The Flow of Inflation Information and the Price Volatility of Maturing TIPS

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Abstract

Treasury Inflation Protected Securities (TIPS) experience a transformation from an inflation hedge security to a fixed nominal rate security during the last coupon payment period. The unique period sets a window to observe the pricing of TIPS when the source of uncertainty affecting the sole future cash flow is the realization of actual consumer price index (CPI) on a TIPS maturity date. Given that the trading of contemporaneous Treasury bills reveals pure discount factors for cash flow on maturity date, the maturing TIPS prices reflect the time series characteristics of the flow of inflation information. Empirical results based on sixteen issues of maturing TIPS document a decrease in the volatility parameter due to the expiration of inflation hedging property three months prior to a TIPS matures. The flow of inflation information continues till ten business days prior to the last CPI announcement before a TIPS matures. The timing of the termination of inflation information flow coincides with the end of CPI survey period.

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JEL Classification: G12, G14

Keywords: Treasury inflation-protected securities, inflation hedge, flow of inflation information
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1. Introduction

Treasury Inflation Protected Securities (TIPS) experience a transformation from an inflation hedge security to a fixed nominal rate security during the last coupon payment period. The period after the penultimate coupon payment provides a unique window to observe the pricing of maturing TIPS when the source of uncertainty affecting the sole future cash flow is the realization of actual consumer price index (CPI) on the maturity date. This study investigates the time series characteristic of the flow of inflation information through the trading of maturing TIPS in resolving the uncertainty in the sole cash flow. Furthermore, the time series patterns of TIPS price volatility reflect the sources of pricing noise attributable to market frictions, the flow of inflation information, and the hedging property of TIPS.

The period after the penultimate coupon payment carries several unique characteristics to price maturing TIPS. There are no cash flows until the maturity date; the final coupon and principal payments on maturity date depend on the actual CPI on the maturity date. The issue of stochastic reinvestment opportunity does not affect the pricing of maturing TIPS during the last coupon payment period. Pure discount factor for nominal cash flow on maturity date can be inferred from contemporaneous Treasury bills traded in the market. Using the price of Treasury bill as a benchmark, the study derives a time series of implied target CPI on maturity date from the daily quoted TIPS prices. The sequence of implied target CPI is a series of updated predictors for the actual target CPI under the risk-neutrality assumption. Given the observed Treasury bill prices as the discount factor for time value of money, the fundamental value of TIPS equals the product of the discount factor and the actual cash flow on maturity date. The
discrepancy between the observed TIPS price and its fundamental value is reflected in the distance between the implied target CPI and actual target CPI on maturity date. The time series characteristics of the flow of inflation information affecting the maturing TIPS prices are measured through the time series changes in the distance between the implied target CPI and actual target CPI on maturity date. A continuous decrease in the gap between the implied target CPI and the actual target CPI indicates a continuous flow of inflation information over time.

The unique study window can be separated into four distinct periods. Period I covers the time period after the penultimate coupon payment date till three months prior to the maturity date. Due to the three-month lag in indexing CPI, the inflation hedge property of TIPS ceases to exit at the end of period I. After completing the transformation process at the end of period I and before the last CPI announcement prior to a TIPS matures, a maturing TIPS is equivalent to a Treasury bill except for the uncertainty surrounding the realization of the actual target CPI. The waiting period for CPI announcement is separated into two periods by a date associated with the end of the flow of inflation information. In period II, while maturing TIPS prices continue to incorporate inflation information, the gap between the implied target CPI and actual target CPI is narrowed. In contrast, in the subsequent period III, the sequence of implied target CPI does not show observable movements to reduce the gap. This is an indication that the information set regarding the forthcoming CPI index is full and the pricing of a maturing TIPS is equivalent to a Treasury bill even though the official announcement of CPI occurs several days later. After the announcement, all uncertain pricing factors are eliminated and any price difference between maturing TIPS and its counterpart Treasury bill reflects trading frictions in the market. Figure 1 shows the four-period framework for the study window.
Cochrane (2001) elaborates two asset pricing approaches: the absolute and relative pricing approaches. Although asset pricing usually involves a choice on a spectrum ranging from absolute to relative pricing, this study can be viewed as a case leaning toward relative pricing. The study window is a natural experimental setting in which TIPS prices are devoid of default or reinvestment risk, the discount factors for the time value of money are observable from contemporaneous Treasury bill prices, maturing TIPS without call features have a limited life span less than six months, and there is no difference in the tax treatment for trading Treasury bills or TIPS.\(^1\) The setting allows us to examine how conditioning inflation information set affects TIPS prices. Using the change in the gap between the implied target CPI and the actual target CPI, this study investigates the time series characteristics of the flow of inflation information due to: (1) the takeoff of inflation hedging power away from a maturing TIPS after period I, (2) the incorporation of CPI information into TIPS prices in a relative pricing setting in periods I and II, and (3) the termination of the flow of CPI information before the announcement of final CPI in period III.

In this study, the determinants of fundamental value of maturing TIPS are specified except for the actual target CPI linked to the maturity date of a TIPS. A major function of security trading is to incorporate information about security’s future cash flows into its price. Our study shows the different stages of the flow of inflation information. We investigate how the sequence of implied target CPI approaches the actual target CPI during the first three distinct periods from the sixteen issues of maturing TIPS since the U.S. Treasury began to issue TIPS in

\(^1\) One disadvantage of TIPS is the potential tax liability on phantom income. Although the securities are exempt from state and local taxes, they are subject to federal taxation. Positive accrued inflation compensation, if any, is reportable income, even though the inflation-adjusted principal will not be received until maturity. Some taxable investors may thus hesitate to invest in TIPS, while others with non-taxable accounts such as retirement accounts might find this market attractive.
January 1997. Furthermore, the patterns of volatility estimated from the sequence of gap reflect the expiration of inflation hedging properties, the end of inflation information flow, and the constant component of trading noise due to market frictions.

2. Background and Implied Target CPI

The fundamental notion behind inflation protection is to preserve the purchasing power of money. By linking value to the CPI, TIPS provide investors with a “real” rate of return. This security can be viewed as one of the safest financial assets due to its minimal exposure to default risk and uncertain inflation. Fifteen countries, including the U.S, have issued inflation protected securities, starting in the 1940s. Some of the countries had extremely high inflation, such as Mexico and Brazil (114.8 percent and 69.2 percent in the year prior to the introduction of inflation protected securities), and others had moderate inflation like Sweden and New Zealand (4.4 percent and 2.8 percent). Based on the U.S. Government Accounting Office debt management report, TIPS made up 8.8% of $13.8 trillion outstanding marketable Treasury securities as of October 31, 2016. Forty issues of TIPS are currently traded in the U.S. market as of October 2016, with maturities ranging from 2017 to 2046. These TIPS are now viewed as an essential component in most well-diversified investment portfolios (Roll, 2004).

The market’s ability to aggregate information about inflation prior to public announcement has been a focus of extensive research. Kandel, Ofer and Sarig (1993) study Israel inflation expectations over 10-day windows of 39 issues of Israeli indexed bonds. They find that major adjustment of the inflation expectations toward the actual level of inflation occurs

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2 According to the date of introduction of inflation-protected securities, these countries are: Finland, France, Sweden, Israel, Iceland, Brazil, Chile, Colombia, Argentina, the U.K., Australia, Mexico, Canada, New Zealand, and the U.S.
in the first two days. Their study documents the timing of the flow of inflation information to pinpoint the unannounced CPI through security trading.

Although Israeli indexed bonds have a long history of maturities, the Israeli market has not been immune to government intervention. The market is also subject to additional complicating factors such as default risk, partial indexation, and the risk of ex post changes in contract terms (Huberman and Schwert, 1985). The U.S. TIPS market operates on a simpler framework and hence, our sample helps provide a more robust link of the flow of inflation information with changes in the maturing TIPS prices. Additionally, we present a comprehensive analysis of the evolution of maturing TIPS prices including the takeoff of inflation hedging power through the security transformation process. Furthermore, one of the TIPS issue was matured during recent financial crisis which was marked with a low investor confidence, low liquidity and high default risk. We analyze how the diverse market conditions affect the pricing of TIPS.

Chu, Pittman, and Yu (2011) investigate when TIPS prices adjust to inflation information. They find that TIPS prices adjust to inflation information without delay during the monthly CPI survey period and even before the beginning of the survey period. The cumulative effect of unexpected inflation on the TIPS holding period returns peaks at the end of the CPI survey period, about 11 business days before CPI announcement date. While Chu et al. investigate the reaction of TIPS daily holding period return to inflation surprise, this study focuses on the time series property of the flow of inflation information reflected in the change in the gap between the implied target CPI and the target actual CPI.

The term target CPI refers to the reference CPI linked to the maturity date of a TIPS security. Due to the delay in collecting and processing consumer price data by the Bureau of
Labor and Statistics, there is a three-month lag in the CPI indexing system for TIPS. For example, the July 2012 TIPS issue matures on July 15, 2012. The target CPI for this TIPS issue is not officially known until the announcement of May 2012 CPI on June 14, 2012. Due to the three-month lag, May 2012 CPI is linked to reference CPI on August 1, 2012. The target CPI is the reference CPI ($RCPI$) on July 15, 2012 according to the following linear interpolation formula:

$$RCPI_{7/15/12} = CPI_{April\ 2012} + (14/31)\ (CPI_{May\ 2012} - CPI_{April\ 2012})$$
$$= 230.085 + (14/31)(229.815 - 230.085) = 229.96306$$ (1)

The daily implied target CPI is derived from daily TIPS prices, assuming the risk-neutrality assumption that the yield on the TIPS is identical to the yield on a synthetic Treasury bill. For a maturing TIPS with maturity date $T$, we select two Treasury bills with maturity dates $T_1$ and $T_2$ that closely sandwich TIPS maturity date $T$, such that $T_1 \leq T \leq T_2$. Since Treasury bills mature on every Thursday, the period between $T_1$ and $T_2$ is seven calendar days apart. For any observation date $t$, the pure discount factor $b(t, T_1)$ and $b(t, T_2)$ are quoted Treasury bill prices maturing on $T_1$ and $T_2$, respectively. A linear approximation is used to obtain the price of the synthetic Treasury bill on observation date $t$: \(^3\)

$$b(t, T) = \frac{1}{7} [ (T_2 - T) b(t, T_1) + (T - T_1) b(t, T_2) ]$$ (2)

Maturity dates for two TIPS issues (January 2009 and April 2010) fall on Thursday. Actual Treasury bill quoted prices instead of synthetic Treasury bill prices are used for these two TIPS issues.

\(^3\) Amihud and Mendelson (1991) use the same linear approximation approach to derive the price of a hypothetical Treasury security with a maturity date lying between two actual Treasury bill maturity dates.
Prices for the TIPS are reported in real terms. The reported prices are clean in the sense that they are net of the accrual of the known portion of the final coupon payment. We convert a real clean price to a nominal invoice price as follows:

\[
P_t = \left( \text{reported clean price} + \frac{c}{2} \right) \frac{I_t}{I_B} \frac{\text{days between settlement date and the last coupon payment date}}{\text{days between coupon payment dates}}
\]

where:

- \(P_t\): the nominal invoice price of a TIPS issue on observation date \(t\),
- \(c\): the annual coupon in real terms,
- \(I_t\): the reference CPI for the observation date \(t\), and
- \(I_B\): the reference CPI for the original dated issue date.

The terminal cash flow to the holders of an TIPS issue, \(P_T\), is specified as

\[
P_T = 100 + \frac{c}{2} I_T I_B
\]

where \(I_T\) is the actual target CPI. In the case of July 2012 TIPS issue, \(I_T\) is the reference CPI on July 15, 2012 (\(RCPI\ 7/15/12\)) as shown in equation (1). The value of \(I_T\) becomes known after the announcement of May 2012 CPI on June 14, 2012 (its actual value is 229.815). On an observation date \(t\) before the announcement date, the implied target CPI, \(I_T^*(t)\), can be derived by assuming risk-neutrality.

Under the assumption of risk-neutrality, TIPS are expected to earn a risk-free rate. Therefore, the risk-free rate is the discount rate, and the discount factor is the pure discount price, \(b(t, T)\). The relationship between invoice price (\(P_t\)) and uncertain terminal cash flow (\(P_T\)) can be linked through the risk-neutral pricing equation:
\[ E_t^N [b(t, T) \tilde{P}_T] = P_t \]  

(5)

where \( E_t^N [\cdot] \) represents the risk-neutral expectation operator on the observation date \( t \).

Substituting \( P_t \) in equation (4) into equation (5) yields:

\[ E_t^N \left[ b(t, T) \left( 100 + \frac{c}{2} \left( \frac{\tilde{I}_T}{I_b} \right) \right) \right] = P_t \]  

(6)

Rearranging equation (6), the risk-neutral expectation of uncertain reference CPI on maturity date is defined as the implied target CPI and can be written as:

\[ E_t^N (\tilde{I}_T) = \frac{I_b P_t}{b(t, T) \left( 100 + \frac{c}{2} \right)} \equiv I_T^* (t) \]  

(7)

In equation (7), all variables used to compute the implied target CPI are given or observable in the Treasury security market. A time series of the implied target CPI, \( I_T^* (t) \), is estimated for each maturing TIPS issue analyzed in this study. The time series of \( I_T^* (t) \) for each maturing TIPS issue becomes a sequence of updated forecasts of the actual CPI used to determine the final single cash flow on the maturity date.

3. The Model and Hypotheses

In this study the flow of inflation information into the information set in pricing equation is measured by the time series properties of the deviation between the implied target CPI and the actual target CPI. A decrease in the deviation over time indicates a flow of inflation information into the information set resulting in an improvement of prediction derived from the TIPS prices. On the other hand, a stable level of deviation would indicate that the flow of inflation information has ceased. After the announcement of CPI, the inflation information has been fully...
revealed. After isolating the time value of money factor, the fluctuations in the TIPS prices after the announcement of CPI are only attributable to the trading frictions in the TIPS market.

The study investigates the time series properties of the deviation between the implied target CPI and the actual target CPI. Define the deviation on observation date \( t \) as the absolute difference.

\[
d_t = |I^*_T(t) - I_T| \tag{8}
\]

The change in the deviation is defined as

\[
y_t = d_t - d_{t-1} = |I^*_T(t) - I_T| - |I^*_T(t-1) - I_T| \tag{9}
\]

We hypothesize that the deviation narrows as time approaches maturity and the information regarding the actual target CPI has been gradually incorporated into TIPS prices. The mean values of \( y_t \) series for period I, II, and III are estimated using the following time series regression model

\[
y_{it} = \alpha_i + \varepsilon_{it}, \quad i = I, II, III
\]

\[
E(\varepsilon_{it}) = 0 \quad \text{and} \quad E(\varepsilon_{it}^2) = \sigma_i^2 \tag{10}
\]

Period I covers 101 to 45 business days prior to the final monthly CPI announcement date. During period I, TIPS are protected against inflation risk. The estimated mean value \( \hat{\alpha}_I \) is used to measure the flow of inflation information during period I. As inflation information flows into the information set in the pricing equation, the deviation is narrowed over time. Hence we expect that \( \alpha_I \) to be less than zero. The stochastic term \( \varepsilon_b \) in period I reflects not only trading frictions in the TIPS market but also the noise in the flow of inflation information and market preference toward inflation hedge property.
Period II covers 44 to 11 business days prior to the final monthly CPI announcement date. The last day of period II coincides with the end of CPI survey period for the last monthly CPI. During period II, the inflation hedging power leaves a maturing TIPS. The estimated $\hat{\alpha}_{II}$ measures the flow of inflation information and is expected to be less than zero. The stochastic term $\varepsilon_{im}$ is comprised of the trading friction and the noise in the flow of inflation information.

Period III covers 10 days prior to the final monthly CPI announcement date till the announcement date. The survey period for the final monthly CPI has passed and the flow of inflation information ceases. Hence we expect $\alpha_{III}$ to be zero. The stochastic term $\varepsilon_{III}$ is attributable only to the trading friction in the TIPS market.

In a nested setting, the mean and volatility parameters across periods I, II and III are tested to identify the patterns among the three mean and volatility parameters. Table 1 presents the summary of hypotheses.

4. Data

Sixteen issues of matured TIPS are included in the current study. Daily TIPS and Treasury bill prices are retrieved from Datastream database. Historical time series of CPI-U and announcement dates are available at the Bureau of Labor Statistics website. Reference CPI and base reference CPI for a specific issue of TIPS are retrieved from the TreasuryDirect website.

Table 2 reports the basic information about all 16 issues of matured TIPS since the U.S. Treasury began to issue TIPS in January 1997. TIPS issues are listed according to the chronological order of TIPS maturity month. TIPS mature on the 15th of maturity month. The base reference CPI ($I_B$) is the reference CPI linked to the original dated date. All coupon and
principal payments for a TIPS issue are inflated by the ratio of reference CPI on event date over the base reference CPI.

TIPS price period in the fifth column of Table 2 starts the first business day after the next-to-the-last coupon payment date till the announcement day of the last CPI before a TIPS matures. For example, the last day for July 2012 issue is June 14, 2012, which is the announcement date for May 2012 CPI. The last day is set as day zero. A business day during the study period is identified by the number of business days prior to the last CPI announcement day. The last column in Table 2 lists actual target CPI ($I_T$) associated with the maturity date for each TIPS issue. The gradual increase in the actual target CPI reflects the mild annual inflation rate of 2.34% experienced in the market during the time horizon covered by this study.

Figure 2 shows the time series of $I_T^*(t)$ minus $I_T$ for individual TIPS issues. The relative size of $I_T^*(t)$ versus $I_T$ also indicates the market preference between TIPS and Treasury bills. When $I_T^*(t)$ is greater than $I_T$, TIPS price is higher than the counterpart Treasury bill price. The market reveals a preference for TIPS over Treasury bill, and vice versa.

Among the 16 TIPS issues, the sequence of updated forecasts $I_T^*(t)$ for January 2009 covers a special study window which includes the recent financial crisis. This period is marked with heightened default risk and lower investor confidence. On September 15, 2008, Lehman Brothers filed for Chapter 11 bankruptcy protection. The panic in the financial market leads to the search for a safe instrument to park capital. TIPS devoid of default and inflation risk are priced so high relative to Treasury bills that there exists a large positive difference between

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4 A business day is defined as a trading day when the market is open for trading Treasury securities. The Treasury security markets are closed on the U.S. Federal holidays and the Good Friday. We use the Wall Street Journal market data section and the U.S. holiday schedule recommended by the SIFMA (Securities Industry and Financial Markets Association) to confirm that a specific weekday is closed for trading Treasury securities.
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$I_T^*(t)$ and $I_T$.\(^5\) Once the inflation hedge characteristic expires at the end of period I, the price behavior of January 2009 issue is indistinguishable from the rest of TIPS issues.

Figure 3 show the convergence of inflation expectation in Period I, II and III. The convergence is measured by the average difference $d_t$ on observation date $t$ across 16 issues of TIPS. We observe that the absolute value of the gap between the implied target CPI and actual CPI reduces from 1.4 CPI points to 0.6 CPI points during period I (day -101 to -45) as the hedging property of TIPS expires by the end of this period. During periods I and II, the time series $I_T^*(t)$ continues to converge toward $I_T$ as TIPS prices incorporate the flow of inflation information. In contrast, there is no discernible convergence movement in period III because the flow of inflation information ceases and inflation information set reaches its full capacity. The econometric methods and empirical results are presented in the following section.

5. Methodology and Results

Ordinary least squares (OLS) and generalized method of moments (GMM) are used to explore the time series properties of $y_{it}$, daily change in the deviation between the implied target CPI under risk-neutrality assumption and the actual target CPI. Table 3 reports the summary statistics of the time series of $y_{it}$ for the three periods investigated in this study. The summary statistics include mean, standard deviation and median values for the first three orders of autocorrelations for the 16 issues of time series $y_{it}$ in each of the three periods.

\(^5\) Campbell, Shiller, and Viceira (2009) propose an opposite argument that during the financial crisis institutional selling and a significant decline in liquidity exerted downward price pressure on TIPS and resulted in a low TIPS price relative to Treasury securities. Haubrich, Pennacchi, and Ritchken (2012) and Fleckenstein, Longstaff, and Lustig (2012) apply a replicating portfolio approach and document the presence of underpricing of TIPS relative to Treasury securities.
The mean values of \( y_{it} \) are OLS estimators of \( \alpha_i, i = I, II, III \) based on the regression model specified in equation (10). We find that the mean values are negative during all three periods under investigation. Traders continuously incorporate the flow of inflation information to update their inflation forecasts as reflected by the continuous convergence between the implied and actual target CPI. The estimated mean value of \( y_{it} \) is a measurement of the flow of inflation information. In contrast, the mean values for the three periods are not statistically different from zero due to large standard deviations.

An examination of the autocorrelations of time series \( y_{it} \) for individual TIPS issues reveals that the time series are highly auto-correlated. Table 3 reports the median value of the first three orders of autocorrelations from the 16 issues of maturing TIPS in each of three periods. The time series \( y_{it} \) for all three periods have negative first order autocorrelations which suggest that OLS estimators for \( \alpha_i, i = I, II, III \) are unbiased, but the estimators are not efficient.

We apply the generalized method of moments (GMM) of Hansen (1982) to test the null hypothesis of \( \alpha_i = 0 \) for \( i = I, II, III \). One of key advantages of the GMM approach is that its parameter estimators are consistent in allowing for weaker assumptions as to disturbance terms. For instance, GMM does not require that the dependent variables \( y_{it} \) be normally distributed. It requires only that the process of \( y_{it} \) be stationary and ergodic. Also, disturbance terms used to construct the orthogonality conditions are allowed to be conditionally heteroskedastic and serially correlated.

The GMM estimation method was motivated by increased interest in rational expectations models during the early 1980s. The underlying rationale of these models is that if expectations are formed rationally by agents formulating the expectations, the innovation of
information should be independent of all variables in the information sets formulating the expectations.

In our model specified in equations (8), (9), and (10), the innovation of inflation information on observation day $t$ is incorporated into $I_t^*(t)$ and affects the dependent variable $y_{it}$. Since $I_t^*(t-1)$ has captured the inflation information set on observation day $t-1$ to formulate the expectation of target CPI as shown in equation (7), the innovation of inflation information reflects in dependent variable $y_{it}$ should be orthogonal to $I_t^*(t-1)$. Hence, $I_t^*(t-1)$ becomes the choice of instrumental variable to formulate the orthogonal conditions for GMM estimation.

Let $\delta$ be the parameter vector with $\alpha$ and $\sigma^2$ ($\delta = [\alpha, \sigma^2]$). The GMM procedure implies orthogonality between the instruments ($Z_t$) and the disturbance terms ($D_t$), so the vector $m_t(\delta)$ can be formed:

$$m_t(\delta) = \begin{bmatrix} \varepsilon_t & \varepsilon_t I_t^*(t-1) \\ \varepsilon_t I_t^*(t-1) & \varepsilon_t^2 - \sigma^2 \\ \varepsilon_t^2 - \sigma^2 & (\varepsilon_t^2 - \sigma^2)I_t^*(t-1) \end{bmatrix}$$

(11)

where $m_t(\delta) = Z_t \times D_t$

$$Z_t = \begin{bmatrix} 1 & 0 & 0 \\ I_t^*(t-1) & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & I_t^*(t-1) \end{bmatrix}$$

and

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$^6$We drop the subscript $i$ from parameters $\alpha$ and $\sigma^2$ for brevity. The GMM method is applied to estimate the two parameters for each one of the three periods.
\[ D_t = \left[ \begin{array}{c} \varepsilon_t \\ \varepsilon_t^2 - \sigma^2 \end{array} \right] \]

The constant variable of one and the lag variable \( I_t^*(t-1) \) are used as the instrumental variables. The population moments in the orthogonality conditions are \( E[m_t(\delta)] = 0 \). Their sample analogue is \( g_N(\delta) = \frac{1}{N} \sum_{t=1}^{N} m_t(\delta) \) where \( N \) is the number of observations. Then, GMM parameter estimates \( \delta \) are obtained by minimizing the quadratic form:

\[
J(\delta) = g_N(\delta)' W g_N(\delta) \tag{12}
\]

where \( W \) is a symmetric positive definite weighting matrix. Hansen (1982) shows that the efficient GMM estimator \( W = S^{-1} \), where \( S = E[m_t(\delta)m_t(\delta)'] \). To incorporate serial correlation in GMM, we use a Newey and West (1987) estimator:

\[
S = \Gamma_0(\delta) + \left[ \sum_{j=1}^{n} \left( 1 - \frac{j}{n+1} \right)(\Gamma_j(\delta) + \Gamma_j(\delta)') \right] \tag{13}
\]

where \( \Gamma_j(\delta) = \frac{1}{N} \sum_{t=j+1}^{N} m_t(\delta)m_{t-j}(\delta)' \). The number of lags in autocovariance, \( n \), is set at 3.

To test the null hypotheses \( H_0 : \alpha_i = 0 \) for \( i = I, II, III \), we apply the likelihood ratio principle:

\[
\text{Likelihood Ratio} = N(J_R - J_U) \sim \chi^2(1) \tag{14}
\]

where \( J_R \) is the J-statistic for the restricted model with three degrees of freedom. \( J_U \) is the J-statistic for the unrestricted model with two degrees of freedom.\(^7\) The number of observations, \( N \), times the difference in the J-statistic between the restricted model and the unrestricted model is asymptotically distributed as a chi-square statistic with one degree of freedom.

\(^7\) Hayashi (2000) observes that expression (14) should be asymptotically chi-squared distributed.
Table 4 reports the results from GMM estimation of the flow of inflation information. The estimated $\hat{\alpha}_1$ and $\hat{\alpha}_2$ are negative and statistically significant at the 1% level for periods I and II, respectively. The null hypotheses $H_0: \alpha_i = 0$ for $i = I, II$ are rejected by the statistically significant likelihood ratio $\chi^2$-statistic derived from the difference between the restricted and unrestricted models. The empirical results document the flow of inflation information revealed through TIPS trading continues during periods I and II. The finding is in contrast with the empirical results found in the Israeli markets. Kandel, Ofer and Sarig found that the adjustment of Israeli indexed bond prices occurs in the first two days over a 10-day observation window.

The $\chi^2$-statistic for the unrestricted model in Period II is 1.30 and insignificant, indicating that the model under risk-neutrality assumption describes how the flow of inflation information influences TIPS prices. In period III, both restricted and unrestricted models yield insignificant $\chi^2$-statistics. The GMM estimate for $\alpha_{III}$ is $-0.0043$, and a small likelihood ratio $\chi^2$-statistic of 1.15 fails to reject the null hypothesis $H_0: \alpha_{III} = 0$. The empirical results reveal that there is no more flow of inflation information during period III and the timing of the termination of inflation information flow coincides with the end of CPI survey period.

To further test whether there exists a statistical difference in the flow of inflation information in periods I, II, and III, the likelihood ratio tests specified in equation (14) is used to test the null hypothesis $\alpha_I = \hat{\alpha}_I$. The results are presented in Table 5 Panel A. In the restricted model, the parameter $\alpha_I$ is set a value of $-0.0138$ which is the GMM estimated value for the flow of inflation information in period I. The likelihood ratio $\chi^2$-statistic between restricted and unrestricted models fails to reject the null hypothesis that $\alpha_I$ equals $\hat{\alpha}_I$. The empirical results
support the finding that the flow of inflation information continues till ten business days prior to
the last CPI announcement before a TIPS matures.

By the same token, the likelihood ratio tests specified in equation (14) is used to test the
null hypothesis that the flow of inflation information in period III is the same as that in periods I
and II. Table 5 Panel B presents the likelihood ratio test results. In the restricted model, the
parameter $\alpha_{III}$ is set a value of $-0.0126$ which is the average of the GMM estimated values of the
flow of inflation information in periods I and II. The likelihood ratio $\chi^2$-statistic between
restricted and unrestricted models reject the null hypothesis at the 5% significance level. The
empirical results substantiate the findings that the flow of inflation information in period III is
characteristically different from that in periods I and II.

Table 6 presents the nested tests of volatility parameters in periods I, II and III. The $\chi^2$-
statistic in Table 6 Panel A rejects null hypothesis that the volatility parameter in period II is the
same as that in period I. Similarly, the $\chi^2$-statistic in Table 6 Panel B rejects the null hypothesis
that the volatility parameter in period III is that same as that in period II. The empirical results
support the observation that volatility parameter decrease across periods I, II, and III.

The estimated volatility parameters for the periods I, II, and III are 0.1035, 0.0814, and
0.0564, respectively. Since the flow of inflation information ceases in period III, the estimated
$\hat{\sigma}_{III}$ measures the price volatility due to the trading frictions in the TIPS market. Assuming that
the random component in the adjustment of implied target CPI is independent of the trading
friction in the TIPS market, the increase in the value of $\hat{\sigma}_{II}$ (0.0814) from the value of $\hat{\sigma}_{III}$
(0.0564) is a measurement of noise in the flow of inflation information. The estimated increase
in the value of $\hat{\sigma}_{II}$ indicates that the noise in the flow of inflation information is about 44% of
noise caused by the trading frictions in the TIPS market. The further increase in the value of \( \sigma_1 \) (0.1035) from the value of \( \sigma_2 \) (0.0814) is an added noise due to the hedging power of a maturing TIPS. The noise is caused by the interaction between the stochastic discount factor and the preference toward inflation risk in period I.

6. Conclusions

A major function of security trading is to incorporate diverse information about security’s future cash flows. The trading of maturing TIPS after the penultimate coupon payment and prior to the final CPI announcement date provides a unique window to investigate TIPS pricing and the flow of inflation information. This study proposes a measurement of the flow of inflation information from the trading prices of TIPS and corresponding Treasury bills. The proposed measurement is the change in the gap between the implied target CPI and the actual target CPI. Time series models with mean and volatility parameters characterizing the measurement are used to document the flow of inflation information and inflation hedging properties over three distinct periods.

Sixteen issues of matured TIPS are included in the study to derive time series of implied target CPI for each matured TIPS issue. The study applies the generalized method of moments (GMM) estimation procedure and finds that the flow of inflation information continues in periods I and II till ten business days prior to the last CPI announcement before a TIPS matures. The timing of the termination of inflation information flow coincides with the end of CPI survey period.

By applying the likelihood ratio test the study also finds that the volatility parameters in the time series models gradually decrease across period I, II and III. The decrease in the
volatility parameter from period I to period II documents the effect of the takeoff inflation hedging power from a maturing TIPS. The further decrease in the volatility parameter from period II to period III can be attributable to the absence of noise in the flow of inflation information. The remaining volatility parameter in period III is due to the noise caused by the trading friction in the TIPS market.
References


Table 1. Summary of Hypotheses

This table summarizes the prior hypotheses for the three sub-periods under investigation and nested null hypotheses for testing the impact of the takeoff of inflation hedging power after period I. The inflation hedging feature remains effective in Period I. The flow of inflation information continues in Period II and reaches its full capacity at the end of period II. During period III, the market behaves as if the actual target CPI is known. There is no flow of inflation information in Period III. The parameter $\alpha_i$ for $i = I, II, III$ represents the value of the daily change in the deviation between the implied and actual target CPI during Period I, II and III, respectively.

<table>
<thead>
<tr>
<th>Study Period</th>
<th>Time span relative to final CPI announcement date</th>
<th>Description of information set $\Omega_t$</th>
<th>Prior hypothesis $\alpha_i$</th>
<th>Nested null hypothesis $\alpha_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>101 to 45 business days prior to the announcement date</td>
<td>Inflation hedge feature plus the flow of inflation information</td>
<td>$\alpha_I &lt; 0$</td>
<td>$\alpha_{II} = \hat{\alpha}_I$</td>
</tr>
<tr>
<td>II</td>
<td>44 to 11 business days prior to the announcement date</td>
<td>Flow of inflation information</td>
<td>$\alpha_{II} &lt; 0$</td>
<td>$\sigma_{II} = \hat{\sigma}_I$</td>
</tr>
<tr>
<td>III</td>
<td>10 days prior to the announcement date till the announcement date</td>
<td>The flow of information ceases implying a full information set</td>
<td>$\alpha_{III} = 0$</td>
<td>$\alpha_{III} = (\hat{\alpha}<em>I + \hat{\alpha}</em>{II}) / 2$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Nested null hypothesis $\alpha_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\sigma_{III} = \hat{\sigma}_{II}$</td>
</tr>
</tbody>
</table>
Table 2. Basic Information across 16 issues of matured TIPS

This table presents the basic information about all the 16 issues of matured TIPS since the U.S. Treasury began to issue TIPS in January 1997. We report the coupon rate in real term, the base reference CPI ($I_B$), which is the reference CPI linked to the original dated date, TIPS price period, number of business days during the last coupon payment period, and the actual target CPI ($I_T$) associated with the maturity date for each TIPS issue.

<table>
<thead>
<tr>
<th>TIPS Issue (Maturity)</th>
<th>Coupon (%)</th>
<th>Base Reference CPI ($I_B$)</th>
<th>Original Dated Date</th>
<th>TIPS Price Period</th>
<th>Number of Business Days</th>
<th>Actual Target CPI ($I_T$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 2002</td>
<td>3 5/8</td>
<td>160.15484</td>
<td>07/15/1997</td>
<td>01/16/02 – 06/18/02</td>
<td>106</td>
<td>179.80000</td>
</tr>
<tr>
<td>January 2007</td>
<td>3 3/8</td>
<td>158.43548</td>
<td>01/15/1997</td>
<td>07/17/06 – 12/15/06</td>
<td>107</td>
<td>201.66452</td>
</tr>
<tr>
<td>January 2008</td>
<td>3 5/8</td>
<td>161.55484</td>
<td>01/15/1998</td>
<td>07/16/07 – 12/14/07</td>
<td>106</td>
<td>209.49645</td>
</tr>
<tr>
<td>January 2009</td>
<td>3 7/8</td>
<td>164.00000</td>
<td>01/15/1999</td>
<td>07/16/08 – 12/16/08</td>
<td>106</td>
<td>214.69971</td>
</tr>
<tr>
<td>January 2010</td>
<td>4 1/4</td>
<td>168.24516</td>
<td>01/15/2000</td>
<td>07/16/09 – 12/16/09</td>
<td>106</td>
<td>216.24610</td>
</tr>
<tr>
<td>April 2010</td>
<td>7/8</td>
<td>189.44516</td>
<td>10/15/2004</td>
<td>10/16/09 – 03/18/10</td>
<td>104</td>
<td>216.71220</td>
</tr>
<tr>
<td>January 2011</td>
<td>3 1/2</td>
<td>174.04516</td>
<td>01/15/2001</td>
<td>07/16/10 – 12/15/10</td>
<td>105</td>
<td>218.75255</td>
</tr>
<tr>
<td>April 2011</td>
<td>2 3/8</td>
<td>198.48667</td>
<td>04/15/2006</td>
<td>10/18/10 – 03/17/11</td>
<td>104</td>
<td>220.72980</td>
</tr>
<tr>
<td>January 2012</td>
<td>3 3/8</td>
<td>177.56452</td>
<td>01/15/2002</td>
<td>07/18/11 – 12/16/11</td>
<td>106</td>
<td>226.33474</td>
</tr>
<tr>
<td>April 2012</td>
<td>2</td>
<td>202.92140</td>
<td>04/15/2007</td>
<td>10/17/11 – 03/16/12</td>
<td>104</td>
<td>227.13073</td>
</tr>
<tr>
<td>July 2012</td>
<td>3</td>
<td>179.80000</td>
<td>07/15/2002</td>
<td>01/17/12 – 06/14/12</td>
<td>105</td>
<td>229.96306</td>
</tr>
<tr>
<td>April 2013</td>
<td>5/8</td>
<td>211.36607</td>
<td>04/15/2008</td>
<td>10/16/12 – 03/15/13</td>
<td>103</td>
<td>231.16013</td>
</tr>
<tr>
<td>July 2013</td>
<td>1 7/8</td>
<td>183.66452</td>
<td>07/15/2003</td>
<td>01/16/13 – 06/18/13</td>
<td>106</td>
<td>232.71797</td>
</tr>
<tr>
<td>January 2014</td>
<td>2</td>
<td>184.77419</td>
<td>01/15/2004</td>
<td>07/16/13 – 12/17/13</td>
<td>107</td>
<td>233.33058</td>
</tr>
<tr>
<td>April 2014</td>
<td>1 1/4</td>
<td>211.63300</td>
<td>04/15/2009</td>
<td>10/16/13 – 03/18/14</td>
<td>104</td>
<td>234.31967</td>
</tr>
<tr>
<td>July 2014</td>
<td>2</td>
<td>188.49677</td>
<td>07/15/2004</td>
<td>01/16/14 – 06/17/14</td>
<td>105</td>
<td>237.44594</td>
</tr>
</tbody>
</table>
Table 3. Summary statistics

This table presents the descriptive statistics and time series properties of the dependent variable \((y_{t,t})\), which measures the change in the gap between the implied target CPI and the actual target CPI. We present the means, standard deviations, and the median values of the first-, second-, and third-order autocorrelations for \(y_t\) for the 3 periods investigated in this study.

<table>
<thead>
<tr>
<th>Period</th>
<th>Number of observations</th>
<th>Time span relative to final CPI announcement date</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Median value of Autocorrelation</th>
<th>(\rho_1)</th>
<th>(\rho_2)</th>
<th>(\rho_3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>912</td>
<td>101 to 45 business days prior to the announcement date</td>
<td>−0.0144</td>
<td>0.1071</td>
<td>−0.0721</td>
<td>0.1043</td>
<td>−0.0113</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>544</td>
<td>44 to 11 business days prior to the announcement date</td>
<td>−0.0124</td>
<td>0.0877</td>
<td>−0.2617</td>
<td>0.0079</td>
<td>−0.0126</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>176</td>
<td>10 days prior to the announcement date till the announcement date</td>
<td>−0.0043</td>
<td>0.0563</td>
<td>−0.2375</td>
<td>−0.0408</td>
<td>−0.0146</td>
<td></td>
</tr>
</tbody>
</table>
Table 4. GMM estimation of the Flow of Inflation Information

The econometric model for estimating the mean of the daily change of $y_{i,t}, i = I, II, III$.

$$y_{i,t} = d_{i,t} - d_{i,t-1} = \alpha_i + \varepsilon_{i,t}$$

$$E(\varepsilon_{i,t}) = 0, \quad E(\varepsilon^2_{i,t}) = \sigma^2_i$$

where $d_{i,t}$ represents the gap between the implied target CPI and the actual target CPI during period $i$. Our null hypothesis is $H_0: \alpha_i = 0$. The alternative hypothesis is $H_1: \alpha_i \neq 0$. To test the null hypothesis, we apply the likelihood ratio principle:

$$Likelihood\ ratio \equiv N(J_R - J_U) \sim \chi^2(1)$$

where $N$ is the number of observations, $J_R$ is the $J$-statistic for the restricted model with three degrees of freedom and $J_U$ is the $J$-statistic for the unrestricted model with two degrees of freedom. The parameters estimated for unrestricted and restricted models using GMM are reported in the table (the t-statistics are reported in the parentheses). The Chi-square ($\chi^2$) statistic, degree of freedom (df), p-value for the models and the difference are also reported. Day 0 is the announcement date for last CPI announcement used to determine the reference CPI on the TIPS maturity date.

Panel A. Period I: days -101 to -45 (Number of observations=912)

<table>
<thead>
<tr>
<th>Model</th>
<th>$\alpha_I$</th>
<th>$\sigma_I$</th>
<th>$J$</th>
<th>$\chi^2$</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted</td>
<td>0</td>
<td>0.0984</td>
<td>0.0222</td>
<td>20.27**</td>
<td>3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(17.13)**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unrestricted</td>
<td>-0.0138</td>
<td>0.1035</td>
<td>0.0119</td>
<td>10.83**</td>
<td>2</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>(-3.62)**</td>
<td>(18.13)**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td></td>
<td>0.0103</td>
<td>9.44**</td>
<td>1</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Panel B. Period II: days -44 to -11 (Number of observations=544)

<table>
<thead>
<tr>
<th>Model</th>
<th>$\alpha_{II}$</th>
<th>$\sigma_{II}$</th>
<th>$J$</th>
<th>$\chi^2$</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted</td>
<td>0</td>
<td>0.0671</td>
<td>0.0255</td>
<td>13.88**</td>
<td>3</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(8.53)**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unrestricted</td>
<td>-0.0115</td>
<td>0.0814</td>
<td>0.0024</td>
<td>1.30</td>
<td>2</td>
<td>0.521</td>
</tr>
<tr>
<td></td>
<td>(-3.71)**</td>
<td>(11.09)**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td></td>
<td>0.0231</td>
<td>12.58**</td>
<td>1</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Panel C. Period III: days -10 to 0 (Number of observations=176)

<table>
<thead>
<tr>
<th>Model</th>
<th>$\alpha_{III}$</th>
<th>$\sigma_{III}$</th>
<th>$J$</th>
<th>$\chi^2$</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted</td>
<td>0</td>
<td>0.0567</td>
<td>0.0087</td>
<td>1.52</td>
<td>3</td>
<td>0.678</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(13.41)**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unrestricted</td>
<td>-0.0043</td>
<td>0.0564</td>
<td>0.0021</td>
<td>0.37</td>
<td>2</td>
<td>0.832</td>
</tr>
<tr>
<td></td>
<td>(-1.09)**</td>
<td>(13.19)**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td></td>
<td>0.0066</td>
<td>1.15</td>
<td>1</td>
<td>0.284</td>
</tr>
</tbody>
</table>

** Significant at the 1% level
* Significant at the 5% level
Table 5. Nested Tests of the Flow of Inflation Information in Periods I, II, and III

The likelihood ration is computed under restricted and unrestricted conditions. In Panel A, the null hypothesis is \( H_0: \alpha_\mu = \alpha_{\hat{t}} = -0.138 \). In Panel B, the null hypothesis is \( H_0: \alpha_{\muIII} = (\alpha_{\hat{t}} + \alpha_{\hat{u}}) / 2 = -0.126 \). To test each of the null hypothesis, we apply the likelihood ratio principle:

\[
Likelihood\ ratio \equiv N(J_R - J_U) \sim \chi^2(1)
\]

where \( N \) is the number of observations, \( J_R \) is the J-statistic for the restricted model with three degrees of freedom and \( J_U \) is the J-statistic for the unrestricted model with two degrees of freedom. The parameters estimated for unrestricted and restricted models using GMM are reported in the table (the t-statistics are reported in the parentheses). The Chi-square (\( \chi^2 \)) statistic, degree of freedom (df), p-value for the models and the difference are also reported.

Panel A. Period II: days -44 to -11 (Number of observations=544)

<table>
<thead>
<tr>
<th>Model</th>
<th>( \alpha_{\muII} )</th>
<th>( \sigma_{\muII} )</th>
<th>( J )</th>
<th>( \chi^2 )</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted</td>
<td>-0.0138</td>
<td>0.0841</td>
<td>0.0034</td>
<td>1.86</td>
<td>3</td>
<td>0.602</td>
</tr>
<tr>
<td>Unrestricted</td>
<td>-0.0115</td>
<td>0.0814</td>
<td>0.0024</td>
<td>1.30</td>
<td>2</td>
<td>0.521</td>
</tr>
<tr>
<td>Difference</td>
<td>0.0010</td>
<td>0.56</td>
<td></td>
<td></td>
<td>1</td>
<td>0.454</td>
</tr>
</tbody>
</table>

Panel B. Period III: days -10 to 0 (Number of observations=176)

<table>
<thead>
<tr>
<th>Model</th>
<th>( \alpha_{\muIII} )</th>
<th>( \sigma_{\muIII} )</th>
<th>( J )</th>
<th>( \chi^2 )</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted</td>
<td>-0.0126</td>
<td>0.0549</td>
<td>0.0250</td>
<td>4.41</td>
<td>3</td>
<td>0.279</td>
</tr>
<tr>
<td>Unrestricted</td>
<td>-0.0043</td>
<td>0.0564</td>
<td>0.0021</td>
<td>0.37</td>
<td>2</td>
<td>0.819</td>
</tr>
<tr>
<td>Difference</td>
<td>0.0229</td>
<td>4.04*</td>
<td></td>
<td></td>
<td>1</td>
<td>0.044</td>
</tr>
</tbody>
</table>

** Significant at the 1% level
* Significant at the 5% level
Table 6. Nested Tests of the Volatility Parameter in Periods I, II, and III

The likelihood ratio is computed under restricted and unrestricted conditions. In Panel A, the null hypothesis is $H_0: \sigma_t = \hat{\sigma}_t = 0.1035$. In Panel B, the null hypothesis is $H_0: \sigma_{III} = \hat{\sigma}_{III} = 0.0814$. To test each of the null hypothesis, we apply the likelihood ratio principle:

$$Likelihood\ ratio \equiv N(J_R - J_U) \sim \chi^2(1)$$

where $N$ is the number of observations, $J_R$ is the $J$-statistic for the restricted model with three degrees of freedom and $J_U$ is the $J$-statistic for the unrestricted model with two degrees of freedom. The parameters estimated for unrestricted and restricted models using GMM are reported in the table (the t-statistics are reported in the parentheses). The Chi-square ($\chi^2$) statistic, degree of freedom (df), p-value for the models and the difference are also reported.

Panel A. Period II: days -44 to -11 (Number of observations=544)

<table>
<thead>
<tr>
<th>Model</th>
<th>$\alpha_{II}$</th>
<th>$\sigma_{II}$</th>
<th>$J$</th>
<th>$\chi^2$</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted</td>
<td>-0.0163</td>
<td>0.1035</td>
<td>0.0173</td>
<td>9.39***</td>
<td>3</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>(−5.64)***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unrestricted</td>
<td>-0.0115</td>
<td>0.0814</td>
<td>0.0024</td>
<td>1.30</td>
<td>2</td>
<td>0.521</td>
</tr>
<tr>
<td></td>
<td>(−3.71)***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td>0.0151</td>
<td></td>
<td>8.0***</td>
<td>1</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Panel B. Period III: days -10 to 0 (Number of observations=176)

<table>
<thead>
<tr>
<th>Model</th>
<th>$\alpha_{III}$</th>
<th>$\sigma_{III}$</th>
<th>$J$</th>
<th>$\chi^2$</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted</td>
<td>-0.0016</td>
<td>0.0814</td>
<td>0.1850</td>
<td>32.56***</td>
<td>3</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(−0.39)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unrestricted</td>
<td>-0.0043</td>
<td>0.0564</td>
<td>0.0021</td>
<td>0.37</td>
<td>2</td>
<td>0.832</td>
</tr>
<tr>
<td></td>
<td>(−1.09)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>0.1829</td>
<td>32.19***</td>
<td>1</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

***significant at the 1% level
**significant at the 5% level
**Figure 1:** Four Periods of the Last Six Months of a Maturing TIPS

This figure shows how the last 6 months of a maturing TIPS is divided into four sub-periods. We also present the TIPS pricing function during each of the sub-periods.
Figure 2: Time Series of Implied Target CPI minus Actual target CPI

This figure presents the time series variations in the deviation between the implied target CPI and the actual target CPI over the last 6 months of each of the eleven maturing TIPS investigated in this study.
Figure 3: The Convergence of Inflation Expectation

This figure presents the evolution of the absolute value of the gap between the implied target CPI and the actual target CPI over the last 6 months, averaged across the eleven maturing TIPS investigated in this study. This figure shows the learning behavior on the part of traders who continuously update their inflation expectations as reflected by the continuously reducing gap between the successive forecast of the future CPI.