
<th>DLIND</th>
<th>DLEAD</th>
<th>NAPM</th>
<th>DEFAULT</th>
<th>CVARIMA</th>
<th>Adj. $R^2$</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F$: 0.033$^b$</td>
<td>$F$: 0.000$^c$</td>
<td>$F$: 0.002$^c$</td>
<td>$F$: 0.025$^b$</td>
<td>$F$: 0.038$^b$</td>
<td>0.3893</td>
<td>(1) 0.004453</td>
</tr>
<tr>
<td>LR: 0.013$^b$</td>
<td>LR: 0.000$^c$</td>
<td>LR: 0.000$^c$</td>
<td>LR: 0.009$^b$</td>
<td>LR: 0.016$^b$</td>
<td>LR: 0.016$^b$</td>
<td>$-7.865$</td>
</tr>
</tbody>
</table>

Omitted variable tests on Model 11
| FF | DFF | SPREAD | M2GROW | PPIINF |
| $F$: 0.081$^a$ | $F$: 0.122 | $F$: 0.644 | $F$: 0.943 | $F$: 0.195 |
| LR: 0.032$^b$ | LR: 0.056$^a$ | LR: 0.508 | LR: 0.910 | LR: 0.103 |

$^a$ Significance at the 10% level.
$^b$ Significance at the 5% level.
$^c$ Significance at the 1% level.

CVARIMA instead of CVMEAN (Model 11). Below the results for each model, I report the results of omitted variable tests (see Table 6).

The results from Table 6 offer additional support for interest rate uncertainty as a significant predictor of real output. The inclusion of DEFAULT and CVMEAN (to the baseline model) increases the adjusted $R^2$ and lowers the AIC, suggesting that Model 10 model fits the data better than any of the models reported in Table 5. Note that all the variables included in Model 10 are significant at the 1% level of confidence. In the second row of Table 6, I report results from omitted variable tests. These results indicate that the other financial variables do not belong in the model given that we fail to reject the null hypothesis that the respective coefficients (jointly) equal zero. 23 Model 11 offers similar results except for the possibility that FF belongs in the system. 24 Overall, the results on the interest rate uncertainty variables as predictors of output are impressive. The results suggest that interest rate uncertainty embodies useful information in terms of predicting industrial production over and above the information contained in lagged industrial production, the lagged first difference of the official index of leading economic indicators, lagged NAPM, lagged DEFAULT, as well as all the other financial variables included in Table 4.

4.2. Out of sample fit

The final column of Tables 5 and 6 contain the root mean squared error (RMSE) from out of sample forecasts at the 1- and 6-month horizons. Specifically, I estimate each respective model from January 1983 to January 1990 and forecast, out of sample, the growth rate of industrial production for February 1990 and July 1990. I continue by adding one observation (February 1990) and then forecast the growth rate of industrial production for March 1990 and
August 1990. I repeat the process through June 1998 and report the RMSE, based on 107 forecasts, in the last column of Tables 5 and 6.25

Notably, the RMSEs at the 6-month horizon are lower than the RMSEs at the 1-month horizon, perhaps reflecting the design of each of the indexes in the baseline model for purposes of forecasting the economy at the 6-month horizon. With regard to the models in Table 5, Model 8, the baseline model with CVMEAN has the lowest RMSE at the 1-month horizon where Models 7 (DEFAULT) and 4 (FF) tie for first at the 6-month horizon.

Consideration of the expanded models in Table 6 reveal that both models improve the fit, out of sample, at both horizons. In particular, Model 10 (baseline plus CVMEAN and DEFAULT) is the best in terms of the RMSE criterion at the 1- and 6-month horizons.

4.3. Ranking the models

Given the significant amount of information contained in Tables 5 and 6, I construct a point system, similar to that employed by Bernanke (1990) to obtain a more convenient assessment of each model. I begin by ranking each model according to the four criteria reported in Tables 5 and 6. The two in sample criteria are the adjusted $R^2$ and the AIC information criterion; the two out of sample criteria are the RMSE for the 1 and 6 months ahead out of sample forecasts, respectively. For each of the four criteria I award the best fitting model 11 points, the second best 10 points, and so on with the last place model receiving zero points. For example, the best fitting model according to the adjusted $R^2$ criterion is Model 10 and therefore Model 10 receives 11 points. Table 7 contains the results.

The results in Table 7 verify the importance of the information contained in both interest rate uncertainty variables given that four of the five top models contain interest rate uncertainty as an explanatory variable. In terms of summarizing the importance of the variables considered it is useful to compare each to the baseline model. Both of the federal funds measures, default risk, and interest rate uncertainty all contribute useful information in terms of predicting the growth

<table>
<thead>
<tr>
<th>Table 7: Ranking of models$^a$</th>
<th>Adj. $R^2$</th>
<th>AIC</th>
<th>RMSE (1)</th>
<th>RMSE (6)</th>
<th>Total points</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 10 (BL + CVMEAN + DEFAULT)</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>44</td>
<td>1</td>
</tr>
<tr>
<td>Model 11 (BL + CVARIMA + DEFAULT)</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>40</td>
<td>2</td>
</tr>
<tr>
<td>Model 8 (BL + CVMEAN)</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>6</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>Model 7 (BL + DEFAULT)</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8.5</td>
<td>32.5</td>
<td>4</td>
</tr>
<tr>
<td>Model 9 (BL + CVARIMA)</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>Model 4 (BL + FF)</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>25.5</td>
<td>6</td>
</tr>
<tr>
<td>Model 5 (BL + DFF)</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>23</td>
<td>7</td>
</tr>
<tr>
<td>Baseline model</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>Model 3 (BL + SPREAD)</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Model 1 (BL + PPIINF)</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Model 6 (BL + POLICY)</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Model 2 (BL + M2GROW)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>12</td>
</tr>
</tbody>
</table>

$^a$ BL: baseline model.
rate in industrial production over and above the information contained in the base line model. The opposite can be said about the spread, policy, producer price inflation, and the growth rate of M2. These latter results are in line with the literature and verify recent accounts that the spread is a weak predictor of output (Emery, 1996; Thoma & Gray, 1998).

5. Conclusion

The results provided in this paper suggest that interest rate uncertainty, as measured by the conditional variance from two different GARCH (1, 1) models of the US 3-month T-bill, embodies important information in terms of predicting the spread as well as the growth rate of industrial production. The bottom line is that model builders, forecasters, and academicians should seriously consider adding a measure of interest rate uncertainty to their existing models of the spread and industrial production.

Notes

1. Specifically, Friedman and Kuttner focus on the role of relative asset supplies and argue that substantial movements in relative asset supplies influenced the spread, and that these movements were unrelated to the business cycle. Duca (1999) makes similar arguments about movements in the spread during the late 1980s where it falsely signaled a recession in 1988–1989. Specifically, Duca argues that the spread rose as a result of the thrift crisis where the yields on CDs rose substantially and given that CDs and commercial paper are close substitutes, resulted in a substantial rise in the spread as well.

2. The outliers are the collapse of Franklin National Bank (1974) and the imposition of the Carter Credit Controls (1980). Thoma and Gray (1998) provide similar evidence as to the fragility of the paper-bill spread in terms of predicting real output.

3. The indexes were natural candidates given that both are designed explicitly to predict future economic activity. The significance of both indexes are very robust to various specifications of industrial production.

4. The Fed was leaning towards tightening during the spring and early summer of 1998. The 180° turnaround in a matter of months is suggestive of the importance the Fed placed on these events.

5. All data are from the Fed and are daily. The T-bill is 3-month secondary market. The low grade CP spread is the yield on the 90-day A2/P2 non-financial paper minus the 3-month T-bill rate. The high grade spread is the yield on the 90-day AA non-financial paper minus the 3-month T-bill rate. The corporate bond spread is the yield on baa corporate bonds minus the yield on aaa rated bonds.

6. Thus, his results are consistent with his theoretical prediction. Kamara’s measure of interest rate uncertainty, as in this paper, is the conditional variance from a GARCH model applied to the (daily) yield on US T-bills.

7. The argument is that during the crisis, bills and paper were weak substitutes. The conjecture is that investors preferred bills relative to paper due to the uncertainties in financial
markets broadening appreciably, i.e., a flight to quality argument, as well as the fact that
bills satisfy margin and collateral calls where paper does not.
8. This is the data set currently available from the Federal Reserve. The historical series
(on commercial paper) ends in September 1997 and is used in Section 3. The Fed is
since receiving data on commercial paper electronically and states that the two series
are incompatible.
9. Ferderer et al. uses these three variables in their model of the spread, as well as other
variables that are not available on a daily basis.
10. The coefficients on both interest rate uncertainty variables are robust to using the DE-
FAULT variable in levels.
11. Bernanke (1990) notes that the simple correlation coefficient between the spread between
aaa and baa corporate bonds and the paper-bill spread is 0.04 over the 1961–1989 period.
The coefficient on DEFAULT in Bernanke’s paper is 0.0077 with a t-statistic of 0.66; in Ferderer et al.’s model, the coefficient on DEFAULT is also insignificantly different
than zero.
12. The dramatic difference in the size of the coefficients on interest rate uncertainty, relative
to the results in Table 2, can be attributed to the different conditional variance series
(i.e., the conditional variance from the first difference of the US T-bill (CVARIMA) is
much smaller than the conditional variance from the level of the US T-bill (CVMEAN).
13. I thank an anonymous referee for this observation.
15. Interest rate uncertainty was remarkably resilient to the Asian crisis as was the rest of
the US economy.
16. All data are monthly and come from the Federal Reserve. Industrial production and M2
are seasonally adjusted.
17. Both of these indexes are specifically designed to predict future (real) economic activity
and are therefore natural candidates for the baseline model. The University of Michigan’s
consumer sentiment index was included but was subsequently dropped due to its weak-
ness as a predictor of real output. Many regressions were estimated and the robustness of
DLEAD and NAPM as significant predictors of real output, according to exclusion tests,
was impressive. The chosen lag length, according to the Akaike information criterion,
was six lags for all regressions.
18. The LR and F-tests for a set of linear restrictions are asymptotically equivalent and both
are provided for completeness. If J denotes the total number of linear restrictions being
tested we have: JF~a LR → χ^2_J, where ~a stands for ‘asymptotically equivalent.’
19. These results are consistent with the previous literature (see Emery (1996) and Thoma
and Gray (1998) and references therein.
20. The fact that POLICY and M2GROW are redundant perhaps reflects the fact that the
official index of leading economic indicators contains these variables along with eight
other economic variables.
21. Given that both interest rate uncertainty measures are generated regressors, I addressed
the validity of the exclusion test results by conducting simulations. The simulations were
performed as follows. Using the estimated standard deviations of the test equations, I
generate artificial normal deviates u^*_i. Using u^*_i and (a) the actual values of the RHS
variables and (b) the estimated regression coefficients of the test equations, I generate artificial values of the dependent variable \( y_{ij}^* \). I then run the test regressions using \( y_{ij}^* \) and calculate (and save) the \( F \)-tests and its \( p \)-value. I repeat for \( j = 1, 2, \ldots, 5000 \) and compute the average (over all replications) rejection frequency and \( p \)-values. The average \( p \)-value for CVMEAN is 0.008 and for CVARIMA the average \( p \)-value is 0.044.

22. Bernanke (1990) conducted a similar exercise using the adjusted \( R^2 \) as the criterion.

23. Each omitted variable test is equivalent to running the regression with the variable included and conducting an \( F \)-test.

24. All variables maintained their significance when FF was added to Model 11. The adjusted \( R^2 \) rose to 0.4093 and the AIC fell to \(-7.874\). Again, the results should be interpreted with caution given the failure to reject a unit root in FF.

25. The forecasting ends June 1998 since the sample ends December 1998. The RMSE for the baseline model + SPREAD (Model 3) is adjusted since Fed data on the spread ends August 1997. I estimated each model over the shorter period and maintained the ranking of the Model 3 in terms of the RMSE.

Acknowledgments

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References


