The Federal Reserve's Monetary Policy Response to Credit Market Stress

David Krisch

Gettysburg College - Department of Economics

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Abstract

The unfolding of the current financial crisis has led to researchers and policymakers evaluating the use of credit market variables in forming the optimal federal funds rate. This paper provides the theoretical justification of why a central bank should offset movements in credit spreads one-for-one. The rationale for consideration of these measures by the Fed asserts that key rate of interest available to households and firms that affects aggregate demand is a risky one. Changes in the credit spread, therefore, change the neutral risk-free rate controlled by the central bank and warrants a monetary policy response. This paper estimates a forward-looking Taylor rule using non-linear 2SLS with ex post data and OLS with real-time data from the end of Volcker disinflation to the third quarter of 2008 to determine if the Fed responded to credit market stress. The results provide strong evidence that the Federal Reserve does respond to multiple credit spread variables, independent of output and inflation, with a greater magnitude of response to less risky corporate assets. Applying the policy recommendation and actual policy over differing Fed eras illustrates a weaker response to credit markets since the Volcker era.

1. Introduction

The Federal Reserve has a dual mandate to maximize output and stabilize prices. The unfolding of the current global financial crisis, however, has left many researchers and monetary policymakers in the United States reviving a dialogue concerning the use of *"financial stress"* indicators as one element in determining monetary policy in addition to the mandated considerations. One such indicator, the credit spread (defined as the difference between corporate and Treasury bond yields), tends to increase during economic contractions and decrease during expansions. Over the previous two business cycles, this pattern has become especially noticeable, drawing the attention of Fed Chairman Bernanke (2009) and additional FOMC governors on the repercussions of rising risk premia on the real economy.

Bernanke (2009) describes the abrupt end of the credit boom experienced after the Volcker disinflation to the closing stages of the Greenspan era as having "widespread financial and economic ramifications". He continues by commenting that during this crisis, "rising credit risks and intense risk aversion have pushed credit spreads to unprecedented levels…[this has] in turn taken a heavy toll on business and consumer confidence and precipitated a sharp slowing in global economic activity (Bernanke 2009)." In response, the Federal Reserve has cut the federal funds rate (its traditional monetary policy instrument) to unprecedented levels and initiated non-traditional "credit easing" programs to aid in unfreezing the credit markets.

While this bold action demonstrates the Fed's willingness to target credit spreads during times of crisis, it is unclear whether it responds to credit markets as a general rule. Governor Mishkin (2008) remarks that during normal financial conditions, the primary concern of policymakers ought to remain the traditional macroeconomic indicators (production, unemployment, and inflation); however, he argues that when turmoil occurs in the financial markets greater consideration should be given to monetary policy.

These elements question the conventional wisdom that the relationship between short-term neutral interest rate (controlled by the Fed) and the interest rate at which firms can borrow (the interest rate on corporate bonds) that keeps the economy in equilibrium is stable (McCulley and Toloui 2008). Recent theoretical work by Cúrdia and Woodford (2008) asserts that the Fed must consider the risky rate of interest in the economy instead of the short-term risk free interest rate to minimize deviations of expected inflation and output from their targeted, natural levels.

These new assertions by policymakers and researchers motivate this paper's analysis of whether the Federal Reserve reacts to multiple credit spread measures in forming an interest rate target. While previous research primarily focuses on asset prices and a single credit spread measure, this paper deviates by examining *multiple* credit spreads and *the monetary policy response to stress in these markets*. This analysis provides strong empirical evidence of Fed reaction to credit spreads from the end of the Volcker disinflation to late-2008.

The remainder of this paper is organized as follows. In the next section, a review of previous literature illustrates the New Keynesian evolution of monetary policy with respect to backward and forward-looking monetary policy rules (or "Taylor Rules"). Section 3 describes the conventional wisdom, theoretical model of the economy, and previous empirical research of central bank reaction to credit spread measures. Section 4 provides the forward-looking monetary policy rule used for estimation, data description, and empirical evidence that the Federal Reserve does in fact react to changes in differing credit markets. Section 5 compares the estimated responses to credit spread measures over differing Fed Chairman periods with the optimal response. Finally, Section 6 presents the conclusions, policy implications, and suggestions for future research.

2. A Primer on Simple Monetary Policy Rules – Frontier Literature

The foundations for the questions posed in this paper originate from the New Keynesian theoretical framework[1] and empirical results explored previously by macroeconomists examining central behavior through monetary policy rules. These works assume that the central bank chooses a short-term interest rate that minimizes the deviation of inflation and output from their natural levels. The response is optimal if the policymaker follows a rule based on the minimization of these variables in the New Keynesian model of the economy consisting of an Aggregate Supply and IS curve.

The seminal work on monetary policy rules by Taylor (1993) contends that the Federal Reserve considers the average inflation rate over four previous quarters and the deviation of real GDP from its trend line in determining the neutral short-term interest rate target. The results from the OLS estimates indicate that the Federal Reserve from 1987 to 1992 actively stabilized the economy by adjusting the interest rate target when inflation and output deviated from their respective targeted levels. This work is the catalyst for research of monetary policy rules.

[1] For details see Goodfriend and King (1997) for a technical overview of New Keynesian theory

Clarida, Galí, and Gertler (2000) extends Taylor (1993) by using a “forward-looking” Taylor rule – incorporating expected inflation for future periods instead of actual or past price levels when forming its inflation target. The authors’ forward-looking rule nests the original Taylor rule as a special case – describing if either lagged inflation or a linear combination of lagged inflation and the output gap is a sufficient statistic for forecasting future inflation, than the forward-looking model collapses back into the original backwards-looking Taylor rule. They test their model to identify if the Federal Reserve during the Pre-Volcker Period (1960:1-1979:2) and Volcker-Greenspan Period (1979:3-1996:4) proactively stabilized for inflation and output.

Using Generalized Method of Moments estimation, Clarida et al. demonstrates the existence of a systematic relationship between the federal funds rate, forecasts of future inflation, and output in a forward-looking model. They find differences between the two periods of central bank policy regimes – the Pre-Volcker Fed practiced destabilizing inflationary behavior, while the Post-Volcker Fed proactively stabilized for inflation and output. The baseline estimates assume policymakers consider a one-quarter future target horizon for the rate of change of GDP deflator inflation and output gap measure. In addition, Clarida et al. offer an alternative estimation of inflation (the rate of change of the consumer price index) and two alternatives for the output gap (the deviation of the unemployment rate from a similar time trend and the deviation of GDP from a fitted quadratic function of time).

Orphanides (2001), however, argues that the results obtained by Taylor (1993) and Clarida et al. (2000) are misleading. The author contends that estimates of a policy reaction function based on ex post revised data provide misleading historical results because it fails to consider the data available to FOMC members in real-time. Orphanides compares estimations of backward and forward-looking Taylor rules with revised data to real-time NIPA data and

Greenbook forecasts. The substantive empirical finding of the work is that ex post coefficients consistently have standard errors greater than those in real-time. While the critique provides areas of concern, Orphanides recognizes that using ex post revised data in a forward-looking Taylor rule estimation provides "fairly accurate" results.

3. Should the Federal Reserve React to Credit Market Stress?

Bernanke and Gertler (1999) contend that monetary policy reaction to asset price measures provides a greater amount of instability. They argue the conventional wisdom that a strong commitment to a flexible inflation-targeting stabilization policy undertaken by the central bank achieves both financial and macroeconomic stability. The authors provide theoretical rationale and empirical evidence that responding to expansionary shocks in equity markets incorporated in a monetary policy rule leads to a greater destabilization of the economy. The prescribed response by the authors is to clean up in the aftermath of a correction, rather attempting to outguess the market during a period of "irrational exuberance".[2] This conclusion echoes the remarks by Mishkin above.

Recently some authors, including Taylor (2008) and McCulley and Toloui (2008), have made the case for a more systematic approach to managing credit spreads through monetary policy. These authors argue that the key interest rate that determines aggregate demand is a risky one. Changes in the credit spread change the neutral risk-free rate controlled by the Fed. Therefore, policymakers should react to changes in the credit spread, ideally one-for-one.

Barbera and Weise (forthcoming) make the same point and argue that asymmetry in the Fed's response to changes in credit spreads – accommodating downward movements during

[2] In a famous speech, Greenspan (1996) describes that the Federal Reserve should not react to the "irrational exuberance" of investors in asset markets. He is referring to the conventional wisdom of central bankers not to respond to asset price "bubbles".

economic expansions while resisting upward movements during contractions – has contributed to economic instability in recent years. The authors employ an IS-AS-TS Wicksellian model[3] to describe the current financial crisis with the addition of a key Minskyan concept – the evolution of perceptions of risk over the business cycle as reflected by credit spreads – to clarify the challenges facing the Federal Reserve. The authors derive a Minskyan backwards-looking Taylor rule within this framework, and report that the Fed acted aggressively in periods where the Baa-Treasury credit spread was above its mean value, but exercised looser monetary policy during periods of where the Baa-Treasury Credit spread was below its average – affirming the comments by Governor Mishkin. The theoretical prescription by the authors is to employ a one-for-one policy response to changes in the risk premium.

Barbera and Weise's argument can be illustrated using a standard New Keynesian model based on an IS and Aggregate Supply (AS)[4] curve:

$$\text{(IS)} \quad y_t = a_0 - \gamma(r_t - r^*) + u_t \tag{1}$$

$$\text{(AS)} \quad \pi_t = E_t\pi_{t,k} + \lambda y_t + z_t \tag{2}$$

where y_t is the output gap, r_t is the real long-term interest rate, r^* is the Wicksellian natural rate of interest, π_t is the inflation rate in period t, $E_t\pi_{t,k}$ is the expected inflation rate in period t+k, u_t is a demand shock, and z_t is a price shock. Equations (1) and (2) are consistent with the linearized versions of New Keynesian model. These models define the real interest rate as a risk-free rate:

$$r_t = i_t - E_t\pi_{t,k} \tag{3}$$

where i_t is the nominal interest rate (in this case the federal funds rate) determined by the central bank. Weise and Barbera assume that the real rate of interest is a risky one:

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[3] See Weise (2007)
[4] This AS curve could also be interpreted as a Phillips Curve

$$\text{(TS)} \quad r_t = (i_t - E_t\pi_{t,k}) + \sigma \tag{4}$$

where σ is the risk premium or the spread between risky and risk-free rates of returns on debt instruments.[5] The complete Wicksellian model is shown in **Figure 3.1**.

Intuitively replacing equation (3) with equation (4) in the IS equation (1) should not be contentious. The economy's demand for goods and services is not affected by the short-term interest rate that the central bank controls through the federal funds rate or longer-term Treasury bond yields, but rather through the interest rates at which households and firms can borrow (Ball 2009). Assuming the Fed's objective is to maximize output and maintain price stability, it should adjust the risk-free nominal rate of interest one-for-one to changes in σ (this is formally derived in Section 4.1). This response in the Wicksellian model allows for back of the envelope examples.

Figure 3.2 shows a shock to the credit markets due to an increase in the risk premium. In period t the economy is in equilibrium. In time period t+1, this credit shock shifts the TS curve upwards from TS_0 to TS_1 and increases the risky rate of interest from r* to r_1. In order to stabilize the economy the Fed accommodates such a shift in the TS curve one-for-one by decreasing the short-term interest rate from i_0 to i_1 to keep the economy at a point of equilibrium observed in time period t. This response to ease credit markets brings the risky rate of interest from r_1 to r*.

Mishkin (2008), however, voices the opinion that the Fed should only react to credit markets during a period where an increase in the credit spread occurs (such as in **Figure 3.2**). **Figure 3.3** illustrates a boom in the credit markets with the same magnitude, where the TS curve shifts downwards from TS_0 to TS_2. The response in order to keep the economy in equilibrium is

[5] See Ball (2009), Weise (2007), Weise and Barbera (forthcoming), Cúrdia and Woodford (2008) for further explanation.

to adjust the nominal short rate of interest from i_0 to i_2. Here, the magnitude of response during the credit boom (the distance between i_0 to i_2) is equal to the magnitude of response (the distance between i_0 and i_1) shown during the credit tightening. This model suggests an augmented response by the Fed to changes in the credit market in addition to reacting to shifts in output and expected inflation.

Cúrdia and Woodford (2008) is the only recent paper to examine monetary policy in the presence of credit spreads in a rigorous theoretical framework. The authors extend the New Keynesian model to incorporate credit spreads, concluding that optimal monetary policy responds to changes in credit markets. In their model, however, credit spreads reflect financial market frictions rather than risk premia. Credit spreads affect aggregate supply as well as aggregate demand, so the optimal monetary policy response is more complicated than conceived in previous studies.

Early empirical literature integrating forward-looking monetary policy rules with asset price and credit measures focuses on foreign central banks. One such author, Smets (1997) asserts that using these variables in forward-looking monetary policy reaction functions are essential to maintain price stability with the presence of asset market shocks. He constructs a forward-looking Taylor rule (similar to Clarida et al.) with three financial variables: a nominal trade-weighted exchange rate, a ten-year nominal bond yield, and a broad stock market index. The author applies this central bank policy reaction function to the behavior of the Australian and Canadian monetary authority between 1989:1 and 1996:3. The findings indicate that the Bank of Canada decreases interest rates by 0.14 percent in response to a one percent appreciation in foreign exchange rates and -0.09 percent to a one percent appreciation in equity markets. The significance of a trade-weighted exchange rate produced an expected result for Canada because of its explicitly stated targeting of foreign exchange rates. The reaction to changes in equity prices, however, produced an unexpected finding considering the conventional wisdom of Bernanke and Gertler.[6] In contrast, the Reserve Bank of Australia does not respond to changes in any of the asset price or exchange rate variables.

In addition, Smets describes the potential pitfalls and advantages of setting monetary policy in terms of a monetary conditions index (MCI). The results yielded from the previous estimations demonstrate that Canada does use an MCI in determining appropriate monetary policy because financial shocks act as the primary force behind asset price innovations. The author cautions, however, that determining the optimal weighting of the financial measurement in a MCI is difficult because the coefficients change over time. This change occurs from the phenomenon of interest and exchange rates affecting the traded and non-traded goods differently. Despite potential pitfalls, the author concludes by suggesting that integrating asset prices and exchange rates into monetary policy provides for greater economic stability.

One of the few recent empirical studies to employ a general forward-looking Taylor rule approach is by Castro (2008). The author compares a traditional monetary policy rule (similar to Clarida et al.) with an augmented non-linear forward-looking policy rule for the Bank of England, European Central Bank, and Federal Reserve. Castro uses the Kalman filter[7] to construct an extended financial conditions index comprised of the weighted real effective exchange rate, real share prices, real property prices, Treasury-Baa credit spread, and future interest rate spread. This addresses the concerns Smets raised in determining an effective weighting for asset price and exchange rate variables. Castro found only the credit spread variable significant in a traditional forward-looking linear Taylor rule for Federal Reserve and

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[6] See Bernanke and Gertler (1999, 2001)

[7] Montagnoli and Napolitano (2005) provide a further explanation of the use of a Kalman filter algorithm

Bank of England – adhering to the conventional wisdom of Bernanke and Gertler. Furthermore, estimates of a non-linear Taylor rule transformation with financial and asset price variables proved viable only in the case of the European Central Bank.

This paper extends previous research by estimating a Taylor rule for the United States augmented by multiple risk premia. This empirical analysis includes the use of 2SLS for ex post revised as well as OLS for real-time data.

4. Has the Federal Reserve Reacted to Credit Market Stress?

4.1. A Simple Policy Rule

This section describes monetary policy with a simple rule for the model described by the equations (1), (2), and (4). The central bank's target rate, i_t* for the current period is:

$$i_t^* = i^* + \beta E_t \pi_{t,k} + \gamma E_t y_{t,q} \tag{5}$$

where i* is the neutral interest rate when both the inflation and output gap are at their targeted levels, β is the Fed's response to expected inflation, and γ is the response to the output gap. The effective federal funds rate, i_t, for this period is:

$$i_t = \rho_1 i_{t-1} + \rho_2 i_{t-2} + (1 - \rho_1 - \rho_2) i_t^* + u_t \tag{6}$$

where ρ_1 and ρ_2 are exogenous smoothing parameters which reflect that the central bank gradually adjusts the actual interest rate towards to i*. Substituting the targeted federal funds equation (5) into the actual federal funds equation (6) yields the final baseline model:

$$i_t = \rho_1 i_{t-1} + \rho_2 i_{t-2} + (1 - \rho_1 - \rho_2)[(r^* - (\beta - 1)\pi^*) + \beta E_t \pi_{t,k} + \gamma E_t y_{t,q}] + u_t \tag{7}$$

where π^* is the inflation target and r* is the real federal funds target rate equal to i*- π^*. The 'Taylor Principle', dictates that the policy rule (7) is stabilizing when $\beta \geq 1$. A risk premium variable (σ) added to the baseline equation (8) yields the augmented Taylor rule equation:

$$i_t = \rho_1 i_{t-1} + \rho_2 i_{t-2} + (1-\rho_1-\rho_2)[(r^*-(\beta-1)\pi^*) + \beta E_t \pi_{t,k} + \gamma E_t y_{t,q}] + \omega\sigma_t + u_t \quad (8)$$

where the response to the coefficient ω by the Federal Reserve should equal one according to the theory above illustrated in **Figures 3.2** and **3.3**.

4.2.1 Ex-post Revised Baseline and Alternative Estimates

I estimate equation (8) for the United States for the period 1984:1-2008:3. I first estimate the equation in a manner similar to Clarida et al. (2000). The data for the CGG-style regressions is from the Haver Analytics USECON database. The dependent variable is the (quarterly average) federal funds rate. The inflation rate is the core PCE inflation rate. The output gap is the log of the ratio of actual GDP in chained 2000 dollars to the Congressional Budget Office's estimate of potential real GDP. All of the data in these regressions is "ex post" – that is, it is the most recent (as of the end of 2008) revised data. This paper considers three alternative measures of credit spreads: the spread between the Moody's Seasoned Baa bond yields and the 10-year Treasury constant maturity rate; the spread between the Aaa and 10-year Treasury yields; and the spread between "High-Yield"[8] and 10-year Treasury yields (shown in **Figure 4.1**). Each credit spread variable are deviations from their mean values.

Equation (8) is estimated using a non-linear, two-stage least squares (2SLS) procedure to eliminate simultaneity bias.[9] Clarida et al. and others use Generalized Method of Moments (GMM) method instead. The key difference between these procedures is that 2SLS assumes that the residuals are normally distributed, where GMM does not. The instruments include four lags

[8] The high yield bond measure used for this paper is the Merrill Lynch High-Yield Corporate Cash Pay Index, which is comprised of BB to CCC corporate "junk" bonds. It should be noted the series sample only encompasses values between 1987:1 and 2008:3. The findings reported for these measures will incorporate the sample period 1989:4-2008:3.

[9] To find an equation from multiple different equations with differing endogenous variables, the final equation (8) is estimated with 2SLS. The 2SLS technique nests many common estimators and is chosen in order to avoid the correlation between right-hand side variables and the residuals (Schmit 2005). Variables are instrumented with lags to make estimations without affecting target value estimates within the period. If forecasted values are known, this is not necessary.

each of the federal funds rate, inflation rate, output gap, credit spreads, commodity price inflation, and the spread between ten year and three year treasury constant maturity yields.

The target horizon for the initial 2SLS policy reaction function estimation assumes the monetary authority considers one-quarter future inflation and the current quarter's output gap (k=1, q=0). The baseline estimation using ex-post revised data (reported in **Table 4.1**) for the interest rate rule parameters π^*, γ, β, ρ_1, ρ_2 produces findings that are consistent with those reported in previous literature.[10] The existence of heteroskedasticity and autocorrelation occurs across all horizons, which I correct for by using Newey-West standard errors (Newey and West 1987).

Values for the β and γ coefficients are strongly significant. Estimates of β lie above unity, suggesting that the Federal Reserve's monetary policy stabilizes the real economy proactively in response to expected changes in the output gap and inflation rate. The value of 2.46 obtained for π^* in the baseline estimation falls within expected target inflation rates for this period while the coefficients for the smoothing parameters ρ_1 and ρ_2 indicates that policymakers substantially smooth adjustments in the federal funds rate.

Adding the Baa-Treasury credit spread to the baseline Taylor rule (Alternative 1, Table 2, k=1, q=0) provides substantial evidence that the Fed responds to this variable. When the risk premium rises by one percentage point above the mean value, the Fed decreases the interest rate by 0.44 percentage points. The estimated inflation target and other coefficients are similar to those in the baseline model.

Augmenting the baseline Taylor rule with the Aaa-Treasury credit spread (Alternative 2, Table 2, k=1, q=0) provides evidence that the Fed responds to this variable. This estimation

[10] See Clarida et al. *(*2000), Orphanides (2001), Castro (2008)

yielded a statistically significant value for the expected inflation coefficient but an insignificant value of the inflation target. When the risk premium rises by one percentage point, the Fed decreases the interest rate by 0.67 percentage points. This effect is statistically significant at the one percent level.

Augmenting the baseline equation with a High Yield-Treasury spread for the baseline target horizon (Alternative 3, Table 2, k=1, q=0), produces significant evidence that the Fed responds to this variable as well. An increase in the High Yield-Treasury spread of one-percentage point results in the Fed decreasing the federal funds rate by 0.08 percentage points. The value for the High Yield coefficient is less than the Baa-Treasury and Aaa-Treasury measurements, establishing a pattern of response - the higher the credit rating, the greater the response to deviations from its mean value. According to the baseline and alternative estimations under the target horizon k=1, q=0, there is strong evidence that the Federal Reserve reacts to changes in the risk premium, rejecting the null hypothesis that it does not react to these measures.

4.2.2 Ex-Post Alternative Horizons

The prior baseline and alternative estimations assume that the Federal Reserve considers the current quarter's output gap and looks ahead one quarter for inflation (k=1, q=0). This section considers two differing target horizons - a forward-looking annual inflation target with the current (k=4, q=0) and subsequent quarter output gap target horizon (k=4, q=1). Both horizons' baseline estimations produce lower inflation targets (2.30 and 2.24 respectively), while values of β lie above unity.

The results yield evidence of Federal Reserve policy reaction to stress in the Baa-Treasury risk premium measures across both alternative horizons. Each coefficient is slightly greater than the finding obtained in the initial horizon (-0.46 and -0.44 respectively), while the augmented forward-looking policy rule estimation is in accord with the Taylor principle. In addition, this study also finds strong evidence for the Aaa-Treasury credit stress measure in both alternative horizons, however, only the second specification (k=4, q=1) produces highly significant values for all estimated variables. The results indicate that the Federal Reserve adjusts the interest rate by -0.63 in response to a one percent deviation from the average risk premium value while the inflation target of 1.66 suggests that considering this measurement produces a lower estimate of the central bank's inflation tolerance. The ex post estimates presented across all horizons reject the null hypothesis that the Federal Reserve does not react to stress in the credit market.

4.3.1 Real-Time Baseline and Alternative Estimations

Orphanides' critique of ex post data analysis prompted the use of Greenbook forecasts and real-time data which are available on the Federal Reserve Bank of Philadelphia's website. This paper uses Greenbook forecasts of the GNP or GDP deflator as a proxy for the variable $E_t\pi_{t,k}$ in equation (8). The FRB Philadelphia has constructed an expected output gap series from Greenbook data for the period 1987:Q3 to 2002:Q4. Weise (2008) constructed an output gap series using Greenbook forecasts and real-time data. These estimates are founded on the assumption that the Fed's estimate of potential GDP was based on a linear trend estimated over the preceding ten years. For each quarter, he ran a regression of real-time log GNP or GDP on a constant and a time trend over the previous ten years of data. To compute the Fed's predicted output gap for the current and future quarters, he extended the trend line and computed the difference in the log of the Greenbook GNP/GDP forecast and the corresponding estimate of trend GDP. This data is available for the period 1968:Q1-2000:Q4. As shown in **Figure 4.2**, for most of the 1987-2000 sample period this data series corresponds closely with the Philadelphia Fed series. This paper uses the Weise series for 1984:Q1 to 2000:Q4 and appends the Philadelphia Fed series for the period to from 2001:Q1 to 2002:Q4 as a proxy for the term $E_t y_t$, in equation (8).

The results for the baseline estimations are reported in **Table 4.2**. Estimates are similar to those in **Table 4.1**, however, with higher inflation target values. Alternative estimations produce substantial evidence that the Federal Reserve reacts to stress in the credit markets. For an increase of the Baa-Treasury spread greater than the mean value for the risk premium, the Fed reacts by lowering the federal funds rate by 0.32. The alternative estimations also produced a similar finding to the baseline results for the High Yield-Treasury spread measure with the Fed lowering the federal funds rate by 0.06 percentage points for a one percent increase.

Similar to ex post estimations, the Aaa-Treasury spread coefficient is significant in the initial horizon, however, the value for the inflation target coefficients lacked statistical significance. The Aaa-Treasury spread coefficient yielded a value of -0.72. The β coefficient, however, was below unity. This suggests that the evidence for the use of Aaa-Treasury credit spread measures were less substantial than other terms.

4.3.2. Real-Time Alternative Horizons

Regressions using alternative horizons also produce strong evidence that the Federal Reserve reacts to stress in credit markets. In the first alternative horizon (k=4, q=0) the reaction of the Federal Reserve to stress in the Baa-Treasury spread is nearly identical to that in the initial horizon. The High Yield-Treasury spread coefficient for this alternative target horizon yields a value of -0.04, which provides less convincing evidence then for the previous measures discussed.

The second alternative horizon (k=4, q=1) yields risk premium coefficients slightly less than the first alternative target horizon examined. The Federal Reserve reacts to a one percentage point increase of the Baa-Treasury risk premium by reducing the federal funds rate by 0.27 percentage points. As in previous horizons, the Aaa-Treasury spread coefficient is strongly significant and yields a greater response to changes in the risk premia than other measures. However, there is less substantial evidence that the Fed responds to changes in the High Yield spread in this specification.

Overall, the results indicate that Federal Reserve responds to credit stress. This paper finds a greater reaction to deviations from mean values in the Aaa-Treasury risk premium measure than Baa-Treasury and High Yield-Treasury spread measures. Real-time and Greenbook forecast forward-looking Taylor rule estimations reject the null hypothesis that the Federal Reserve does not respond to stress in the credit markets.

4.4 Sensitivity Testing

In addition to baseline and alternative estimations conducted with ex post and real-time data, four sensitivity checks test the stability of the results. I first estimate equation (8) by GMM as Clarida et al. and others have done. Next, from the Haver USECON database I replace PCE deflator inflation with CPI and GDP deflator inflation. Next, I replace the output gap with the unemployment gap.[11] Finally, I test the sensitivity of the estimates and the magnitude of responses for two different sample periods.

4.4.1 Generalized Method of Moments

A GMM estimation of the ex post data (reported in **Table 4.3**) yields similar findings to those described in Section 4.2. The Fed's reaction to a one percentage point rise in the Baa-

[11]Calculated from the difference between the annualized rate of unemployment and the natural rate of unemployment from the Haver USECON database.

Treasury credit spread measure above its mean value for the sample period is to decrease the fed funds rate by 0.85 for the baseline target horizon (k=1, q=0,), 0.46 for the first alternative horizon (k=4, q=0), and 1.13 for the second alternative horizon (k=4, q=1). The reaction to Aaa-Treasury credit spread measure is -0.98, -0.34, and -0.30 for the respective target horizons. Finally, for the High Yield-Treasury credit spread measure the response is -0.18, -0.15, and -0.13 for the respective target horizons. In each case, there is strong evidence that the Fed uses these measures in determining the optimal short-term interest rate. These results reject the null hypothesis that the Fed does not react to credit market stress.

4.4.2 Inflation and Output Gap Stability

Alternative estimations using ex post data with CPI inflation (reported in **Table 4.4**) and GDP deflator inflation (reported in **Table 4.5**) produce results consistent with those described in Section 4.2. The CPI inflation measure yielded Baa-Treasury credit stress responses smaller than the initial estimates for all target horizons. The Aaa-Treasury and High Yield-Treasury credit spread response is similar to those results reported with PCE inflation. A similar pattern holds for the GDP deflator inflation measure.

Estimates with an alternative measure for the output gap – the unemployment gap (reported in **Table 4.6**) – produced similar findings to those reported in **Table 4.1**. In this case, I reverse the sign to keep the output gap results consistent to those previously examined. The sign for the credit spread variables and the relative strength of response are qualitatively similar to the 2SLS GDP gap findings. For all specifications, there is strong evidence that the Fed reacts to differing credit spread variables with alternative output and inflation measures.

4.4.3 Subsample Reaction and Sensitivity

Tables 4.7 and **4.8** report results for multiple subsamples. These results show that the Federal Reserve had differing responses for early and later sample periods. **Table 4.7** reports 2SLS forward-looking monetary policy rule estimations for the sample period 1984:1-1999:4 (Volcker-Greenspan).[12] The Baa-Treasury spread coefficients for this sample period's respective target horizons are -0.69 (k=1, q=0), -0.80 (k=4, q=0), and -0.83 (k=4, q=1). These values are greater than those reported in **Table 4.1**. This pattern repeats for the High Yield-Treasury spread. For this subsample, the results are consistent with the baseline sample period.

Table 4.8 reports the equation estimations for the sample period 1993:1-2008:3 (Greenspan-Bernanke). The values obtained for the Baa-Treasury coefficients for this sample period's respective target horizons are -0.35 (k=1, q=0), -0.36 (k=4, q=0), and -0.32 (k=4, q=1). As in the results reported in **Tables 4.1** and **4.7**, the results obtained for the credit spread variables are negative. In this period, however, the Baa-Treasury and Aaa-Treasury spread reaction values are smaller than the previous estimates. Furthermore, the estimate of β lies below unity suggesting destabilizing behavior under the Taylor rule in equation (8). High Yield-Treasury spread coefficients, however, are quantitatively similar to those found in **Table 4.1** and adheres to the Taylor principle. These results indicate that the Fed does react to credit spread measures.

The same procedure of subsample sensitivity performed using real-time data produced similar findings. As shown in **Table 4.9**, coefficients for the credit spread variables in the earlier sample period are greater than those reported in **Table 4.2**. For each credit spread measure across target horizons, the alternative estimations are consistent and statistically significant. The Baa-Treasury and High Yield-Treasury estimates in each target horizon lie above unity.

[12] Overlap between subsample estimations exists because of the small sample size

Table 4.10 reports the estimation results for the subsample 1992:1-2002:4. Estimations of coefficients on the Baa-Treasury and Aaa-Treasury spreads are significant. There is strong evidence that the Fed integrates the Baa-Treasury and High Yield-Treasury spread measures to its policy rule, with less substantial evidence for the Aaa-Treasury measure for this period.

The real-time and ex post subsample estimates show that Fed's response to Aaa and Baa-Treasury spread measures were smaller during the Greenspan–Bernanke era than the Volcker-Greenspan era. These findings give insight of the shifting philosophy of the Federal Reserve since the Volcker disinflation.

5. Policy in practice – optimal responses, historical behavior, and recommendations

This section examines the major credit contractions and expansions during the last fifteen years (1993Q3 to 2008Q3). **Figures 5.1-5.2** show the estimated response of the federal funds rate to the Baa-Treasury and Aaa-Treasury spread based on estimates from **Table 4.7** (ex post) for the target horizon (k=1, q=0) and the optimal one-for-one recommendation. This historical analysis focuses on four distinct episodes: the rise of the "New Economy", the collapse of LTCM and tech bubble correction, the "global savings glut", and the current crisis.

5.1 The "New Economy" of the mid-1990s

During the "new economy" era of the 1990s, a massive expansion occurred as a result of increases in trade, advances in technology, improvements in worker productivity, and additional availability of private international capital. **Figure 5.1** shows that monetary policy was looser than prescribed by either the optimal policy recommendation or the first sub-sample period's Taylor rule estimated coefficient for the Baa Credit Spread. **Figure 5.2** illustrates the same pattern with the Aaa credit spread reaction.

During the peak of the "new economy" in the fourth quarter of 1994, the Federal Reserve should have tightened the federal funds rate by 0.75 percent under the optimal policy recommendation and 0.40 percent under the Volcker-Greenspan rule compared to the 0.22 percent estimate for the Greenspan-Bernanke rule for changes in the Baa spread. This pattern of looser monetary policy continues until the robust growth and excessive availability of cheap capital ended in the late 1990s.

5.2. The Asian Contagion, Collapse of LTCM, and Tech Bubble Correction

The effects of the Asian financial crisis and subsequent Russian Bond default of 1998 on other emerging economies was the catalyst for fall of Long Term Capital Management (LTCM). The result was an upward shift in the TS curve as stress increased in the corporate bond markets during the fourth quarter. Monetary policy loosened but by less than the recommended response according the optimal rule or that of the first subsample estimated reaction. The Fed should have decreased the federal funds rate by 0.45 percent under the optimal rule and 0.29 percent under the Volcker-Greenspan rule, instead of the 0.16 percent under the Greenspan-Bernanke rule in Baa bond market.

To prevent a global crisis, the Fed organized private capital to bail out LTCM. Additionally, Greenspan surprisingly cut interest rates by 0.25 percent in mid-October (Krugman 2009). Growth soon returned in the economy with a quantitatively similar response of the Volcker-Greenspan, Greenspan-Bernanke, and the optimal rule to the Aaa-Treasury spread. In the case of the Baa-Treasury spread, there was a very slight deviation of the Greenspan-Bernanke from the optimal response or that of the earlier Fed era. Growth soon returned to a normal boom time level in 1999, until the first quarter of 2000 with the collapse of the technology bubble.

The burst of the tech bubble in the first quarter of 2000 and the recession of 2001 caused risk premium increases in the corporate bond market. The pattern of the Fed practicing tighter monetary policy than the optimal or early subsample prescription during the LTCM crisis magnified after the tech bubble collapse. Moderate growth, however, soon returned in the 2000-2003 period.

5.3. Storm Clouds on the Horizon? - The Global Savings Glut, Housing Boom, and Financial Innovation

During 2005, then Governor Bernanke hypothesized that a global "savings glut" was to blame for the increase in the current account deficit (Bernanke 2005). The lynchpin of his argument was that after multiple financial crises from 1994-2003, the developing countries that were once net importers of capital became net exporters. In addition, an increase in dollar denominated profits from the oil trade resulted in low interest rates and a strong domestic currency. The influx of capital allowed individuals to take out home equity lines of credit and qualify for home loans at "sub-prime" rates, contributing to the current crisis.

Another contribution to the crisis was the formation of the "shadow banking system".[13] This shadow banking system consisted of investment banks, hedge funds, and bank-created Special Investment Vehicles (SIV) that allowed for the creation of opaque investments with large 'safe' returns. Financial innovations[14] – securitization of subprime mortgage back securities (MBS), collateralized debt obligations (CDO), and credit default swaps (CDS) – combined with regulation failures and excessive leverage made for a banking crisis if there was a fall in the housing market (or United States consumption in general). If Americans defaulted on loans held

[13] See Crotty (2008) for a detailed overview of the shadow banking system. Krugman (2009) provides a more accessible overview of these entities.
[14] The Treasury Department defines these now as "legacy" assets in the private-public partnership program

on bank balance sheets, there would be a systemic failure of the global financial system that would ultimately spillover into the real economy.

In the meantime, however, looser monetary policy than the optimal policy rule or that of the Volcker-Greenspan era for both the Aaa and Baa-Treasury spreads in **Figures 5.1-5.2** show a return to pre-LTCM crisis levels between 2005 and early 2007. This was one sign of the bubble forming and the Fed should have tightened the federal funds rate aggressively. At its height in the first quarter of 2007, the Fed should have increased the federal funds rate by 0.33 percentage points in response to the increase of the Baa credit spread.

5.4. The Credit Contraction of 2007 and the start of "The Great Recession"

The first signs of the global economic crisis surfaced in 2006 when trouble arose from housing prices reaching unaffordable levels and ARM adjusting. In addition, residential investment fell, GDP slowed, and delinquency rates increased during this period. By the third quarter of 2007, this was realized by investors. The previous Aaa rated subprime mortgages were now defaulting at high rates. The losses of these assets that sat in SIVs and as top tiered capital on bank balance sheets resulted in a major write-downs. Banks hoarded liquidity and consequently the global credit markets halted from the loss of confidence in anything other than the world's safest asset – United States Treasuries.

Figure 4.1 shows the Aaa and Baa-Treasury corporate credit spreads rising to levels near post-Volcker highs. The weakening economy and higher credit spreads caused the Fed to decrease the federal funds rate from 5.25 to 2 percent. By the third quarter of 2008, **Figure 5.1** shows that the response was smaller than the optimal rule by 1.21 percent and early subsample rule by 0.78 percent. A similar pattern occurs in the Aaa credit response, however, with greater magnitude. Policymakers during the fourth quarter took bold action by decreasing the Fed Funds rate to 0.25, leaving conventional monetary policy ineffective. The augmented policy rule during this period prescribes a negative federal funds rate – resulting in the need for alternative policy 'tools' to fight the crisis. The Federal Reserve began unconventional monetary policy actions by opening up the discount window and introducing the TALF program in late 2008.

6. Conclusion

This paper provides the theoretical justification for why a central bank should offset movements in credit spreads one-for-one. This model assumes that the changes in credit spreads are uncorrelated with inflation and output. There is strong evidence that the Federal Reserve does respond to multiple credit spread variables, with a greater magnitude of response to less risky corporate assets. Finally, applying the policy recommendation and actual policy over differing Fed eras shows a weaker response to credit spreads since the Volcker era.

While it is clear that the Fed responds to corporate credit spreads, there is still the question of other channels of credit that led to the current downturn. An aggregated measure of credit might improve the analysis of the current crisis and monetary policy in general. Determining the weights of differing credit measures in this aggregated variable and evaluating non-traditional monetary policy is a focus of future research.

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Figures and Tables

Figure 3.1. The Wicksellian (IS-AS-TS) Model

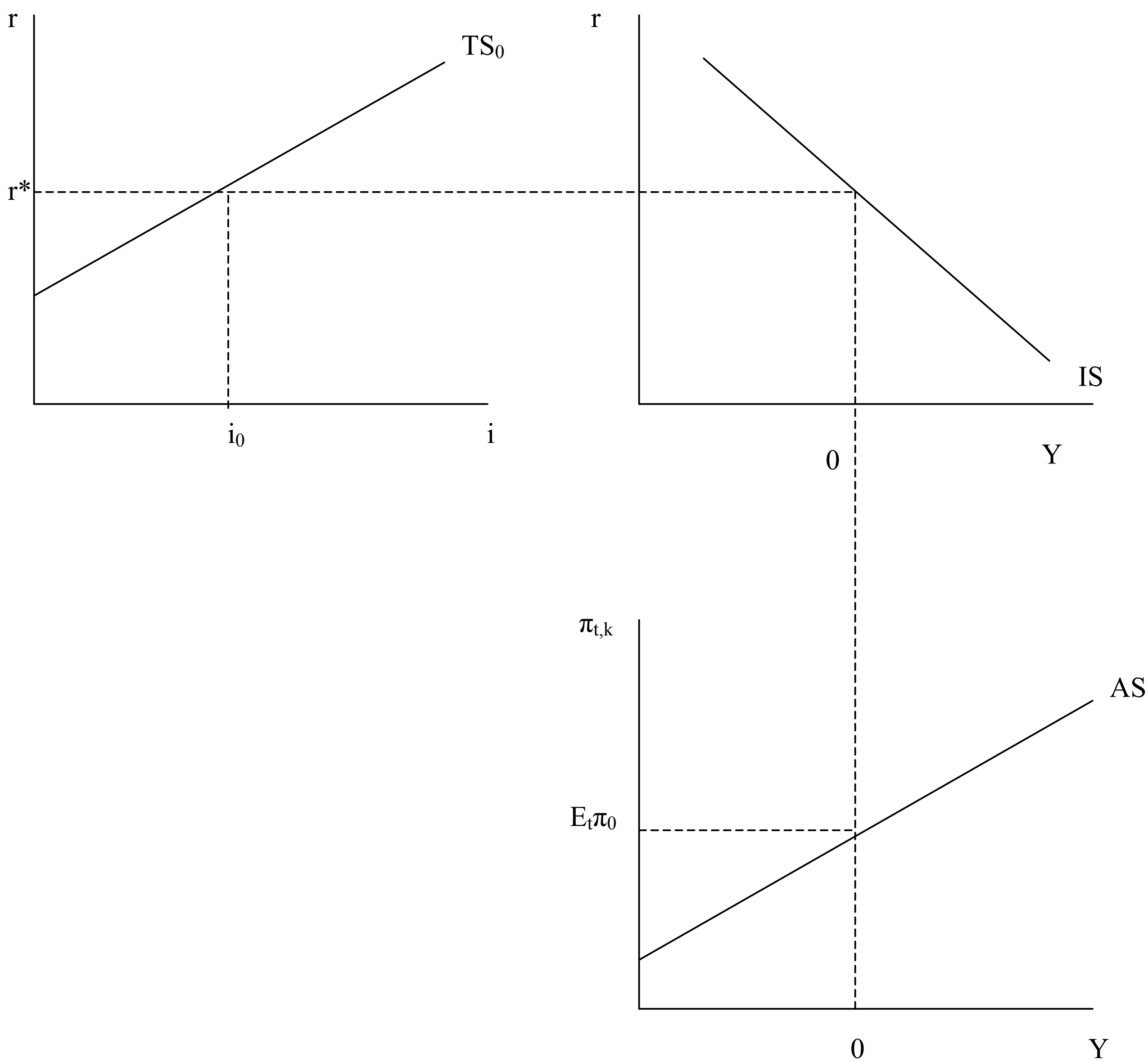

Figure 3.2 – The Wicksellian Model with a Credit Shock

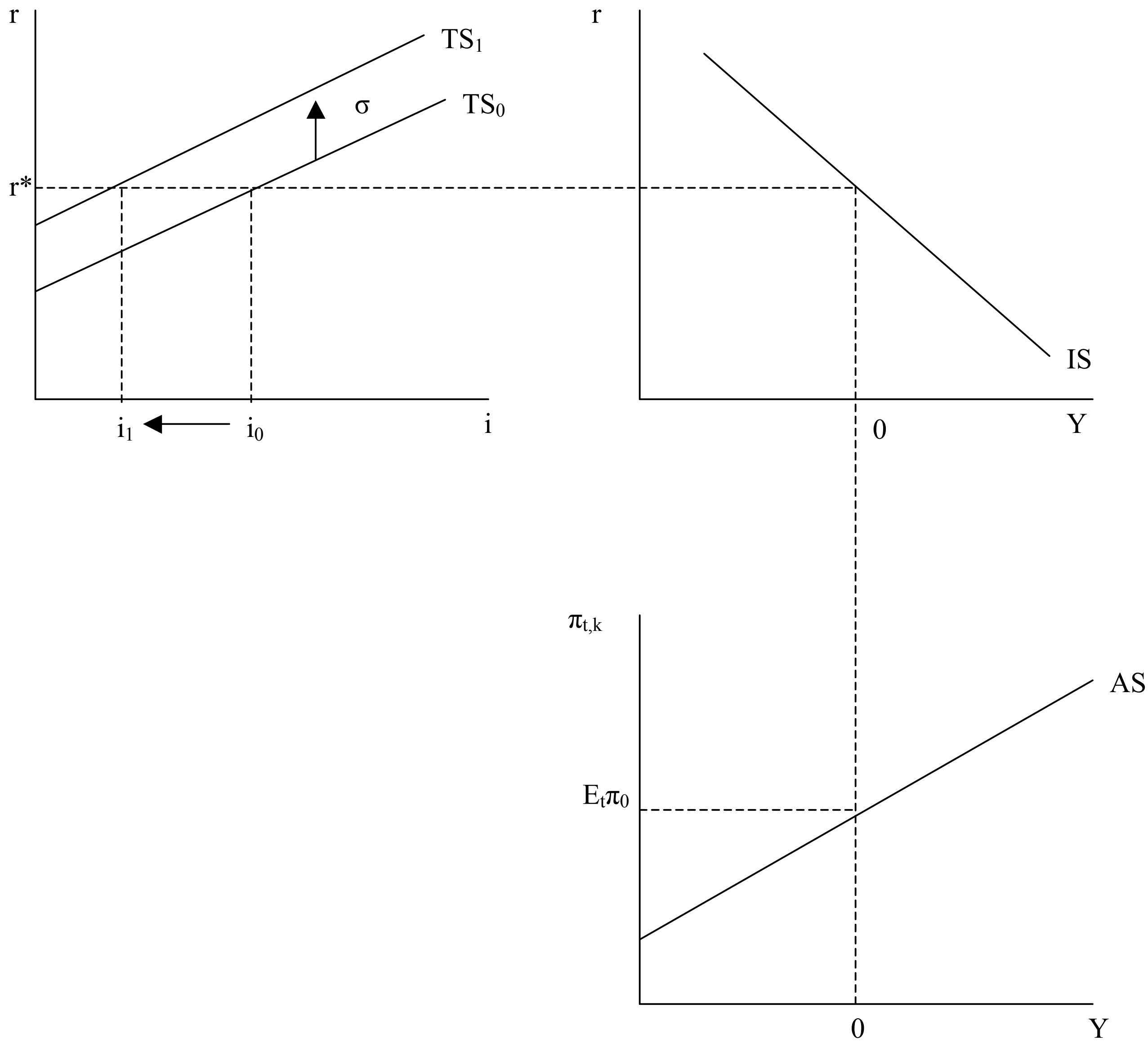

Figure 3.3. The Wicksellian Model with a Credit Boom

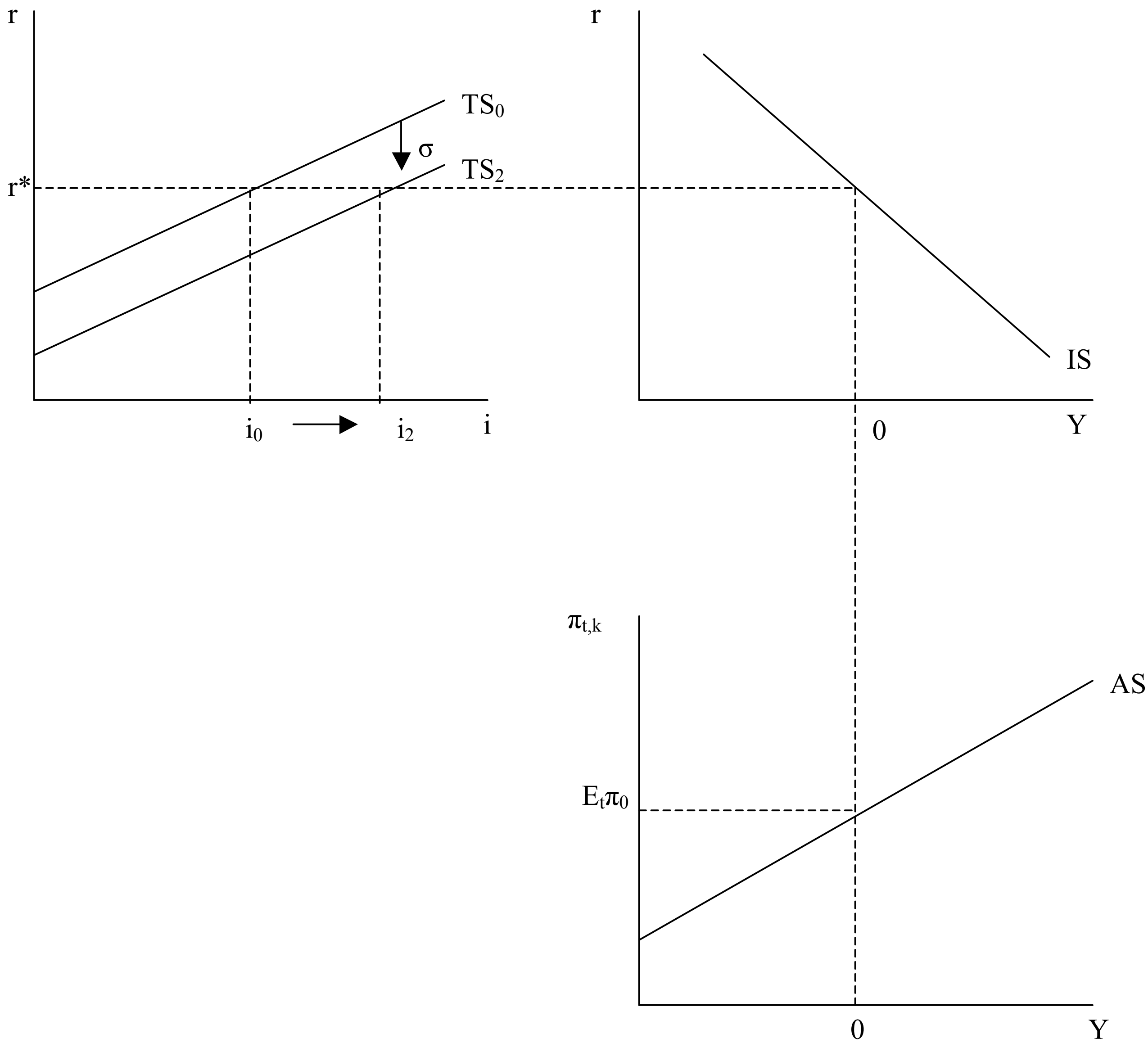

Figure 4.1. Credit Spreads Between Corporate and Treasury Bond Yields (1984:1-2008:3)

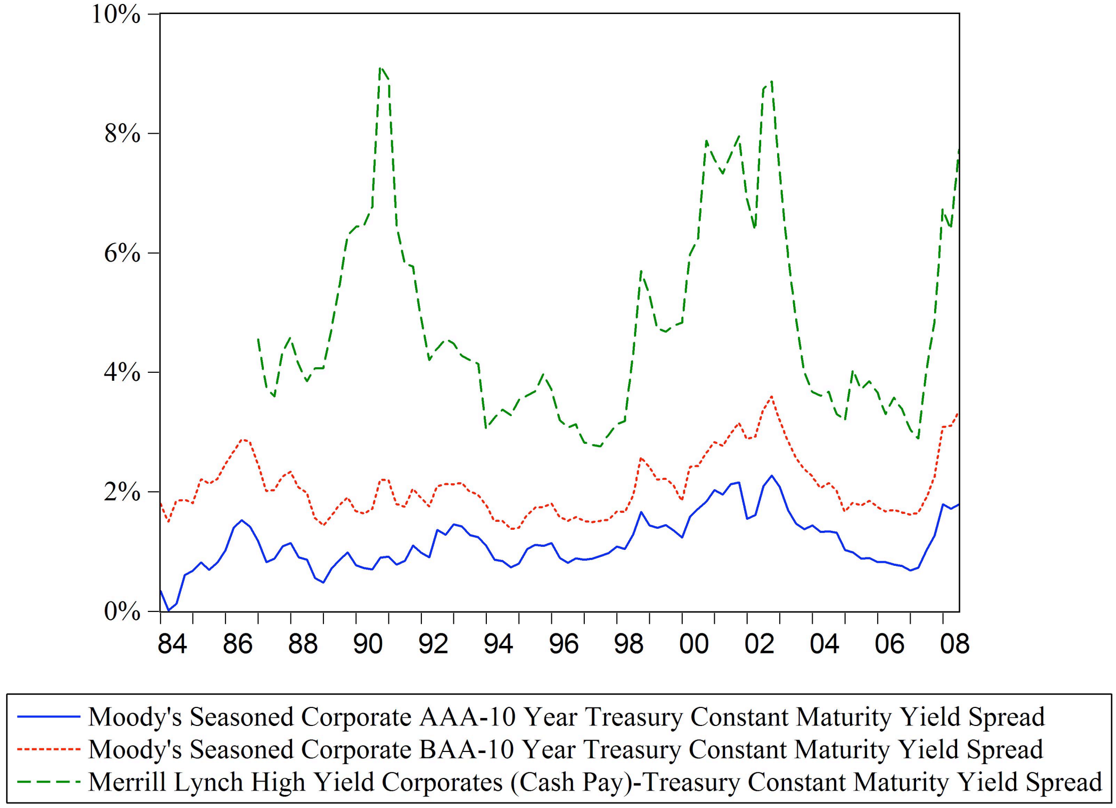

Figure 4.2.Alternative Output Gap Series

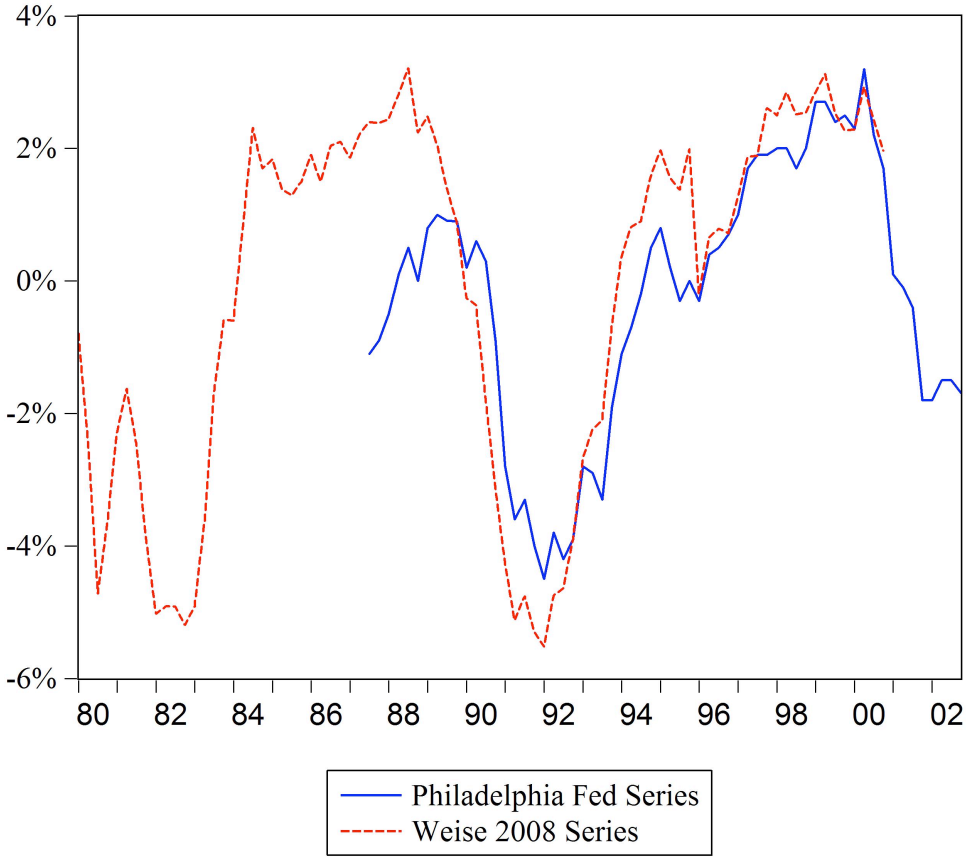

Figure 5.1. Federal Funds Rate Response to Baa-Treasury Credit Spread Taylor Rules w/ ex post data (k=1, q=0)

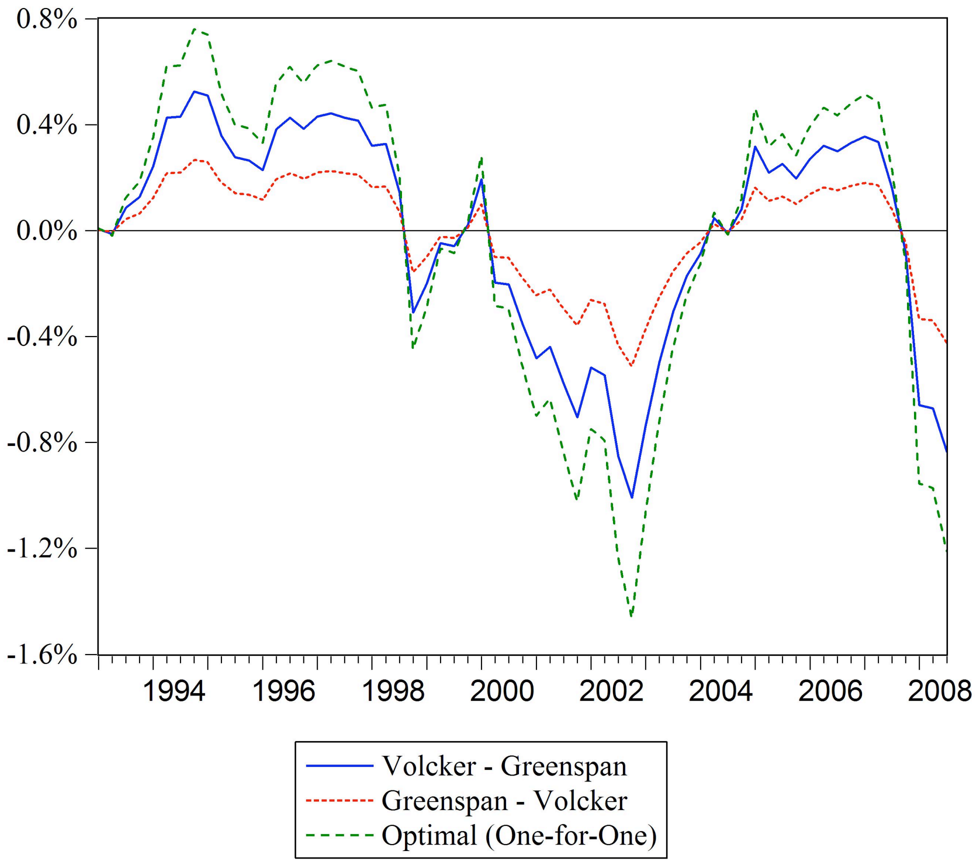

Figure 5.2. Federal Funds Rate Response to Aaa-Treasury Credit Spread Taylor Rules w/ ex post data (k=1, q=0)

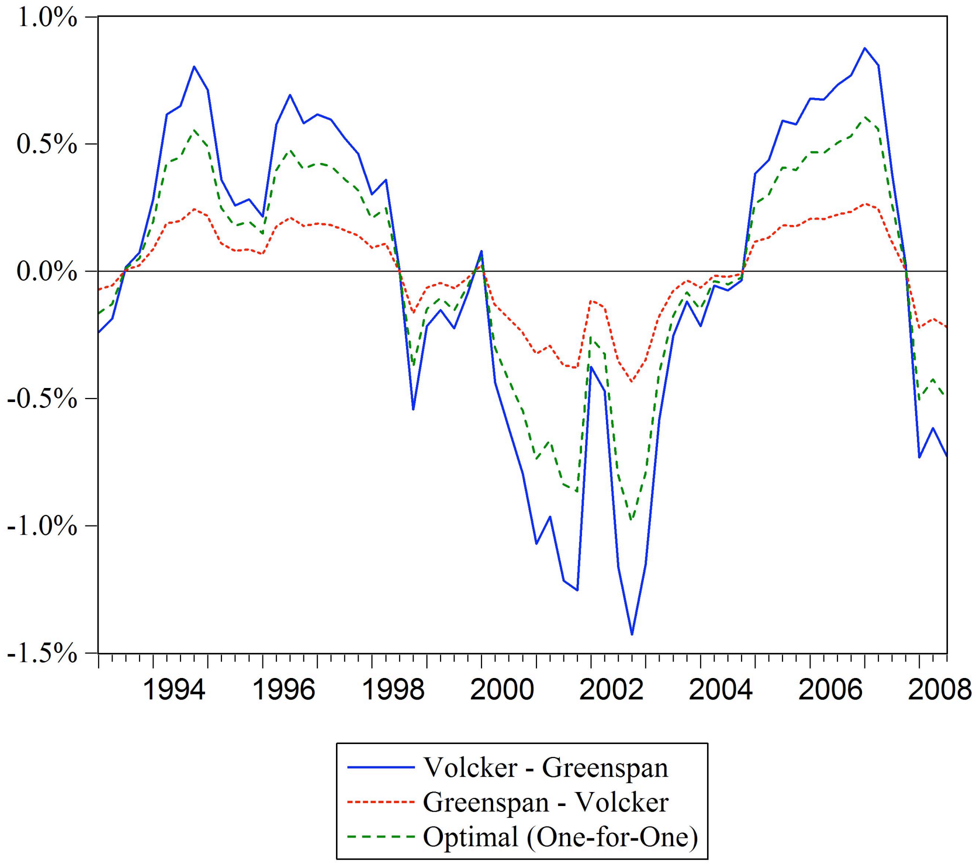

Table 4.1. Estimation Results from US Forward Looking Baseline and Alternative Models (1984:1 – 2008:3 w/ex post data)

Var	Base	Alt. 1	Alt. 2	Alt. 3	Base	Alt.1	Alt. 2	Alt.3	Base	Alt.1	Alt. 2	Alt. 3
	k=1, q=0				k=4, q=0				k=4, q=1			
π^*	2.46	2.46	-2.27	2.10	2.30	2.35	1.23	1.94	2.26	2.32	1.66	1.94
	(0.35)	(0.37)	(35.95)	(0.39)	(0.34)	(0.31)	(1.66)	(0.37)	(0.30)	(0.29)	(0.89)	(0.36)
ρ_1	1.44	1.22	1.15	1.49	1.38	1.17	1.10	1.40	1.34	1.15	1.10	1.44
	(0.17)	(0.18)	(0.18)	(0.10)	(0.16)	(0.16)	(0.16)	(0.09)	(0.16)	(0.16)	(0.16)	(0.09)
ρ_2	-0.56	-0.38	-0.33	-0.59	-0.51	-0.34	-0.30	-0.49	-0.48	-0.32	-0.29	-0.53
	(0.15)	(0.15)	(0.14)	(0.09)	(0.13)	(0.12)	(0.12)	(0.08)	(0.13)	(0.12)	(0.12)	(0.08)
β	1.96	1.69	1.03	1.96	2.04	1.79	1.19	2.21	2.13	1.86	1.32	2.31
	(0.41)	(0.32)	(0.26)	(0.53)	(0.44)	(0.33)	(0.22)	(0.68)	(0.43)	(0.34)	(0.24)	(0.79)
γ	0.88	0.85	0.96	1.01	0.83	0.80	0.91	1.05	1.04	0.94	1.04	1.04
	(0.27)	(0.23)	(0.18)	(0.25)	(0.26)	(0.21)	(0.16)	(0.28)	(0.24)	(0.21)	(0.19)	(0.32)
Baa-		-0.44				-0.46				-0.44		
TRES		(0.16)				(0.14)				(0.15)		
Aaa-			-0.69				-0.69				-0.63	
TRES			(0.22)				(0.18)				(0.19)	
High-				-0.08				-0.10				-0.08
TRES				(0.03)				(0.03)				(0.02)

Table 4.2.Estimation Results from US Forward Looking Baseline and Alternative Models (1984:1 – 2008:3 w/Real Time data)

Var	Base	Alt. 1	Alt. 2	Alt. 3	Base	Alt.1	Alt. 2	Alt.3	Base	Alt.1	Alt. 2	Alt. 3
	k=1, q=0				k=4, q=0				k=4, q=1			
π^*	3.69	4.56	1.29	3.31	3.37	3.61	9.85	2.58	3.37	3.65	22.35	2.57
	(0.49)	(1.49)	(1.33)	(0.72)	(0.27)	(0.42)	(22.43)	(0.20)	(0.28)	(0.45)	(189.88)	(0.25)
ρ_1	1.12	1.05	1.04	1.28	1.03	0.97	0.99	1.20	1.10	1.04	1.07	1.28
	(0.12)	(0.12)	(0.13)	(0.10)	(0.16)	(0.15)	(0.16)	(0.11)	(0.16)	(0.16)	(0.16)	(0.11)
ρ_2	-0.30	-0.23	-0.24	-0.40	-0.29	-0.22	-0.24	-0.39	-0.32	-0.25	-0.28	-0.43
	(0.10)	(0.09)	(0.09)	(0.09)	(0.12)	(0.10)	(0.11)	(0.11)	(0.12)	(0.11)	(0.11)	(0.11)
β	1.79	1.43	0.57	1.65	1.91	1.69	1.08	2.10	1.92	1.72	1.03	2.22
	(0.32)	(0.33)	(0.35)	(0.42)	(0.22)	(0.23)	(0.24)	(0.18)	(0.24)	(0.25)	(0.29)	(0.30)
γ	0.73	0.71	0.59	0.72	0.55	0.55	0.53	0.62	0.54	0.55	0.51	0.65
	(0.09)	(0.09)	(0.09)	(0.16)	(0.07)	(0.06)	(0.07)	(0.08)	(0.08)	(0.08)	(0.08)	(0.11)
BAA-		-0.32				-0.29				-0.27		
TRES		(0.10)				(0.09)				(0.10)		
AAA-			-0.72				-0.59				-0.54	
TRES			(0.20)				(0.17)				(0.17)	
High-				-0.06				-0.04				-0.02
Tres				(0.03)				(0.03)				(0.03)

Table 4.3. Generalized Method of Moments (GMM) Estimation Results from US Forward Looking Baseline and Alternative Models (1984:1 – 2008:3 w/ex post data)

Var	Base	Alt. 1	Alt. 2	Alt. 3	Base	Alt.1	Alt. 2	Alt.3	Base	Alt.1	Alt. 2	Alt. 3
	k=1, q=0				k=4, q=0				k=4, q=1			
π^*	1.67	2.45	2.42	2.51	1.04	1.95	8.38	2.12	0.63	53.42	4.78	2.11
	(0.39)	(0.13)	(0.15)	(0.55)	(1.57)	(0.26)	(13.87)	(0.14)	(2.51)	(218.50)	(3.31)	(0.10)
ρ_1	1.59	1.15	1.10	1.16	1.41	1.06	1.19	1.37	1.42	1.11	1.22	1.27
	(0.05)	(0.07)	(0.08)	(0.05)	(0.06)	(0.05)	(0.04)	(0.04)	(0.05)	(0.34)	(0.04)	(0.05)
ρ_2	-0.67	-0.27	-0.31	-0.33	-0.52	-0.22	-0.34	-0.46	-0.53	-0.21	-0.36	-0.38
	(0.05)	(0.06)	(0.07)	(0.05)	(0.05)	(0.04)	(0.04)	(0.03)	(0.05)	(0.30)	(0.03)	(0.04)
β	2.22	3.54	2.09	1.30	1.38	1.78	0.93	2.59	1.28	0.95	0.85	2.81
	(0.36)	(0.36)	(0.26)	(0.20)	(0.30)	(0.20)	(0.17)	(0.52)	(0.30)	(2.27)	(0.19)	(0.49)
γ	1.01	1.72	1.55	1.29	0.89	1.11	0.96	1.67	0.94	0.00	0.97	1.61
	(0.20)	(0.16)	(0.11)	(0.13)	(0.16)	(0.10)	(0.10)	(0.19)	(0.17)	(1.24)	(0.12)	(0.18)
Baa-		-0.85				-0.46				-1.13		
TRES		(0.12)				(0.08)				(0.75)		
Aaa-			-0.98				-0.34				-0.30	
TRES			(0.19)				(0.06)				(0.06)	
High-				-0.18				-0.15				-0.13
TRES				(0.02)				(0.01)				(0.01)

Table 4.4.Estimation Results using CPI Inflation from US Forward Looking Baseline and Alternative Models (1984:1 – 2008:3 w/ex post data)

Var	Base	Alt. 1	Alt. 2	Alt. 3	Base	Alt.1	Alt. 2	Alt.3	Base	Alt.1	Alt. 2	Alt. 3
	k=1, q=0				k=4, q=0				k=4, q=1			
π^*	2.94	2.94	2.16	2.53	2.78	2.82	1.77	2.35	2.75	2.79	2.17	2.35
	(0.32)	(0.34)	(1.12)	(0.34)	(0.33)	(0.36)	(1.55)	(0.46)	(0.29)	(0.33)	(0.85)	(0.46)
ρ_1	1.44	1.28	1.17	1.45	1.39	1.24	1.12	1.40	1.37	1.23	1.13	1.40
	(0.15)	(0.16)	(0.16)	(0.09)	(0.15)	(0.15)	(0.15)	(0.08)	(0.15)	(0.15)	(0.14)	(0.08)
ρ_2	-0.58	-0.45	-0.37	-0.59	-0.52	-0.40	-0.33	-0.52	-0.51	-0.39	-0.33	-0.52
	(0.14)	(0.14)	(0.12)	(0.09)	(0.13)	(0.12)	(0.11)	(0.07)	(0.12)	(0.12)	(0.11)	(0.07)
β	1.85	1.67	1.17	1.74	1.87	1.64	1.17	1.74	1.93	1.69	1.27	1.74
	(0.35)	(0.31)	(0.23)	(0.34)	(0.38)	(0.32)	(0.22)	(0.45)	(0.36)	(0.32)	(0.22)	(0.45)
γ	0.61	0.62	0.77	0.70	0.56	0.56	0.73	0.70	0.67	0.66	0.79	0.70
	(0.22)	(0.20)	(0.16)	(0.15)	(0.23)	(0.22)	(0.16)	(0.17)	(0.20)	(0.21)	(0.18)	(0.17)
Baa-		-0.33				-0.34				-0.33		
TRES		(0.14)				(0.13)				(0.13)		
Aaa-			-0.63				-0.65				-0.59	
TRES			(0.20)				(0.18)				(0.18)	
High-				-0.08				-0.08				-0.08
TRES				(0.03)				(0.02)				(0.02)

Table 4.5.Estimation Results using GDP Deflator Inflation from US Forward Looking Baseline and Alternative Models (1984:1 – 2008:3 w/ex post data)

Var	Base	Alt. 1	Alt. 2	Alt. 3	Base	Alt.1	Alt. 2	Alt.3	Base	Alt.1	Alt. 2	Alt. 3
	k=1, q=0				k=4, q=0				k=4, q=1			
π^*	1.54	2.02	2.55	1.91	2.43	2.52	0.87	2.39	2.40	2.47	1.91	2.35
	(3.92)	(1.06)	(0.30)	(0.93)	(0.29)	(0.34)	(6.99)	(0.66)	(0.26)	(0.29)	(1.08)	(0.56)
ρ_1	1.50	1.32	1.20	1.51	1.38	1.20	1.12	1.42	1.34	1.18	1.10	1.44
	(0.15)	(0.13)	(0.13)	(0.08)	(0.17)	(0.15)	(0.15)	(0.09)	(0.17)	(0.15)	(0.15)	(0.09)
ρ_2	-0.55	-0.40	-0.32	-0.56	-0.44	-0.29	-0.26	-0.47	-0.41	-0.27	-0.24	-0.48
	(0.13)	(0.12)	(0.10)	(0.08)	(0.15)	(0.13)	(0.12)	(0.08)	(0.15)	(0.13)	(0.12)	(0.08)
β	0.67	0.40	0.00	0.06	3.44	2.38	1.10	2.12	3.69	2.55	1.35	2.43
	(1.25)	(0.81)	(0.42)	(0.90)	(1.58)	(0.98)	(0.48)	(1.58)	(1.62)	(1.02)	(0.55)	(1.85)
γ	0.94	0.83	0.99	0.95	0.94	0.83	0.98	1.12	1.32	1.06	1.15	1.16
	(0.60)	(0.40)	(0.23)	(0.53)	(0.52)	(0.34)	(0.22)	(0.55)	(0.55)	(0.36)	(0.26)	(0.62)
Baa-		-0.39				-0.43				-0.43		
TRES		(0.13)				(0.14)				(0.14)		
Aaa-			-0.74				-0.69				-0.66	
TRES			(0.18)				(0.16)				(0.16)	
High-				-0.08				-0.10				-0.09
Tres				(0.02)				(0.03)				(0.03)

Table 4.6.Estimation Results using the Unemployment Output Gap from US Forward Looking Baseline and Alternative Models (1984:1 – 2008:3 w/ex post data)

Var	Base	Alt. 1	Alt. 2	Alt. 3	Base	Alt.1	Alt. 2	Alt.3	Base	Alt.1	Alt. 2	Alt. 3
	k=1, q=0				k=4, q=0				k=4, q=1			
π^*	2.45	2.48	3.59	1.80	2.18	2.23	3.59	1.30	2.10	2.15	-0.30	1.42
	(0.60)	(0.72)	(2.73)	(1.00)	(0.44)	(0.47)	(2.73)	(1.24)	(0.39)	(0.41)	(5.18)	(0.92)
ρ_1	1.49	1.30	1.25	1.50	1.40	1.24	1.25	1.38	1.35	1.19	1.13	1.37
	(0.18)	(0.19)	(0.19)	(0.12)	(0.17)	(0.17)	(0.19)	(0.10)	(0.18)	(0.17)	(0.17)	(0.10)
ρ_2	-0.59	-0.43	-0.40	-0.60	-0.52	-0.38	-0.40	-0.49	-0.48	-0.34	-0.30	-0.47
	(0.16)	(0.16)	(0.16)	(0.11)	(0.14)	(0.13)	(0.16)	(0.09)	(0.15)	(0.14)	(0.14)	(0.09)
β	1.87	1.54	0.80	1.55	2.07	1.74	0.80	1.55	2.11	1.77	1.16	1.70
	(0.50)	(0.38)	(0.37)	(0.43)	(0.51)	(0.39)	(0.37)	(0.55)	(0.51)	(0.39)	(0.29)	(0.57)
γ	0.51	0.47	0.60	0.78	0.57	0.50	0.60	0.89	0.76	0.63	0.76	0.95
	(0.37)	(0.29)	(0.22)	(0.26)	(0.31)	(0.26)	(0.22)	(0.25)	(0.30)	(0.26)	(0.20)	(0.26)
Baa-		-0.42				-0.42				-0.41		
TRES		(0.16)				(0.14)				(0.14)		
Aaa-			-0.62				-0.62				-0.59	
TRES			(0.21)				(0.21)				(0.18)	
High-				-0.08				-0.10				-0.09
TRES				(0.03)				(0.03)				(0.03)

Table 4.7. Volcker-Greenspan Estimation Results from US Forward Looking Baseline and Alternative Models (1984:1 – 1999:1 w/ex post data)

Var	Base	Alt. 1	Alt. 2	Alt. 3	Base	Alt.1	Alt. 2	Alt.3	Base	Alt.1	Alt. 2	Alt. 3
	k=1, q=0				k=4, q=0				k=4, q=1			
π^*	2.37	2.74	4.11	2.33	2.39	2.68	5.86	2.23	2.47	2.70	9.90	2.37
	(1.63)	(0.35)	(1.42)	(0.31)	(0.94)	(0.28)	(5.52)	(0.16)	(0.70)	(0.26)	(37.53)	(0.20)
ρ_1	1.31	1.11	0.91	1.41	1.30	1.08	0.88	1.41	1.26	1.05	0.88	1.46
	(0.20)	(0.21)	(0.20)	(0.13)	(0.19)	(0.18)	(0.18)	(0.12)	(0.19)	(0.17)	(0.18)	(0.13)
ρ_2	-0.43	-0.28	-0.19	-0.49	-0.43	-0.27	-0.19	-0.48	-0.41	-0.24	-0.18	-0.50
	(0.16)	(0.17)	(0.14)	(0.13)	(0.14)	(0.13)	(0.11)	(0.12)	(0.15)	(0.12)	(0.12)	(0.12)
β	1.26	1.81	0.77	2.70	1.43	1.93	0.89	4.50	1.59	2.02	0.96	6.72
	(0.40)	(0.38)	(0.22)	(0.83)	(0.38)	(0.41)	(0.18)	(1.80)	(0.39)	(0.42)	(0.21)	(4.84)
γ	0.88	0.86	0.77	1.09	0.79	0.74	0.72	1.24	0.99	0.87	0.79	1.07
	(0.39)	(0.33)	(0.15)	(0.34)	(0.34)	(0.29)	(0.13)	(0.44)	(0.33)	(0.28)	(0.15)	(0.69)
Baa-TRES		-0.69				-0.80				-0.83		
		(0.29)				(0.30)				(0.30)		
Aaa-TRES			-1.45				-1.54				-1.49	
			(0.47)				(0.44)				(0.44)	
High-TRES				-0.14				-0.19				-0.19
				(0.03)				(0.05)				(0.05)

Table 4.8. Greenspan-Bernanke Estimation Results from US Forward Looking Baseline and Alternative Models (1993:1 – 2008:3 w/ex post data)

Var	Base	Alt. 1	Alt. 2	Alt. 3	Base	Alt.1	Alt. 2	Alt.3	Base	Alt.1	Alt. 2	Alt. 3
	k=1, q=0				k=4, q=0				k=4, q=1			
π^*	1.86	1.94	2.01	-1.00	1.71	2.18	2.66	8.23	1.74	2.29	6.12	0.62
	(0.47)	(0.47)	(0.46)	(237.03)	(0.33)	(0.81)	(2.99)	(274.01)	(0.27)	(1.49)	(102.49)	(14.06)
ρ_1	1.70	1.41	1.44	1.52	1.62	1.37	1.37	1.47	1.61	1.41	1.40	1.50
	(0.10)	(0.11)	(0.12)	(0.11)	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.11)	(0.10)
ρ_2	-0.79	-0.55	-0.57	-0.63	-0.69	-0.50	-0.49	-0.57	-0.68	-0.52	-0.51	-0.59
	(0.10)	(0.09)	(0.11)	(0.10)	(0.12)	(0.09)	(0.09)	(0.09)	(0.10)	(0.09)	(0.10)	(0.09)
β	1.92	0.48	0.43	1.01	2.98	0.57	0.72	0.97	3.39	0.68	0.95	1.16
	(1.27)	(0.60)	(0.66)	(0.88)	(2.48)	(1.01)	(1.04)	(1.38)	(2.50)	(1.22)	(1.28)	(1.66)
γ	0.82	0.67	0.80	0.85	0.89	0.64	0.79	0.80	1.05	0.64	0.83	0.81
	(0.30)	(0.16)	(0.18)	(0.22)	(0.52)	(0.24)	(0.26)	(0.32)	(0.52)	(0.29)	(0.30)	(0.38)
Baa-TRES		-0.35				-0.36				-0.32		
		(0.09)				(0.10)				(0.09)		
Aaa-TRES			-0.44				-0.47				-0.41	
			(0.12)				(0.12)				(0.12)	
High-TRES				-0.08				-0.09				-0.08
				(0.03)				(0.03)				(0.02)

Table 4.9. Volcker-Greenspan Estimation Results from US Forward Looking Baseline and Alternative Models (1984:1 – 1994:4 w/real-time data)

Var	Base	Alt. 1	Alt. 2	Alt. 3	Base	Alt.1	Alt. 2	Alt.3	Base	Alt.1	Alt. 2	Alt. 3
	k=1, q=0				k=4, q=0				k=4, q=1			
π^*	3.98	5.50	2.50	1.72	3.62	3.69	4.03	2.84	3.62	3.69	3.92	2.92
	(0.89)	(4.48)	(0.78)	(5.58)	(0.18)	(0.22)	(0.49)	(0.23)	(0.15)	(0.17)	(0.38)	(0.18)
ρ_1	1.01	0.91	0.77	1.17	0.73	0.67	0.61	0.90	0.76	0.71	0.67	1.02
	(0.14)	(0.12)	(0.13)	(0.27)	(0.24)	(0.18)	(0.18)	(0.30)	(0.24)	(0.19)	(0.19)	(0.30)
ρ_2	-0.20	-0.08	-0.05	-0.19	-0.08	0.00	0.01	-0.12	-0.09	-0.01	-0.02	-0.20
	(0.10)	(0.10)	(0.10)	(0.23)	(0.15)	(0.10)	(0.10)	(0.22)	(0.16)	(0.10)	(0.11)	(0.21)
β	1.63	1.22	0.61	3.32	2.33	2.14	1.48	3.27	2.48	2.32	1.65	4.06
	(0.53)	(0.40)	(0.29)	(11.77)	(0.26)	(0.28)	(0.28)	(0.90)	(0.22)	(0.21)	(0.28)	(1.23)
γ	0.69	0.82	0.52	4.25	0.38	0.45	0.38	0.44	0.37	0.45	0.36	0.41
	(0.12)	(0.16)	(0.09)	(9.51)	(0.05)	(0.09)	(0.07)	(0.24)	(0.05)	(0.10)	(0.08)	(0.26)
Baa-		-0.64				-0.50				-0.48		
TRES		(0.16)				(0.19)				(0.19)		
Aaa-			-1.30				-1.10				-0.99	
TRES			(0.31)				(0.25)				(0.23)	
High-				-0.14				-0.18				-0.20
TRES				(0.11)				(0.07)				(0.07)

Table 4.10. Greenspan -Bernanke Estimation Results from US Forward Looking Baseline and Alternative Models (1992:1 – 2002:4 w/real-time data)

Var	Base	Alt. 1	Alt. 2	Alt. 3	Base	Alt.1	Alt. 2	Alt.3	Base	Alt.1	Alt. 2	Alt. 3
	k=1, q=0				k=4, q=0				k=4, q=1			
π^*	3.01	1.91	1.92	1.54	2.35	1.50	1.63	2.72	2.49	1.91	1.96	-1.88
	(0.75)	(0.23)	(0.22)	(0.67)	(0.21)	(1.06)	(0.63)	(1.20)	(0.37)	(0.21)	(0.19)	(46.60)
ρ_1	1.31	1.27	1.33	1.32	1.27	1.25	1.29	1.28	1.37	1.36	1.41	1.39
	(0.08)	(0.11)	(0.10)	(0.09)	(0.09)	(0.11)	(0.10)	(0.09)	(0.09)	(0.13)	(0.11)	(0.10)
ρ_2	-0.50	-0.47	-0.50	-0.50	-0.48	-0.46	-0.48	-0.48	-0.54	-0.53	-0.56	-0.55
	(0.08)	(0.09)	(0.08)	(0.08)	(0.09)	(0.09)	(0.08)	(0.08)	(0.08)	(0.11)	(0.10)	(0.09)
β	1.41	-0.02	-0.16	0.51	2.07	0.64	0.49	1.40	1.66	-0.03	-0.39	0.94
	(0.34)	(0.50)	(0.53)	(0.44)	(0.43)	(0.64)	(0.62)	(0.59)	(0.41)	(0.77)	(0.80)	(0.69)
γ	0.64	0.42	0.45	0.51	0.63	0.48	0.51	0.56	0.59	0.38	0.37	0.49
	(0.10)	(0.12)	(0.12)	(0.12)	(0.09)	(0.13)	(0.11)	(0.12)	(0.08)	(0.13)	(0.12)	(0.14)
Baa-		-0.36				-0.28				-0.30		
TRES		(0.14)				(0.16)				(0.18)		
Aaa-			-0.50				-0.41				-0.45	
TRES			(0.17)				(0.18)				(0.19)	
High-				-0.08				-0.05				-0.04
TRES				(0.04)				(0.04)				(0.05)