Developing a Market-Based Monetary Policy Transparency Index and Testing Its Impact on Risk and Volatility in the United States

Amir Kia*
Finance and Economics Department
Utah Valley University
Orem, UT 84058-5999
USA

Tel: 801-863-6898
Email: akia@uvu.edu

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Abstract

This paper extends the literature by developing an objective market-based index, which is dynamic and continuous and can be used to measure the monetary policy transparency for a country or, simultaneously, a series of countries. It was found that the more transparent the monetary policy is, the less risky and volatile the money market will be. Furthermore, during the tenure of Chairmen Greenspan and Bernanke the volatility and risk in the money market fell. The policy regime changes of adjusting the target rate by multiples of 25 or 50 basis points resulted in a reduction in volatility in money markets. Finally, the Fed policy of announcing policy decision at the conclusion of each FOMC meeting resulted in a lower risk and forecast error in the money market in the United States.

Keywords: Monetary policy transparency, forward-looking agents, risk, volatility, money market

JEL Codes: E43, E51, E52, E58

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I. Introduction

Central banks are unequivocally moving towards greater openness or to more transparent monetary policy frameworks by engaging in, among other things, inflation targeting, publishing inflation forecasts and increasing the number of public statements from bank officials. Whether such moves are desirable or not, or to what degree they are desirable, is still open to question. The theoretical studies in favor of and/or against more transparency in central banking, although ample, are not unanimous in their findings, and empirical tests of these arguments are scarce, mostly because transparency in the monetary policy is a concept hard to measure.

The existing transparency measures have some limitations. Most of them are not in time-series form and therefore can only be used for cross-sectional studies and for a limited number of hypotheses. They are based on the quantity, timeliness, and periodicity of information provided by central banks and finally, they are somehow static. In general, the existing measures of transparency can be divided into four groups:

(i) Descriptive accounts of transparency: This kind of transparency measure concentrates on strategies that central bankers follow in order to communicate with the public. It mostly includes do's and don'ts of the central bankers' actions, see, e.g., Blinder *et al.* (2001). The main problem with this measure is that no index can be derived/constructed from these do's and don'ts.

(ii) Central bank surveys or self-evaluating transparency indexes: A series of surveys are sent to central banks to investigate the extent to which they communicate their private information to the public, including the degree to which they are following the *Code of Good Practices on Transparency in Monetary and Financial Policies* developed by the International Monetary Fund (IMF), see, e.g., Fry *et al.* (2000) and Sundararajan *et al.* (2003). With this type of measures there is a possibility of misunderstanding the survey questions and/or manipulating responses by the central banks to obtain an appropriate score.

(iii) Official documents and information: Researchers construct indexes of transparency of monetary policy by evaluating the behavior of central bankers (e.g., whether they give speeches regularly or not) and the type and frequency of documents the central bank makes available to the public (such as minutes from meetings, inflation reports, etc.), see, e.g., Eijffinger and Geraats (2002) and de Haan and Amtenbrink (2002). One possible weakness with this approach is that the particular items looked at and the weight assigned to them by each set of authors may differ for purely subjective reasons.

Furthermore, these measures quantify the degree of openness of central banks based on the information provided, but do not necessarily reflect the true degree of understanding, by the public, of central banking practices. In sum, the common problem with the above three measures is that they are not in time-series form; instead, they are calculated for cross-sectional studies. Thus, these measures limit the number of hypotheses that may be tested concerning the impact of more transparent monetary policies in the economy.

(iv) Market-based indicators: These indexes are based on what market participants understand from the central banks' actions and signals as well as the implementation of the monetary policy. The degree to which market participants understand and anticipate monetary policy can be gauged by using time-series market-based expectations of monetary policy, and more particularly, high frequency measures of monetary policy surprises. In general, the time-series market-based measures of policy surprises in the U.S. include those based on federal funds futures rates, e.g., Robertson and Thornton (1997), Poole and Rasche (2000), Kuttner (2001) and Söderström (2001). The existing market-based indicators also have limitations.

These measures restrict the analysis to post 1988, when the federal funds futures market was established. Furthermore, as it was mentioned by Poole *et al.* (2002), Fed funds futures rate could reflect the expected changes in the target rate only if the times of target rate changes were known. Since this information became available only after 1994, these measures further restrict researchers to post 1994. Finally, as it was shown by Robertson and Thornton (1997), there is a potential bias for the federal funds futures rate to forecast future target rate, but this rate may forecast future funds rates and not the Fed action.

Other measures are based on actual market rates including Treasury bill rates and Eurodollar deposit rates, e.g., Cochrane and Piazzesi (2002). These measures mostly concentrate on a change in the single interest rate at the time of a target change. A single rate does not contain full information on the monetary policy transparency as, in general, interest rates, and especially their relationships, reflect the behavior of market participants (arbitrageurs and speculators). Consequently, these measures are static and, more seriously, they are very narrowly defined by putting too much emphasis on a single piece of information.

Finally, some policy surprise measures are based on the analysis of the financial press, e.g., Poole *et al.* (2002) and Söderström (2001). These measures can be subjective as the interpretation of the financial press fully depends on the background and experience of the researchers. The overall limitation of these measures arises from the fact that they are usually a series of unequal intervals. Therefore, they may restrict the researcher to studies with quarterly or less frequent data or to specific techniques of estimation such as the factor-model approach which allows the researcher to deal systematically with data irregularities [e.g., Stock and Watson (2002)].

It should be noted that the construction of a market-based index depends on the characteristics of the market or markets whose prices are used to establish the index. Consequently, it is extremely important to identify the market(s) carefully before constructing a monetary policy index based on the information generated from the market(s). The purpose of this paper is to develop an index, which is dynamic and can be used to measure the monetary policy transparency for an individual or, simultaneously, a series of countries. To the best knowledge of the author, no such index exists in the literature. In this study the measure is developed for the United States monetary policy for the 1982-2007 (August) period. The choice of the country is based on the fact that the United States has a complex banking system (12 Federal Reserves) with no clear policy objectives, like inflation targeting, interest rate band, etc. Consequently, the index, if successful in detecting the Federal Reserve monetary transparency, will be useful in checking the central bank transparency of any country, especially countries that have clear monetary policy goals like Canada and New Zealand.

This paper makes two major contributions to the literature. First, a monetary policy index was constructed. Such an index is dynamic and can also be continuous when intraday minute or shorter interval observations are used. Second, it was found, using the index, that the more transparent the monetary policy is, the less risky and volatile the money market will be. A description of our data is given in Section II. Section III is devoted to the theoretical foundation of the index and its construction. Section IV covers the empirical tests on the power of the index in investigating the hypothesis that higher transparency reduces risk and volatility in the money market. The final section provides a summary and conclusions.

II. Data Description

The daily data on the effective Fed funds, the Treasury bill (secondary market) and the exchange rates (Japanese Yens per one US dollar) for the period 1982 (October 5)-2007 (August 8) are used. The number of observations is 6482 days. The source of these data is the St. Louis Federal Reserve website. The effective Fed funds rate is a weighted average of the rates on Fed funds transactions of a group of Fed funds brokers who report their transactions daily to the Federal Reserve Bank of New York.

The choice of the sample period is based on the availability of data on target Fed funds rates. According to Sarno and Thornton (2003), the Fed was explicitly targeting the funds rate from 1974 to October 1979. The Fed switched to a non-borrowed reserves operation procedure in October 1979, and in October 1982 switched to a borrowed reserves operating procedure. However, "Exactly when the Fed switched from a borrowed reserve operating procedure to an explicit funds rate targeting procedure is contentious [...] there seems to be general agreement that the Fed has explicitly targeted the funds rate at least since the late 1980s." (Sarno and Thornton, 2003, p. 1099). In any event, for the purpose of this paper and the construction of the index, available target rates with their respective dates are needed.

To the best knowledge of the author, a non-interrupted set of data on Fed funds target rates is only available from October 1982. For the period 1982-1989 we used a series prepared by the Federal Open Market Committee (FOMC) Secretariat. This series is based on the staff's interpretations of FOMC transcripts and other documents publicly available.[1] Note that May 7, 1988 falls on a Saturday, when markets were closed. Following Rudebusch (1995), we used May 9, 1988 as the day when the target was changed. Furthermore, for the target change of "early January 1989", we assumed January 5 as the day when the target was changed. For the period 1990 onwards, the series reported on the Board of Governors of the Federal Reserve System's website was used.[2] Following Poole *et al.* (2002), let us call "event days" the days on which the FOMC meets (whether the target was changed or not) and the inter-meeting days on which the target rate was changed.

In the calculation of the transparency index, we used 360-day Fed funds and Treasury bill rates to avoid an artificial reduction in the index. For all other analyses in this paper, however, rates are expressed on a 365-day basis. For the period under consideration, the Fed has made some transparency-oriented changes. Some of the most representative changes include: (i) On October 19, 1989 when the Fed started the practice of adjusting the funds target rate by 25 or 50 basis points,[3] (ii) on March 23, 1993 when the Fed began releasing the minutes of the FOMC meetings (with 6-8 week lag), (iii) on November 16, 1993 when the Fed began releasing the transcripts of the FOMC meetings (with 5-year lag), (iv) on February 4, 1994 when the Fed began

[1] Rudebusch (1995) also constructed a Federal funds target rate series. His series is available for the periods 1974-1979 and 1984-1992. Although Rudebusch's series has been widely used by researchers, we use the FOMC Secretariat's series because it allows us to study the longest consecutive time period.
[2] Alternatively, the series can be found in the Federal Reserve Bank of New York's website.
[3] According to Poole and Rasche (2003), this practice started in August 1989; however, we will follow Sarno and Thornton's (2003) estimation of October 1989, since it is likely that it took the market at least two months to realize that the FOMC had enacted this practice. Also note that according to Rudebusch

announcing policy decisions after each FOMC meeting, (v) on August 16, 1994 when the Fed began describing the state of the economy and further rationale for the policy action after FOMC decisions, (vi) on August 19, 1997 when the FOMC started including a quantitative Fed funds target rate in its Directive to the New York Fed Trading Desk, and (vii) on May 18, 1999 when the Fed extended its explanations regarding policy decisions, and started including in press statements an indication of the FOMC's view regarding prospective developments (or the policy bias). (viii) On January 19, 2000 when the FOMC issued a press statement explaining that it would include a balance-of-risk sentence in its statements, replacing the previous bias statement.[4] The practice was first implemented at the following FOMC meeting, on February 2. Finally, since March 19, 2002, the Fed has included in the FOMC statements the vote on the directive and the name of dissenter members (if any). [5]

The index developed in this paper will be used to determine whether transparency-oriented reforms at the Fed have indeed increased the market's understanding of Fed policies. Finally, we will also test the changes in monetary policy transparent during Chairman Alan Greenspan's tenure (August 11, 1987 to January 31, 2006) as well as Chairman Ben Bernanke's tenure (February 1, 2006 to August 8, 2007).

III. A Money-Market Measure of the Transparency of Fed Policymaking

In this section, we will construct an index of the transparency of monetary policy. Our index is based on the degree to which money market participants anticipate the decisions taken at the regularly scheduled FOMC meetings (whether a target change occurred or not), as well as those (target changes) made outside these meetings. Specifically, by monetary policy transparency, following Sundararajan *et al*. (2003, p. 5), we mean "[…] an environment in which the objectives of the policy; its legal, institutional, and economic framework; policy decisions and their rationale; data and information related to monetary and financial policies; and the accountability of the policymaking body are provided to the public in an understandable, accessible and timely basis." Under this definition, there is an absence of asymmetric information between monetary policy makers and other economic agents. The implementation of the

(1995), the target change occurred on October 18, 1989, not on the 19. Since the Secretariat series are used we will assume that the change started on the 19.

[4] Federal Reserve Board, "Modifications to the FOMC's Disclosure Procedures", January 19, 2000.

[5] It should also be noted that Chairman Greenspan delivered a speech in October 2001 and highlighted FOMC's moves toward greater transparency. For a review of these changes, see Poole and Rasche (2003) and Swanson (2006).

monetary policy can be made public in one or more of the following ways: remarks of the Chairman of the Federal Reserve as well as other senior management of the Fed, testimony before the House and Senate Banking Committee, the release of the Beige book, the minutes of the FOMC meetings, changes in reserve requirements, changes in the discount rate and open market operations.

A. The Model

Since the index developed in this paper is market based, we assume there is no uncertainty. Specifically, we distinguish between risk and uncertainty in the sense of Knight (1921). The risk exists if agents can use historical data to assign numerical probabilities to random events. However, random events to which agents cannot assign probabilities are said to involve uncertainty. It should be noted that there are periods of uncertainty in the sample period, specifically towards the end of the Federal Reserve Chairman Paul Volcker's tenure and the start of the new Chairman Greenspan's tenure. In that period, because of the change in authority, market participants could not easily understand or interpret the Fed signals. Other periods of uncertainty are associated with the October 87 stock market crisis as well as September 2001 attacks. We will adjust the index for these events. Note that we do not consider the Fed reaction relevant to the Asian crisis as an uncertain event from the agents' point of view since agents could use the recent historical reaction of the Fed related to the October 87 crisis to calculate the probability associated with what action the Fed was likely to take.

Furthermore, we assume Fed funds and three-month Treasury bill rates are cointegrated. Since the construction of the monetary policy index in this paper is based on the data of the short end of the yield curve, we need short-term rates, say Fed funds and Treasury bill rates, to be cointegrated. The existing literature provides empirical evidence for this assumption. For example, Sarno and Thornton (2003) as well as Kia (2006) have shown the Fed funds (FF) and three-month Treasury bill (TB) rates are cointegrated. Furthermore, the adjustment toward the long-run equilibrium largely occurs through the movements in the FF rate rather than the TB rate. Finally, we assume market participants are forward looking in the sense of Lucas (1976). Kia (2006) provides empirical evidence in support of this assumption. He shows that agents are forward looking in the money market of the United States in the sense that their behavior is not policy invariant and expectations are formed rationally.

Suppose full monetary policy transparency exists, i.e., there is no asymmetric information between monetary policy makers and market participants. We may express the daily behavior of FF as:

$$FF_t = FF_{t-1} + \alpha\,(OER_t - ER_t), \tag{1}$$

where OER is the optimum excess reserve ratio by banking system, ER is the actual excess reserve ratio and α is a coefficient which can change as the behavior of forward-looking market participants changes. Because of the uncertainty in check clearing, banks in the United States should keep a positive excess reserve. However, since the excess reserve, similar to the required reserve, has a negative return, banks keep an optimum excess reserve, which is equal to the actual excess reserve only at equilibrium. The variable OER is affected mostly by factors like day-of-the-week, seasons, the geographic position as well as the size of the bank, etc., while ER is mainly affected by the Fed open market operations. It should be noted that before July 30, 1998, when the two-week reserve computation period was implemented, the day-of-the week effect (e.g., Wednesday effect) was stronger, see Kotomin and Winters (2007).

Equation (1) is consistent with backward and forward-looking Taylor rule, see Bernanke and Boivin (2003), and the literature within. This is due to the fact that the Fed always changes FF by influencing ER in Equation (1). Even the change in FF through a signal effect [or an open-mouth-operation *a la* Thornton (2004)] is conducted by a change in the expression (OER_t - ER_t) in Equation (1). Suppose the Fed gives a signal to the market that the rate will go up the following day. Since the reserves a bank must hold in the United States are the average of the two-week period (the *maintenance* period) reserves of the bank, each bank tries to increase its ER the days when the FF is low and vice versa. If, because of the Fed's signal, FF is expected to rise the following day, banks will increase their ER on that day when the opportunity cost of reserves (FF) is relatively low and reduce their ER, by lending it to those banks in need of funds, the following day when FF is relatively high. In this way they can earn some positive return on their excess reserves. This speculative activity leads to a higher FF the day before the change in FF. Consequently, we can see that even the signal effect of the Fed is affecting (OER_t - ER_t) of the banking system.

To construct an equation which expresses the daily behavior of TB, let us start with an equilibrium situation, where $OER_t = ER_t$, an outright sell of Treasury bills by the Fed results in a reduction of ER. Banks compete for interbank funds and the Federal funds rate will go up. Furthermore, as FF goes up (interbank market becomes tight) banks also sell their other liquid assets, like Treasury bills and, therefore, exert an upward pressure on TB. This means that an increase in $FF_t – TFF_T$ results in an increase in TB, where TFF_T is the target Fed funds rate at time T, the previous event day. Defining TFF_{T+1} the target rate at the next FOMC meeting or event day, then an increase in $[E(TFF_{T+1}|I_t) – TFF_T]$ leads to an expected potential speculative loss in keeping treasury bills, where E is the expectation operator, I_t is available information at time t. Speculators will sell their bills to reduce their loss and exert an upward pressure on TB. Consequently, we may express the daily movements of TB as:

$$TB_t = TB_{t-1} + \gamma \{(FF_t - TFF_T) + [E(TFF_{T+1}|I_t) - TFF_T]\}, \qquad (2)$$

where γ is a coefficient which can change as the behavior of forward-looking market participants changes. The expression $(FF_t - TFF_T)$ is known as unintended Fed funds rate. Add and subtract TFF_{T+1} in the second expression of (2) to get:

$$TB_t = TB_{t-1} + \gamma \{(FF_t - TFF_T) + [E(TFF_{T+1}|I_t) - TFF_{T+1}] + [TFF_{T+1} - TFF_T]\}. \qquad (2)'$$

In Equation (2)', given TFF_T at time t, the expression $(FF_t - TFF_T)$ reflects the Fed action to influence the interest rates and $[E(TFF_{T+1}|I_t) - TFF_{T+1}]$ is the unexpected change in the target rate while $[TFF_{T+1} - TFF_T]$ is the actual change in the target rate on the next event day. On the next event day, t=T+1, if the Fed does not change the target rate we will have $FF_{T+1} = TFF_T$ and if the expected target rate for the following event day is the same as the current target rate we would expect $TB_{T+1} = TB_{t-1}$. Equation (2)' is also consistent with the literature. For example, Hsing (2007), Demiralp and Jorda (2004) as well as Cochrane and Piazzesi (2002) have shown that the FF and unintended Fed funds rate affect Treasury bills. Furthermore, expression $[E(TFF_{T+1}|I_t) - TFF_{T+1}] + [TFF_{T+1} - TFF_T]$ corresponds to Equation (8) of Kuttner (2001), which was also tested on three-month Treasury bills rate.

Since the rate on non-collateralized overnight interbank loans (Fed funds) is risky, while loans to the Federal Government (Treasury bills) are risk-free, the difference between FF and TB rates (Dif) is positive. Thus, Dif measures the default risk minus maturity risk premiums. Suppose further that there is no expected significant change in the structure of the U.S. banking industry (i.e., risk associated with interbank loans is constant) and/or in the credibility of the U.S. government. Under these assumptions, there is no reason to believe that Dif deviates from its equilibrium value (its trend) unless Fed actions, and/or other exogenous shocks, change one or both of these rates in a different proportion. In fact, one can consider Dif as a measure of the stance of monetary policy. For example, Simon (1990) provides evidence that the TB-FF spread has a predictive power for the future changes in FF. Furthermore, Bernanke and Blinder (1992) show the funds rate or the spread between the funds rate and some other interest rates is a good indicator of the Federal Reserve's monetary policy stance. Specifically, they provide evidence that short-run fluctuations in the Fed funds rate, or the spread between the funds rate and some other interest rates are dominated by shifts in the stance of monetary policy. More importantly, they show the Fed funds rate, or its spread from some other interest rates, is not affected by current (within-month in their monthly observations) developments in the economy.

In general, one would expect at equilibrium to have

$Dif_t = FF_t - TB_t$= risk premium – maturity risk premium= $FF_{t-1} - TB_{t-1} = Tdif_t$, (3)

provided there is no expected change in the structure of the interbank market and/or the credibility of the United States government to pay its debt. $Tdif_t$ is the trend value or the equilibrium level of Dif. Substituting (2)' and (1) into (3), to get:

$$Dif_t = FF_{t-1} + \alpha\,(OER_t - ER_t) - TB_{t-1} - \gamma\,\{(FF_t - TFF_T) + [E(TFF_{T+1}|I_t) - TFF_{T+1}] + [TFF_{T+1} - TFF_T]\}, \quad (4)$$

where at equilibrium, which markets are at rest, $OER_t = ER_t$, $FF_t = TFF_T$ and $E(TFF_{T+1}|I_t) = TFF_T$, i.e., it is expected $TFF_{T+1} - TFF_T = 0$. In general, at t=T+1, we have $OER_{T+1} = ER_{T+1}$, $FF_{T+1} = FF_t + [TFF_{T+1} - TFF_T] = TFF_{T+1}$ and $E(TFF_{T+1}|I_t) = TFF_{T+1}$. In other words, at equilibrium or on the event day when there is no potential speculative/arbitrage profit we would expect $Dif_t = Tdif_t$ and, therefore, Equation (3) is satisfied. [6]

In general, under a forward-looking assumption (rational expectations), the deviations of Dif from its trend should be short-lived if there is an absence of asymmetric information between monetary policy makers and other economic agents. This is due to the fact that such deviations lead to potential arbitrage or speculative profits. Such potential profits result in arbitrage and/or speculative activities until the deviation of Dif from its equilibrium value (trend) is eliminated. Thus we can establish the following:

Proposition: *Because FF and TB are cointegrated and money market participants are forward looking, the life of deviations of Dif from its trend value depends on the degree of monetary policy transparency, provided there is no uncertainty. The deviations are short-lived if monetary policy is highly transparent, and vice versa.*

Figure 1 about here

Let us consider Figure 1. The upper panel shows the movements of the FF and TB rates. The lower panel shows the movements of Dif around its trend or equilibrium level. Suppose 100% monetary policy transparency exists, i.e., the Fed fully conveys its private information on monetary policy decisions to the market. Let us start from equilibrium, i.e., $Dif_t = Tdif_t$, and assume at time t the Fed conducts a "discretionary" monetary policy. For example, it tightens the market by, say, an outright sale of Treasury bills in order to increase the target rate from FF_0 to FF_1 at time t+1, which is the target-change day or the day of the FOMC meeting.[7] There will be a

[6] One may argue that Treasury bills are not taxed by state and local governments and, therefore, Dif_t also includes a tax premium (τFF_t), where τ is the tax rate. However, in this case $Tdif_t$ also includes this premium and at equilibrium, when there is no potential for speculative or arbitrage profit, these two premia should be equal so that again $Dif_t = Tdif_t$. I would like to thank Doug Pearce who brought this point to my attention.

[7] Note that a "discretionary" conduct of policy means that the central bank is free at any time to alter its instrument setting instead of complying with a rule. In an "interest-rate smoothing" regime the central bank

drain in reserves. Banks compete for interbank funds and the Federal funds rate will go up, by α $(OER_t - ER_t)$ in Equation (1). This will lead to an increase in the Federal funds-Treasury bill rate differential, Dif_t. Banks will also sell their Treasury bills or other liquid assets to obtain the required liquidity, thus exerting a further downward pressure on Treasury bill prices, i.e., TB rises by γ $(FF_t - TFF_T)$ in Equation (2). These speculative/arbitrage activities will continue until the interbank and the money markets are again in equilibrium. At such a time, we would expect, when full transparency exists, Dif_{t+1} and Tdif to almost coincide.

The Fed's action and the subsequent market's reaction will continue until the next target-change day or FOMC meeting when the Fed's desired target rate (FF_1) is officially announced. According to this analysis, one would expect under full monetary policy transparency, deviations of Dif from its average/trend (or equilibrium) to be temporary. The solid curve in the lower panel of Figure 1 depicts such movements. If we assume there is a lack of (less than 100%) monetary policy transparency, then deviations of Dif from Tdif last longer and may not be temporary (see the broken curve in the panel). The reason is that the forward-looking market participants (the coefficients are not policy invariant) could easily be confused by the action of the Fed and may overreact/underreact in the intended or the opposite direction where the authorities wish the market to go. This may create difficulty for the central bankers, resulting in more activities by the Fed to correct the situation.

For example, given our assumption that market participants are forward looking and so their behaviors are not policy invariant, an outright sale of Treasury bills by the Fed may be considered an interest rate smoothing action by the market and may lead the participants to purchase Treasury bills in order to sell them at a higher price when the Fed starts buying them back, thus resulting in widening the deviations of Dif from Tdif. In other words, if I_t in Equation (2) contains different pieces of information than what monetary authorities have, then deviations of Dif from Tdif last longer. Consequently, any $|D_t|$ — where $D_t = Dif_t - Tdif_{t-1}$ — is an indication of the monetary policy transparency, a small $|D_t|$ means a high transparency and vice versa.

Note that we are assuming the market is not efficient in the strong form, i.e., the market participants do not know the Fed's private information before it is publicized. If the market is efficient in the strong form, market participants will, on average, perceive the target rate in advance, and if there exists potential for arbitrage/speculative profits, arbitrageurs and speculators will trade until potential profits are eliminated. Specifically, arbitrage and speculative activities will eliminate any D_t, which is associated with potential arbitrage/speculative profits. If the

follows a "rule-based" policy. However, the discretionary conduct of policy also includes interest-rate smoothing, as the central bank is free to react at any time to the movements of the market.

market is not efficient in the strong form, arbitrageurs and speculators must be given inside information through Fed's signals/operations.

Let us now assume the Fed is following an "interest-rate smoothing" policy. Starting from full monetary policy transparency and equilibrium, suppose market participants, due to some signals from the Fed and/or some economic shocks, which caused movements in the equilibrium interest rate, expect a positive change in the target rate. An expected increase in the target rate (TFF_{T+1}) at the next FOMC meeting leads to an expected potential speculative loss in keeping treasury bills. Profit maximization leads arbitrageurs/speculators to operate along the short end of the yield curve by selling their three-month bills and buying very short-term bills or lending overnight. This action tends to reduce FF and increase in TB through the expression $\gamma [E(TFF_{T+1}|I_t) - TFF_T]$, in Equation (2). To moderate the fall in very short-term rates as well as FF, the Fed sells bills to put an upward pressure on FF through $\alpha (OER_t - ER_t)$ in Equation (1). Arbitrage and speculative activities as well as the Fed reactions continue until the interbank and money markets are again in equilibrium.

As before, one would expect D, under full monetary policy transparency, to approach zero at equilibrium when the potential for arbitrage/speculative profits is eliminated. In this case, the magnitude of D, in absolute value, is small and short-lived as Dif represented by the solid curve shows in Figure 1. Clearly, when monetary policy transparency is low, as the movements of Dif represented by the broken curve indicate, D is high in absolute value and is long-lived. Note that again, even while monetary policy transparency from the central bank point of view may remain constant, the market perception of a monetary policy action may change when such an action is conducted.

Let us consider another case of 100% monetary transparency. Suppose the Fed changes the target rate and hints that this rate will soon be changed (increased) again, say, within the next three months. Let us start from equilibrium, where D=0. To avoid the capital loss resulting from the increase, holders of three-month Treasury bills sell their bills and invest in shorter-term assets or in the overnight market. This leads to an increase in TB and a fall in FF, i.e., Dif falls and $|D_t|>0$. To moderate the fall in FF and make its intention clear, the Fed exerts an upward pressure on non-borrowed reserves, for example, by an outright sale of Treasury bills. Given the fact that TB is high, instead of selling bills, banks compete for interbank funds and exert an extra upward pressure on FF. Market actions and the Fed reactions continue until equilibrium is again achieved (D=0). Specifically, there are enough speculative and arbitrage activities by the forward-looking market participants to make deviations of Dif from Tdif short lived along the solid line in the lower panel of Figure 1 so that at the time of the target rate announcement $|D_t|=0$ or is very close to zero (i.e., an indication of 100% or very close to 100% transparency). Thus, when FF and TB are cointegrated and market participants are forward looking, $|D_t|$ can capture a market-based monetary policy transparency, provided uncertainty does not exist.

In sum, so far, based on some conditions (assumptions) of which their validity was verified in the literature, we have established a theoretical justification behind our index. Such an index is dynamic and includes expected policy actions. It should be mentioned that one may argue that Dif may deviate from its trend not only because of speculative and arbitrage activities of the market participants based on their expectations (understanding) of future Fed actions, but also based on additional factors, such as the mobility of capital.

As it was mentioned earlier in this section, Dif measures default risk premium minus maturity risk premium. There is no theoretical reason or empirical evidence, to the best knowledge of the author, to believe that these premiums deviate on average from their equilibrium values (trends) when the structure of the interbank market or the credibility of the U.S. government in servicing the outstanding debt or expected future debt remains constant. This is especially true at high frequency observations. It is, however, possible that the credibility of a bank or some banks in the interbank market may change. But FF is the weighted average of the interbank rates, which should not be changed as one or some banks pay more on their loans while some other banks pay less. An overall banking crisis, if it exists in the sample, should, of course, be dummied out.

Let us investigate whether the deviation of Dif from its trend can be a function of the mobility of capital at high frequency data even for a large country like the United States. Before such a scenario can be investigated, it should be noted that the mobility of capital, as well as any other internal or external shocks, aside from the expectations on Fed activities, do influence FF and TB in the same proportion, especially at high frequency observations, provided the structure of the interbank market remains the same. To provide some empirical evidence for this argument, we investigate the Granger causality between the change in the log of the US exchange rate (ge) and the gap between Dif and its forty-day (to capture two months) moving average (cdif), i.e. $gap_t = Dif_t - cdif_{t-1}$. This test is based on the assumption that the exchange rate (Japanese Yens per US dollar) movements at high frequency data capture the mobility of capital.

Both of these variables are stationary. The stationarity test results are available upon request. Note also that in all of these tests we conditioned the dependent variables on the variables included in the set DUM, where DUM = (M_t, T_t, WED_t, TH_t, $D851231_t$, $D861231_t$, $GREEN_t$, $Bernanke_t$, $OCT87_t$, $ASIA_t$, TA_t, TAF_t, $SWED_t$, $REMA_t$, $minutes_t$, $transcripts_t$, $state_t$, $D940418_t$, $D970819_t$, lrr_t, $D981015_t$, $D99518_t$, $D000202_t$, $D010103_t$, $D010418_t$, $D010917_t$,

$D020319_t$, $EDAY_t$, $TARATE_t$). The dummy variables M_t, T_t, WED_t and TH_t are for Mondays, Tuesdays, Wednesdays and Thursdays, respectively. For example, M = 1 for Mondays and zero, otherwise. Dummy variables $D851231_t$ and $D861231_t$ are equal to one on December 30 and 31, 1985 and December 31, 1986, respectively, and are equal to zero, otherwise. These dummy variables are included to capture the high volatility of the Fed funds rate on those days. Dummy variable $GREEN_t$ =1 from August 11, 1987 to January 31, 2006, and is equal to zero, otherwise. This variable accounts for the tenure period of Chairman Alan Greenspan. $Bernanke_t$ = 0 since February 1, 2007 when Chairman Bernanke was appointed chair of the Fed and is zero, otherwise. $OCT87_t$ and $ASIA_t$ are dummy variables accounting for the October 87 and Asian crises, respectively. In both events, central banks in industrial countries flooded the money markets with liquidity to ease the downfall in the stock markets. The easing of the markets took at least until the end of October of the year the crisis took place.

Consequently, we created $OCT87_t$ = 1 for October 19 to 30, 1987 and zero, otherwise, and $ASIA_t$ = 1 for October 17 to 30, 1997 and zero, otherwise. Dummy variable TA_t = 1 since February 4, 1994 (when the Fed began announcing policy decisions after each FOMC meeting) and is equal to zero, otherwise. Dummy variable TAF_t = 1 since October 19, 1989 (when the Fed started the practice of adjusting the funds rate target by 25 or 50 basis points) and is zero, otherwise. Dummy variable $SWED_t$ accounts for settlement days on Wednesdays, i.e., it is equal to one on Wednesdays when it is a settlement day and zero, otherwise. Dummy variable $REMA_t$ = 1 since February 2, 1984 when the reserve maintenance period was modified from one week (for most large institutions) to two weeks (for all institutions) and is zero, otherwise.

Dummy variable $minutes_t$ =1 since March 23, 1993, when the Fed began releasing the minutes of the FOMC meetings (with 6-8 week lag) and equals zero, otherwise. Dummy variable transcripts =1 since November 16, 1993 when the Fed began releasing the transcripts of the FOMC meetings (with 5-year lag) and equals zero, otherwise. Dummy variable $state_t$ =1 since August 16, 1994 when the Fed began describing the state of the economy and further rationale for the policy action after FOMC decisions, and is equal to zero, otherwise. Dummy variable $D970819_t$ =1 since August 19, 1997, when the FOMC started including a quantitative Fed funds target rate in its Directive to the New York Fed Trading Desk, and equals zero, otherwise. On March 26, 1998 the Fed moved from contemporaneous reserve requirements back to lagged reserve requirements. This policy went into effect with the reserve maintenance period beginning July 30, 1998. Dummy variable lrr_t = 1, since July 30, 1998 and is equal to zero, otherwise, accounts for this policy regime change. Dummy variable $D99518_t$ =1 since May 18, 1999, when Fed extended its explanations regarding policy decisions, and started to include in press statements an indication of the FOMC's view regarding prospective developments (or the policy bias), and zero, otherwise. Dummy variable $D000202_t = 1$ since February 2, 2000, when the FOMC started to include a balance-of-risks sentence in its statements replacing the previous bias statement, and zero, otherwise. Dummy variable $D020319_t = 1$ since March 19, 2002, when the Fed included in FOMC statements the vote on the directive and the name of dissenter members (if any), and zero, otherwise.

Dummy variables $D940418_t$, $D981015_t$, $D010103_t$, $D010418_t$ and $D010917_t$ are equal to one for April 18, 1994; October 15, 1998; January 3, 2001; April 18, 2001 and September 17, 2001 (when the Fed changed the FF target outside its regular meetings), respectively, and zero otherwise. Dummy variable $EDAY_t$ is equal to one for the days ("event") when the Fed funds target rate was changed whether at a regularly scheduled FOMC meeting, or otherwise, and also for the days on which the FOMC met, but did not change the target rate. It is equal to zero, otherwise. Dummy variable TARATE is equal to one for the days when the Federal funds target rate actually was changed and is equal to zero, otherwise. These days can be among the regularly scheduled FOMC meeting dates or other days. Note that TARATE is a subset of EDAY, as it excludes the days when FOMC met, but did not change the target.

We will use Akaike's (1970, 1974) information criterion (AIC), Schwarz's (1978) information criterion (SC), the generalized cross validation (GCV) method developed by Craven and Wahba (1979), used by Engel *et al.* (1986), as well as Hannan and Quinn's (1979) criterion (HQ) to determine the lag length (k) for a global lag length of 60 days to incorporate a three-month period. According to the lag specification tests, the optimum k for all these criteria was found to be one. The Wald test (adjusted for heteroscedasticity and autocorrelation) result [Chi-Squared(1)=0.47 with significance level 0.49] strongly rejects the null hypothesis that ge Granger causes gap. This result is consistent with the finding of Bernanke and Blinder (1992) who provide empirical evidence that the Fed funds rate, or its spread from some other interest rate (including three-month Treasury bill rate), is independent from current developments in the economy. Consequently, we conclude that Dif deviates from its trend only because of speculative and arbitrage activities of the market participants based on their expectations (understanding) on future Fed actions.

B. Basic Index

The index will be constructed in three steps:

(1) We identify "event days" as the days on which the Federal funds target rate was changed whether at a regularly scheduled FOMC meeting or outside the meetings and also the

days on which the FOMC met but did not change the target rate. When the FOMC meetings took place over two days, we choose the second day of the meeting as the event day.

Our first event date in the sample is October 5, 1982, the first meeting of the FOMC during our period of study. On this date, the FOMC adopted a target for the Federal funds rate of 10%. Our second event date is October 8, 1982, when the FOMC changed the target (to 9.5%) outside a regularly scheduled meeting. Our last event date is August 7, 2007, the last meeting of the FOMC within our sample period. On this occasion, the Fed left the target rate unchanged. In total, we have 256 event days in the sample period.

(2) For each event day, we calculate $|D_t| = |Dif_t - Tdif_{t-1}|$, where $Tdif_{t-1}$ is the average of Dif_t between two event dates. Namely, we calculate daily observations of the absolute value of the deviation of FF minus TB from the trend differential at each event date.[8] For example, for the event day of October 8, 1982, $Tdif_{j-1}$, as the arithmetic average of Dif_t for t = 5-Oct-82, 6-Oct-82, 7-Oct-82, is $Tdif_{j-1} = (2.13 + 1.40 + 2.06)/3 = 1.863333$, while, $|D_j| = |Dif_j - Tdif_{j-1}| = |1.88 - 1.863333| = 0.016667$.

(3) We consider the maximum/minimum of $|D_t|$, at the event dates in the sample period, to be the least/most transparent monetary policy over the period, and we calculate the index as follows:

$$T_t = \text{transparency index} = \frac{100}{e^{|D_t|}}\,. \qquad (5)$$

If $|D| = 0\%$, we will have $T = 100\%$, the highest transparency degree and for $|D| = 10\%$ we will have $T = 0.0045\%$ which may be considered zero transparency for the case of the United States. Consequently, our calculated index for the first event day in the sample period (October 8, 1982) is $100/e^{|0.016667|} = 98.347$. In sum, when the Treasury bill market is not efficient in a strong form, forward-looking market participants can completely perceive the target rate, only due to 100% transparency, so that $e^{|D|} = 1$. See Figure 2 for the annual average of the basic transparency index.

Figure 2 about here

Since we assumed no uncertainty in the sense of Knight (1921), to make the index unbiased, Figure 2 has been adjusted for the uncertainty created by the October 87 stock market crisis and before the start of Chairman Greenspan's tenure in 1987. The index in this figure is also adjusted for the uncertainty created by Russia's debt crisis which led to the near-collapse of Long-

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[8] Although it would be more intuitive to calculate Tdif as the daily geometric average (as opposed to the arithmetic average), about 10% of the time Dif is a negative value and often the number of days between event days is an even number. Furthermore, consistent approximations of the geometric average are not possible for all dates in the sample. To make the measure consistent across all observations we use simple

Term Capital Management in 1998. This event caused credit markets to freeze and resulted in the intervention of the Fed. Finally, the index is adjusted by the uncertainty created by the September 2001 crisis.[9] For all other analyses in this paper the raw index is used. For instance, for the entire sample, index T averages 83.64%. The maximum value of T is 100 (full transparency or full anticipation) and it occurs on September 26, 1995. The least transparent outcome (T = 23.42%) occurs, early on in the sample, on December 16, 1987 while a fairly low value for T also occurs on September 17, 2001. These two low values are clearly due to the uncertainty created by the events of the stock market crisis in 1987 and of September 2001, respectively.

It should be again noted that the index developed in this paper is market based. It, therefore, reflects what market participants perceive from hints, actions or reactions (to exogenous shocks) of the monetary authorities and not what these authorities intend to convey to the market. Specifically, the public availability of the data does not suffice to achieve transparency. What is important is how agents manipulate the data to extract useful information. In other words, a market-based measure of monetary transparency depends on the understanding (manipulation) of the data. Namely, market participants may observe a different norm/direction in the policy during the day or within a month or a period than what the central bank actually follows. Furthermore, even though monetary authorities believe they have been as transparent as before, the index developed in this paper reflects changes in what market participants understand from policy regime changes. Consequently, a market-based transparency index may fluctuate as policy regime changes or when there are exogenous shocks to the system when agents are forward looking. This can be clearly seen in our index (Figure 2).

As explained in Section II, during the sample period, there have been policy regime changes, which, without any doubt, resulted in a higher monetary policy transparency in the United States. These changes occurred on August 11, 1987, October 19, 1989, March 23, 1993, November 16, 1993, February 4, 1994, August 16, 1994, August 19, 1997, May 18, 1999, February 2, 2000 and, March 19, 2002. We will use our index to determine whether the above transparency-oriented changes at the Fed have indeed increased the market's understanding of the Fed policy changes.

Since the basic index, T, has irregular intervals, a quarterly sample out of the observations was constructed. Namely, we took the average of the index in each quarter.

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arithmetic averages. Another potential problem with geometric averages occurs when the differential is zero or close to zero, since in such a case the geometric mean artificially drives the trend to zero.

[9] It should be noted while after September 11, 2001 market participants knew the Fed would ease policy, but a great deal of uncertainty existed on the magnitude of the expansion as well as on the economy.

According to both Dickey-Fuller and Phillips-Perron tests, variable T is stationary.[10] Table 1 reports the means with their standard errors (adjusted for autocorrelation and heteroscedasticity) of the index before and after each policy regime change. All means are statistically significant. The above policy regime changes resulted in positive and statistically significant changes in the transparency index. Consequently, according to these results, the index developed in this paper clearly captures the increase in the monetary policy transparency created by the above policy regime changes. Namely, the index developed in this paper fully reflects a transparency index. Note that since policy regime changes in 1993 and 1994 (see above) took place within a very short period of each other, we investigated the power of the index on these changes together, see rows 6 and 7 of Table 1. The result of the individual impact of these policy regime changes (available upon request) also indicates an improvement in the index.

Table 1 about here

C. Extension of the Index

Being a variable with unequal intervals, the basic index developed in this paper can be used in studies with quarterly or less frequent data. Alternatively, it restricts the researchers to specific techniques of estimation, such as the factor-model approach which allows researchers to deal systematically with data irregularities [e.g., Stock and Watson (2002)]. To make the measure suitable for all kinds of research, using the above methodology and logic, we extend our index as follows. For the event days, the index is defined exactly as before [Equation (5)]. For all other days, we compute an estimated or forecasted value of D_t, called $\hat{D}_t$, where $\hat{D}_t = |Dif_t - Adif_t|$, with Dif_t is defined as before ($= FF_t - TB_t$) and with $Adif_t = \dfrac{\sum_{i=1}^{j} Dif_{t-i}}{n}$, where j is the last event day and n is the number of days since the last event day. Given $\hat{D}_t$, we calculate an index for non-event days $\hat{T}_t$,

$$\hat{T}_t = 100 / e^{|\hat{D}_t|}. \tag{6}$$

Note that our index $\hat{T}_t$ is dynamic and also continuous in the sense that we can construct it for intraday minute or even shorter-interval, instead of daily, observations. It should be mentioned that there are several important characteristics of the Federal funds market (e.g., the

[10] The absolute value of the augmented Dickey Fuller *t* was estimated to be 6.77 [more than 2.89 (5% critical value)] and the absolute value of the Phillips-Perron non-parametric *t* was estimated to be 7.12

last day of the reserve maintenance period, the last day of quarters, years and months, etc.) that lead to predictable movements in the funds rate without any impact on three-month Treasury bill rate. The daily index, consequently, can be affected, mostly, negatively by these characteristics. To avoid a biased calculation of the daily index, we will filter (dummy out) the daily index for these features of the Fed funds market.

To further clarify how the index is constructed on non-event days consider once again the first two event dates in the sample i = October 5, 1982 and j = October 8, 1982, and assume that we want $\hat{T}_t$ for t = October 7, 1982. We first compute $Adif_t = \frac{\sum_{i=1}^{j} Dif_{t-i}}{n}$ = (2.13+1.40)/2 = 1.765. We then compute $\hat{D}_t = | Dif_t - Adif_t| = |2.06-1.765| = 0.295$, and $\hat{T}_t = 100/e^{0.295} = 74.453159$. Figure 3 depicts the annual average of the extended index. Note that for event days the extended index is given by T_t and for non-event days, by $\hat{T}_t$. On average, for the entire sample period, the extended transparency index equals 85.68% which is close to the estimated average of the basic index (83.64%).

Figure 3 about here

As Figure 3 shows, the extended index is smoother than the basic index as it contains more information. However, these two indices show almost the same movements during the sample period, except in 1998 when they deviate from each other by 10%. We will again investigate, using our daily observations and extended index, whether the regime changes of August 11, 1987, October 19, 1989, March 23, 1993, November 16, 1993, February 4, 1994, August 16, 1994, August 19, 1997, May 18, 1999, February 2, 2000, and March 19, 2002 have resulted in more transparency (as measured by our extended index). According to both Dickey-Fuller and Phillips-Perron tests, our extended index $\hat{T}$ is stationary.[11] Table 1 also reports the means with their standard errors (adjusted for autocorrelation and heteroscedasticity) of the daily index before and after each policy regime change. As the results reported in the table indicate, all means and their changes are positive and statistically significant, confirming the earlier findings that these policy regime changes resulted in a higher monetary policy transparency. Furthermore, the results imply that the daily monetary policy transparency index

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[more than 2.89 (5% critical value)]. Both of these tests were done for a lag length of zero (where, for a global lag of 20 days, the AIC and SC criteria are at their minimum).

[11] The absolute value of the augmented Dickey Fuller *t* was estimated to be 43.42 [more than 2.86 (5% critical value)] and the absolute value of the Phillips-Perron non-parametric *t* for the lag length of 4 (where,

developed in this paper also fully and clearly captures the increase in the monetary policy transparency created by the above policy regime changes. Namely, the daily index developed in this paper also fully reflects a monetary policy transparency index. It should be emphasized again, that as both developed indexes reflect, the view of the market, based on the actions of the central bank, could rapidly change if agents are forward looking. Both indexes are based on two important assumptions: FF and TB are cointegrated and market participants are forward looking, i.e., expectations are formed rationally and the behaviors of participants in the overnight money market in the United States are not policy invariant.

IV. Risk and Volatility in the Money Market: Further Evaluation of the Index

It is commonly believed [e.g., Thornton (1996) and Blinder *et al.* (2001)] that monetary policy transparency leads to lower uncertainty and risk in financial markets. If our indexes, both the basic and the extended, are a true proxy for monetary policy transparency in the United States, it should have a negative relationship with the risk observed in the money market in the country. This section is devoted to such an investigation. We will first test if the index has a negative impact on the risk in the money market. We will conduct this test by using the rational expectations model of the term structure. The test is based on the idea that the more the Fed conveys its private information to the market the higher the forecast ability of the market participants will be and, consequently, they will demand a lower risk premium. We then test if our index has any impact on the volatility in the money market in the United States. This test is based on the idea that a higher volatility of the return in the money market is associated with a higher risk in the market and, therefore, if a more transparent monetary policy results in a lower volatility it will help to reduce risk in the money market.

A. Risk in the Money Market and the Index

The pure (rational) expectations model of the term structure (RE), in which the term premia are set identically to zero, implies that at any moment in time, the expected TB, for example, prevailing at the beginning of three months from now (${}_{1+3}TB_t^e$) should be equal to the implied forward three-month Treasury bill rate (FTB_t) in the absence of term premium or any other risk. From the first statement of the theory [e.g., Van Horne (1965)], we know that

for a global lag of 20 days, the AIC and SC criteria are at their minimum) was estimated to be 44.22 [more than 2.86 (5% critical value)].

$FTB_t = [(1 + TB6_t/4)^2/(1 + TB_t/4)] – 1$. Here TB6 is the six-month spot rate and we assume both six- and three-month spot Treasury bill rates are at the annual rate. Specifically, we can write:

$${}_{1+3}TB_t^e = FTB_t. \quad (7)$$

If this equality is violated, investors and speculators, trade three- and six-month Treasury bills, to capture potential arbitrage profits, until Equation (7) is restored. For example, if ${}_{1+3}TB_t^e > FTB_t$ speculators will sell their six-month bills and buy three-month bills, pushing the price of six-month bills down ($TB6_t$ will go up) and increasing the price of three-month bills up ($TB3_t$ will go down). This speculative activity continues until the potential for speculative profits is eliminated, i.e., ${}_{1+3}TB_t^e$ is again equal to FTB_t. Furthermore, by orthogonal decomposition at any given time t we have:

$$TB_t = TB_t^e + V_t, \quad (8)$$

where V_t is the agents' forecast error in the absence of transaction costs, risk and other premia (including term premium, liquidity premium and reinvestment premium). Substituting (7) in (8) yields:

$$TB_{t+1} = FTB_t + V_{t+1}. \quad (9)$$

If the market is efficient (expectations are rational), $TB_{t+1} - FTB_t = V_{t+1}$ is stationary [e.g., Campbell and Shiller (1987)] and, in the absence of risk premia and transaction costs, has a zero mean. The error term (V_t) is stationary as both Dickey-Fuller and Phillips-Perron tests reject the null hypothesis that V_t is not stationary. The absolute value of the augmented Dickey Fuller *t* was estimated to be 7.40 and the absolute value of the Phillips-Perron non-parametric *t* for the lag length of 4 was estimated to be 7.73, both *t* statistics results are higher than 2.86 (5% critical value).[12] However, the mean of V_t over our sample period was found to be -0.26%, at the annual rate, with an autocorrelated-heteroscedastic adjusted *t* statistic of -41.15.[13] The mean of the absolute value of V was found to be 0.38%, at the annual rate, with an autocorrelated-heteroscedastic adjusted *t* statistic of 31.66. Both of these means are far from being zero, indicating term premium or other risk premia exist, assuming a trivial transaction cost. Although a completely different approach was used, this result (i.e., on average, the RE hypothesis is valid in the United States money market, and risk premia exist) is consistent, among many others, with the finding of Van Horne (1965), Mankiw and Miron (1986) and Taylor (1992).

We will, consequently, modify Equation (9) to

$$TB_{t+1} = FTB_t + RP_{t+1} + V_{t+1} = FTB_t + W_{t+1}, \quad (10)$$

[12] The lag length in augmented Dickey-Fuller or Phillips-Perron nonparametric tests was obtained according to AIC and SC criteria for a global lag of 20 days.

[13] Autocorrelation is due to the overlapping observations. We used, as before, Newey and West's (1987) robusterror for 5-order moving average to correct the standard error.

where RP is risk premia and $W_t = RP_t + V_t$. Note that RP includes term, liquidity, interest exposure and reinvestment risk premia where reinvestment risk premium has a negative effect on RP. If our index is a satisfactory representative of the monetary policy transparency in the United States it should have a negative relationship with W_t in Equation (10), see Thornton (1996), Haldane and Read (2000) and Blinder *et al.* (2001), among others, for arguments and econometric tests on the relationship between transparency and forecast errors of market participants.

We estimate the following equation:

$$\left|W_t\right| = \xi_0 + \xi_1 LT_{t-1} + DUM_{t-1}' \varsigma + \epsilon_t, \qquad (11)$$

where $\left|W_t\right|$ is the absolute value of the forecast error from Equation (10), LT_t is the logarithm of $\hat{T}_t$, ξ's are constant parameters, ς is a vector of constant parameters and ϵ_t is the white noise disturbance term. Vector DUM, defined before, included in the equation in order to capture the impact of monetary policy regime changes as well as other shocks on the risk premia.

Note that variables LT and DUM enter in Equation (11) with one lag length (three months ago) since the implied forward rate was used three months before (at the time of forecast) the actual rate was realized. Our index, if it is a real proxy for monetary transparency in the United States, should have a negative relationship with the risk premia if the estimated ξ_1 is negative and statistically significant. Since our sample is daily observations, LT is our extended index and the lag length is 90 days. Note that the index and the calculated forward rate [an element of $\left|Wt\right|$ $(= TB_t - FTB_{t-1})$] have the same lag length in Equation (11). However, there is no theoretical reason to believe that the index can be influenced by the calculated forward rate. Furthermore, we can investigate the causality between these two stationary variables by estimating each variable by its 20 lagged values as well as the lagged values of the other variable.

By doing so, we found the Wald test on the coefficients of twenty lagged values of LT_t in a regression of LT_t on its twenty lagged values as well as twenty lagged values of $\left|Wt\right|$ is 158.88 (*p*-value=0.00), while the Wald test on twenty lagged values of $\left|Wt\right|$ is 14.74 (*p*-value=0.79). At the same time, the Wald test on the coefficients of twenty lagged values of $\left|Wt\right|$ in a regression of $\left|Wt\right|$ on its twenty lagged values as well as twenty lagged values of LT_t is 5504.33 (*p*-value=0.00), while the Wald test on twenty lagged values of LT_t is 48.27 (*p*-value=0.00). This result implies that LT_t Granger causes $|Wt|$ while $|Wt|$ does not Grange cause LT_t. Specifically; we conclude LT_t is strongly exogenous in Equation (11).[14]

Equation (12) is the parsimonious estimated result of Equation (11), where the figures in brackets are standard errors adjusted for autocorrelation and heteroscedasticity.

$$|W_t| = 1.12\ (0.21) - 0.14\ (0.04)\ LT_{t-1} - 0.16\ (0.02)\ TA_{t-1} + 0.15\ (0.07)\ REMA_{t-1}$$
$$-0.18\ (0.06)\ GREEN_{t-1} + 0.53\ (0.03)\ D010917_{t-1} + 0.43\ (0.01)\ D010103_{t-1}$$
$$+ 0.05\ (0.01)\ D010418_{t-1} + 0.18\ (0.01)\ D940418_{t-1} + 0.57\ (0.15)\ OCT87_{t-1}$$
$$-0.62\ (0.25)\ D851231_{t-1} - 1.71\ (0.38)\ D861231_{t-1} - 0.34\ (0.06)\ Bernanke_{t-1}. \qquad (12)$$

$\bar{R}^2=0.14$, $\sigma=0.37$, RESET=0.45 (significance level=0.71)

The estimated coefficient of LT is negative and statistically significant implying that as the monetary policy is more transparent the forecast errors and risk premia will fall. This result confirms Thornton (1996), Haldane and Read (2000), Blinder *et al.* (2001) and Swanson (2006). According to the estimated coefficient of dummy variable TA, the Fed policy of announcing policy decision (Target rate) at the conclusion of each FOMC meeting, since February 4, 1994, resulted in a lower risk and forecast error in the money market in the United States.

The positive and statistically significant estimated coefficient of REMA implies that modifying the reserve maintenance period from one week (for most large institutions) to two weeks (for all institutions) in February 1984 resulted in a higher forecast error, while the negative and statistically significant coefficient of the dummy variable GREEN and Bernanke means the forecast error in the money market fell during the tenure of Chairman Greenspan and continued to fall. The estimated coefficient of D010917, as one would expect, is positive and statistically significant, which reflects a higher risk environment associated with September 2001.

Furthermore, as the positive and statistically significant estimated coefficient of D010103, D010418 and OCT87 indicates, the unexpected change in the target rate on January 3, 2001 and April 18, 2001 as well as during the October 87 stock crisis resulted in a higher forecast error. However, according to the estimated coefficient of dummy variable D940418, which is negative, the forecast error (and/or risk premia) fell on April 18, 1994 when the Fed changed the FF target outside its regular meetings. The surprising result is the estimated coefficients of dummy variables D851231 and D861231. Both are negative and statistically significant implying a high volatility of FF on December 31, 1985 and December 30 and 31, 1986 resulted in a lower forecast error on those days.

[14] All Wald test results are adjusted for autocorrelation and heteroscedasticity.

We also used quarterly averages of the daily observations to create a quarterly sample to test the power of our basic index T. For quarterly observations of T, we also took the average of our basic index in each quarter. Since the quarterly constructed index are highly correlated with the set of variables in DUM we estimated Equation (11) without DUM, since otherwise the resulting multicolinearity leads to a statistically insignificant estimated coefficients. We used the Least Squared estimation technique to estimate the equation with our quarterly data.[15] The estimated Equation (11) with LT being the logarithm of our quarterly index is as follows:

$$\left|W_t\right| = 3.14\ (1.13) - 0.63\ (0.25)\ LT_{t-1}. \tag{13}$$

$\bar{R}^2$=0.05, σ=0.33, DW=1.32, Godfrey(5)=2.55 (significance level=0.03), White=1.03 (significance level=0.96), ARCH(5)=3.97 (significance level=0.55), RESET=0.43 (significance level=0.73)

To further verify the above result we took the quarterly average of the extended index. This time we estimated Equation (11) with DUM. In the first round of regression, among dummy variables, only the coefficient of few dummy variables, including OCT87 and Bernanke, were statistically significant. After dropping dummy variables with statistically insignificant coefficients, we found the coefficient of those few dummy variables to be also statistically insignificant. We, consequently, dropped those dummy variables from the regression. The parsimonious estimated Equation (11) with LEXT being the logarithm of the quarterly average of our daily index is as follows:

$$\left|W_t\right| = 9.42\ (1.98) - 2.03\ (0.44)\ LEXT_{t-1}. \tag{14}$$

$\bar{R}^2$=0.17, σ=0.31, DW=1.71, Godfrey(5)=1.15 (significance level=0.34), White=4.54 (significance level=0.48), ARCH(5)=4.36 (significance level=0.50), RESET=0.19 (significance level=0.90)

According to the Godfrey test result, the error term is not autocorrelated in both equations (13) and (14) and as White and ARCH test results indicate it is also homoscedastic in these equations. According to the RESET test result, there is no misspecification in either equation. The negative and statistically significant coefficient of LT and LEXTclearly confirms the earlier

[15] Again we found LT to be strongly exogenous in Equation (11) as the Wald test on the coefficients of four lagged (incorporating a year) values of $\left|Wt\right|$ in a regression of $\left|Wt\right|$ on its four lagged values as well as four lagged values of LT_t is 47.11 (*p*-value=0.00), while the Wald test on four lagged values of LT_t is 23.36 (*p*-value=0.00). Alternatively, the Wald test on the coefficients of four lagged values of LT_t in a regression of LT_t on its four lagged values as well as four lagged values of $\left|Wt\right|$ is 20.66 (*p*-value=0.00), while the

finding in this paper that a higher monetary policy transparency leads to a lower forecast error (a higher efficiency in the money market).

B. Volatility in the Money Market and the Index

To further investigate the strength of our transparency index we will examine the relationship between our index and risk, measured by the volatility, in the money market. It is important to note that theoretically the impact of transparency on volatility is arguable. For example, in a 1976 *Freedom of Information Act* filing, the Fed argued in favor of secrecy motivated by its desire to reduce interest rate variability [see Goodfriend (1986)]. This view is consistent with the literature [see, e.g., Dotsey (1987)] that argues that the cleaner and more frequent the “signal” (or the more transparent monetary policy is) the larger the responsiveness of interest rates to news, and thus the greater their volatility.

Another strand of the literature, however, argues that more transparency tends to reduce market volatility. Tabellini (1987), for example, shows that when market participants face parameter uncertainty (or multiplicative uncertainty) and learn over time, using Bayes’ rule, the learning process is the source of additional volatility in asset prices. In this case, more transparency tends to reduce market volatility. Since recent empirical evidence suggests that the 1994 transparency move by the Fed is not associated with higher market volatility [e.g., Thornton (1996)], we will follow Tabellini (1987) and assume a more transparent monetary policy tends to lower volatility.

We know that FF and TB are cointegrated and the adjustment toward the long-run equilibrium largely occurs through the movements in the FF rate rather than the TB rate [Sarno and Thornton (2003) and Kia (2006)]. Hence, we would expect the volatility of the daily movements in FF, say VFF, to affect the volatility of the daily movements in TB, say VTB, (i.e., the risk in the money market). We, therefore, investigate the usefulness of our index in capturing the impact of monetary policy transparency on the volatility of the money market. We assume the volatility of TB is a function of the volatility of FF and policy regime changes as well as other shocks specified in EDUM defined below. We assume such a relationship has a linear approximation as specified by Equation (15):

$$VTB_t = \Gamma_0 + \gamma\, LT_t + \sum_{i=1}^{k}\Gamma_i\, VFF_{t-i} + \sum_{i=1}^{k}\Phi_i\, VTB_{t-i} + EDUM_t'\Gamma + \varepsilon_t, \qquad (15)$$

Wald test on four lagged values of $\left|Wt\right|$ is 2.84 (p-value=0.59).This result implies that LT_t is strongly exogenous in Equation (11).

where $\Gamma_0,...,\Gamma_k$, $\Phi_0,..., \Phi_k$, γ and Γ are constant parameters. Dummy vector EDUM = (DUM_t, STU_t, $TUE1_t$, HB_t, $HA1_t$, $HB3_t$, $HA3_t$, LDY_t, $LQBA_t$, LQ_t). Dummy variables included in DUM were defined earlier. To capture the possible volatility in the money market created by other factors, like window dressing, holidays and other seasonality, following Hamilton (1996), we included dummy variables STU_t, $TUE1_t$, $HB1_t$, $HA1_t$, $HB3_t$, $HA3_t$, LDY_t, $LDBYA_t$, $LQBA_t$ and LQ_t.

These dummy variables are defined as: STU = 1 on Tuesdays before settlement Wednesdays and zero, otherwise. TUE1 = 1 on Tuesdays before settlement Wednesdays if Wednesday was a holiday, and zero, otherwise. HB1 = 1 for the day before a one-day holiday, and zero, otherwise. HA1 = 1 for the day after a one-day holiday, and zero, otherwise. HB3 = 1 for the day before a three-day holiday, and zero, otherwise. HA3 = 1 for the day after a three-day holiday, and zero, otherwise. LDY =1 for the last day of the year, and zero, otherwise. LDBYA = 1 for 2 days before, 1 day before, on, 1 day after, or 2 days after the end of the year, and zero, otherwise. LQBA = 1 for the day before, on, or after the last day of the first, second and third quarters, and zero, otherwise. And finally, LQ = 1 for the last day of the first, second, third and fourth quarters, and zero, otherwise.

Note that in Equation (15) VFF is predetermined and if γ is negative then the higher the monetary policy transparency (LT) is, the lower the volatility of the three-month Treasury bill rate will be. Following, among many, Schwert (1989), Kearney (2000) as well as Kia (2003), the methodology developed by Davidian and Carroll (1978) was used. Let x be any variable in column vector $x_t = (\Delta TB_t, \Delta FF_t,)'$ and estimate Equation (16) for ΔTB_t and ΔFF_t.

$$x_t = \sum_{i=1}^{20} \alpha_i^x x_{t-i} + EDUM_t'\mu^x + u_{xt}, \qquad u_{xt} \sim niid(0, \Sigma). \tag{16}$$

The parameters α^x's and vector μ^x are assumed to be constant. We assume a lag length of 20 days (reflecting a month) is sufficient for the market participants to learn from the past movements in the TB rate. The dummy variables included in vector EDUM capture the shocks on the rate during our sample period. Furthermore, a 20th-order autoregression for the absolute values of errors from Equation (16), including dummy variables in vector EDUM that allow for different daily standard deviations, should be estimated:

$$|\hat{u}_{xt}| = \sigma_t^x = \sum_{i=1}^{20} \delta_i^x \sigma_{t-i}^x + EDUM_t'\eta^x + v_t, \tag{17}$$

where δ_i^x , for i = 1 to 20 and the column vector η^x are constant parameters. The absolute value of the fitted value of u_{xt} (i.e., $|\hat{u}_{xt}|$) is the standard deviation (adjusted heteroscedasticity and autocorrelation) of $x_{t,}$ for $x_t = \Delta TB_t$ and ΔFF_t. However, since the expected error is lower than the standard deviation from a normal distribution, following Schwert (1989), all absolute errors are multiplied by the constant 1.2533.

As it was also mentioned by Kia (2003), the conditional volatility in Equation (17) represents a generalization of the 20-day rolling standard estimator used by Officer (1973), Fama (1976) and Merton (1980). This is due to the fact that the conditional volatility estimated by Equation (17) allows the conditional mean to vary over time in Equation (16), while it also allows different weights to be applied to the lagged absolute unpredicted changes in Treasury bills and Fed funds rates.

Note that here the conditional mean of these rates was also allowed to vary with the shocks represented by dummy variables included in vector EDUM. Furthermore, Engle (1993) reviews the merit of this measure of volatility, among others. This measure of volatility is similar to the autoregressive conditional heteroscedasticity (ARCH) model of Engle (1982), which, in its various forms, has been widely used in the finance literature. Davidian and Carroll (1978) argue that the specification in Equation (17) based on the absolute value of the prediction errors is more robust than those based on the squared residuals in Equation (16).

However, it should be noted that the variables in equations (15) and (17), excluding dummy variables, are generated regressors. Consequently, when these equations are estimated, their *t* statistic should be interpreted with caution. To cope with this problem, following, among many, Kearney (2000) and Kia (2003), the equation for the conditional volatility [i.e., Equation (15)] is estimated jointly with the equations determining the conditional volatilities of ΔTB and ΔFF using the generalized Least Squares (GLS) estimation procedure (SUR).[16]

In the GLS system, two equations are generated by Equation (16), two equations are generated by Equation (17) and including Equation (15) a system of five equations with 6482 observations (with a final sum of 3679 usable observations) is estimated. In the GLS estimation, for each equation and the system of equations, we used Newey and West's (1987) robusterror for 5-order moving average to correct for heteroscedasticity and autocorrelation. The GLS estimator incorporates the possibility of cross-equation correlation among the error terms. The final parsimonious GLS estimation result of Equation (15) is given by Equation (18), where standard errors appear in brackets.[17]

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[16] See Kia (2003), Footnote 4, for a full explanation on why in our case the GLS estimation technique should be used.

[17] The stationarity test results for VTB are as follows: The absolute value of the augmented Dickey Fuller *t*, for a lag length of 8 = 13.72 and the absolute value of the Phillips-Perron non-parametric *t* test for the lag length of 3 = 55.42, both *t* statistics are higher than 2.86 (5% critical value) indicating the conditional

$$
\begin{aligned}
VTB_t = {} & 0.09\ (0.01) - 0.005\ (0.002)\ LT_t + 0.009\ (0.004)\ VFF_{t-1} \\
& - 0.03\ (0.001)\ VFF_{t-4} - 0.03\ (0.001)\ TAF \\
& 0.58\ (0.03)\ VTB_{t-1} + 0.38\ (0.03)\ VTB_{t-2} - 0.005\ (0.002)\ GREEN_t \\
& - 0.02\ (0.001)\ ASIA_t - 0.02\ (0.0005)\ D940418_t \qquad (18)
\end{aligned}
$$

$\overline{R}^2 = 0.51$ and σ = the standard error of the regression = 0.015

The estimated coefficient of our monetary policy index (LT) is negative, indicating that a more transparent monetary policy leads to a lower volatile money market. This result confirms the finding of Tabellini (1987), among many, that a higher degree of transparency tends to lower market volatility. Among all dummy variables included in EDUM, the coefficients of dummy variables GREEN, TAF, ASIA and D940418 were found to be statistically significant. As the negative coefficient of dummy variable GREEN indicates, the volatility and risk in the money market fell during the tenure of Chairman Greenspan. As it would be expected, the estimated coefficient of TAF is negative, implying that the policy regime change of announcing policy decisions after each FOMC meeting, since October 1989, led to a lower volatility in the money market in the United States.

As it would be expected, the estimated sign of dummy variable ASIA was negative, reflecting the massive intervention of all industrial countries' central banks in their money markets. The estimated coefficient of D940418 is negative implying that on April 18, 1994, when the Fed changed the FF target outside its regular meetings, it helped to lower volatility in the money market.

We also repeated the above exercise with our quarterly data explained above and our basic index. We found our basic index has a negative effect on volatility, but the estimated coefficient was statistically significant only at 92% level (the full result is available upon request). This could be due to a lack of observations on the index in each quarter. In sum, we showed in this section the monetary policy transparency indexes developed in this paper can be used successfully to detect the impact of monetary policy transparency on risk and volatility.

V. Summary and Conclusions

The existing measures of monetary policy transparency include indicators based on descriptive accounts, surveys, official documents and information as well as market interest rates.

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volatility VTB is stationary. The stationarity test results for VFF are as follows: The absolute value of the augmented Dickey Fuller *t*, for a lag length of 1 = 34.42 and the absolute value of the Phillips-Perron non-parametric *t*-test for the lag length of 4 = 44.96, both *t* statistics are higher than 2.86 (5% critical value)

However, these measures have some limitations, such as a lack of an objectively designed index or indexes without time-series properties. In this paper, we developed an objective market-based index, which is dynamic and continuous and can be used to measure monetary policy transparency for a country or, simultaneously, a series of countries, using time-series as well as cross-sectional data.

Assuming that participants in the money market are forward looking, we developed our index for the United States monetary policy for the period October 1982-August 2007. We found, using our index, that the more transparent the monetary policy in the United States is, the less risky and volatile the money market will be. Moreover, the rational expectations model of the term structure is valid in the United States money market, but risk premia in this market exist.

Using our constructed index, we found a negative relationship between monetary policy transparency and risk and volatility in the economy. Furthermore, risk and uncertainty in the money market fell in the United States during the tenure of Chairman Greenspan as well as Chairman Bernanke (at least the first 19 months of his tenure, covered in this paper). Moreover, the Fed policy of announcing policy decision at the conclusion of each FOMC meeting resulted in a lower risk and forecast error in the money market. We also found that the Fed's change of policy regime in October 1989, when the Fed started the practice of changing the Fed funds target rates by 25 or 50 basis points, led to a lower volatility in the money market. Finally, we conclude that the practice of a more transparent monetary policy leads to more stability (lower volatility) and lower risk in the financial markets.

One possible extension of this study is to modify the index for markets where market participants are not forward looking. Moreover, future studies should use the index developed in this paper to investigate if a more transparent monetary policy leads to higher economic growth. Even though the Federal Reserve became officially transparent only recently, it would also be interesting to do the same exercise for the period starting when the Federal Reserve was first established. Finally, one could also extend this line of research by comparing the power of different time-series market-based measures of monetary policy transparency, including our index and the popular policy surprise measures based on Federal funds futures data.

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indicating the conditional volatility VFF is stationary. Note that the lag length for these tests was determined in such a way that, for a global lag of 20 days, the AIC and SC criteria are at their minimum.

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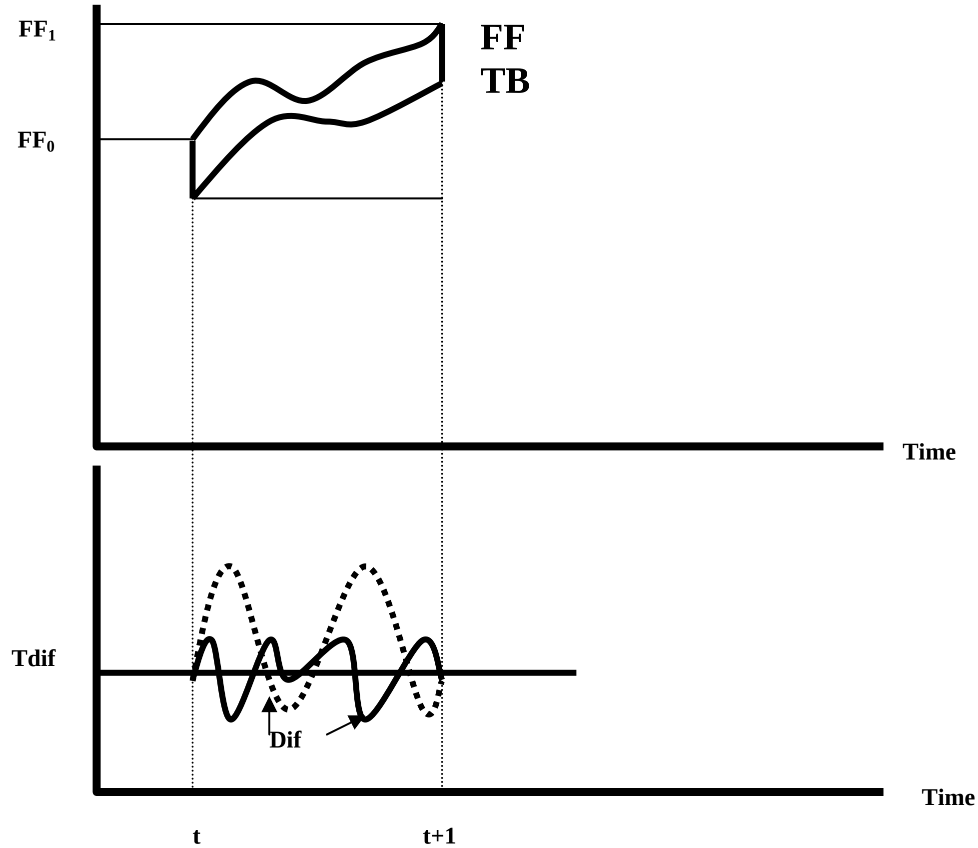
Figure 1: Monetary Policy Transparency



$$\mathbf{Dif_t = FF_t - TB_t}$$

$$\mathbf{D_t = Dif_t - Tdif_{t-1}}$$

Figure 2: Transparency Index

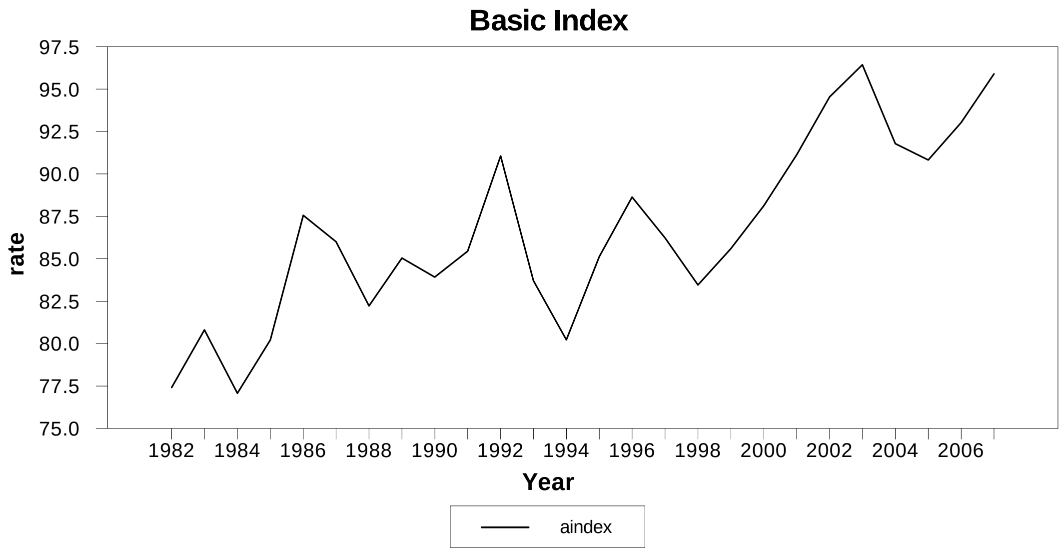


Figure 3: Extended Transparency Index

Table 1: Policy Regime Changes and Monetary Transparency - Standard Errors Adjusted for Heteroscedasticity and Autocorrelation in Brackets

Period	Quarterly Index	Daily Index
Oct. 1982-Aug. 1987	79.57 (1.91)	80.84 (1.14)
Change in: Aug. 1987-Jan. 2006: Greenspan period*	4.19 (2.29)	3.62 (1.66)
Oct. 1982-Oct. 1989	78.89 (2.11)	81.81 (0.86)
Change in: Oct. 1989-Aug. 2007: 25 and 50 bp period**	9.21 (2.36)	6.99 (0.96)
Oct. 1982-March 1993	81.35 (1.75)	82.64 (0.70)
Change in: March 1993-Aug. 2007: Releasing minutes & transcripts and announcing Target Change period***	7.24 (2.11)	7.20 (0.81)
Oct. 1982-Aug. 1997	82.50 (1.43)	83.79 (0.54)
Change in: Aug. 1997-Aug. 2007: Target & NY period****	7.44 (1.92)	7.54 (0.71)
Oct. 1982-May 1999	82.60 (1.31)	84.10 (0.50)
Change in: May 1999-Aug. 2007: Explanation period*****	8.70 (1.82)	8.19 (0.68)
Oct. 1982-Feb. 2000	82.56 (1.25)	84.24 (0.48)
Change in: Feb. 2000- Aug. 2007: Balance of Risk period******	9.66 (1.67)	8.50 (0.66)
Oct. 1982-March 2002	83.12 (1.18)	84.81 (0.46)
Change in: March 2002-Aug. 2007: Vote & Names period*******	12.68 (1.38)	9.21 (0.59)
Oct. 1982-Jan. 2006	84.91 (1.15)	86.32 (0.44)
Oct. 2006-Aug. 2007: Bernanke Period	9.60 (1.56)	8.11 (0.61)

*Alan Greenspan took office as Chairman of the Fed on August 11, 1987.
** On October 19, 1989, the Fed started the practice of changing the Fed funds target rate in multiples of 25 and 50 basis points.
*** On March 23, 1993 the Fed began releasing the minutes of the FOMC meetings and on November 16, 1993 the Fed began releasing the transcripts of the FOMC meetings. Beginning on February 4, 1994, the Fed started announcing policy decisions at the conclusion of the FOMC meetings and on August 16, 1994 it began describing the state of the economy and further rationale for the policy action after FOMC decisions. Since these policy regime changes took place within a very short period of each other, we investigate the power of the index on these changes together.
****The FOMC started to include a quantitative Fed funds rate in its Directive to the NY Fed Trading desk.
***** Since May 18, 1999, the Fed extended its explanations regarding policy decisions, and started to include in press statements an indication of the FOMC’s view regarding prospective developments (or the policy bias).
****** On January 19, 2000, the FOMC issued a press statement explaining that it would include a balance-of-risks sentence in its statements, replacing the previous bias statement. The practice was first implemented the following FOMC meeting, on February 2.
******* Since March 19, 2002, the Fed has included in FOMC statements the vote on the directive and the name of dissenter members (if any).