When Do TIPS Prices Adjust to Inflation Information?

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Abstract

The trading of Treasury Inflation-Protected Securities (TIPS) provides a unique set of market price data to investigate when security prices adjust to inflation information. After controlling for changes in the real rate, changes in the reference Consumer Price Index (CPI), and the weekday effect, the seemingly random fluctuation of daily TIPS holding period returns start to reveal the pattern of TIPS price adjustment to inflation information. The study finds that TIPS prices adjust to inflation information during the price survey period, which precedes CPI announcement by 22 to 42 trading days. TIPS prices also make a significant adjustment on the CPI announcement day. The findings are based on regression analysis of time-series cross-section data from three maturing TIPS. Furthermore, bootstrap results are used as a benchmark to gauge the robustness of our empirical findings. The empirical evidence presented in this paper is consistent with a TIPS market where TIPS price adjustment is concurrent with the change in consumer price.

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1. Introduction

The adjustment of Treasury Inflation-Protected Securities (TIPS) prices to the monthly update of the Consumer Price Index (CPI) is investigated using three matured TIPS with maturities occurring in January 2007, January 2008, and January 2009. In an efficient market, security prices adjust to new information instantaneously. TIPS prices are linked to the CPI and are expected to adjust to inflation information. The Bureau of Labor Statistics follows a monthly cycle lasting for about 45 trading days to update the CPI. The monthly cycle includes a price survey period to sample retail prices and an announcement of CPI about four weeks after the price survey period. This study asks the question when TIPS prices adjust to inflation information. The hypotheses state that the adjustment of TIPS prices occurs concurrently with the consumer price survey period as well as TIPS prices react to the CPI announcement and make the final adjustment to inflation information.

The trading of TIPS provides a unique set of market price data to answer the research question. We use a regression model to investigate the timing of TIPS price adjustment to inflation information. The regression model utilizes TIPS prices over a three-year period from each of three matured TIPS issues. We draw our time-series cross-section data from the last three years of maturing TIPS prices to reduce the noise associated with changing long run real rate expectations. To avoid the last few months when a TIPS issue gradually transforms from an inflation hedge security into a Treasury bill, the study periods end four months before maturity dates. The regression model investigates the impact of market determined measures of unexpected inflation on TIPS daily holding period return (HPR) over a 51-day window, beginning 45 business days prior to a monthly CPI announcement and continuing through five business days after the announcement. Our regression model also includes three control variables that affect the change in the daily HPR of TIPS: (1) changes in the real rate of interest (DRY), (2) changes in the historical inflation reference index that adjusts nominal prices of TIPS for inflation (DRATIO), and (3) a set of dummy variables (DumDay) to indicate weekday effect on daily HPR.

This study finds that TIPS prices do adjust to inflation information during the consumer price survey period, which precedes CPI announcement by 22 to 42 days. We also find a significant price adjustment on the announcement date.

2. Factors Influencing TIPS Prices

The cash flows associated with TIPS are directly tied to the announced inflation. TIPS prices, which are free from default risk and are protected against inflation, provide a unique set of market data to observe how security prices adjust to inflation information. When TIPS matured on January 15, 2007, the final redemption payment on the par amount was adjusted for all the inflation since the TIPS were issued in January 1997. This is accomplished by multiplying the stated par amount by the ratio of reference CPI tied to the redemption date over the reference CPI for the issuance date. Each semi-annual coupon payment is adjusted the same way.

Since the cash flow to be paid depends on actual cumulative inflation, the TIPS price reacts much differently over time than the conventional bond. While the conventional bond price will respond to changes in the expected rate of inflation and changes in the real rate, the TIPS will respond only to changes in past inflation and changes in the real rate, assuming contemporaneous adjustment of the contractual cash flow to the current CPI.

However, the adjustment of TIPS contractual cash flow is not contemporaneous. The market relies on repeated trading to synthesize inflation information and on the announcement of CPI to make the final price adjustments. For example, April 2007 CPI measures price level occurring between March 15, 2007 and April 15, 2007. The April 2007 CPI was released on May 15, 2007. The retail price survey period for April 2007 CPI covers 22 to 42 business days before the official announcement of April 2007 CPI on May 15, 2007.[1]

The study window covering 48 days around a CPI announcement date is separated into four periods.[2] Period I coincides the monthly CPI retail price survey period which covers around 22 days to 42 days prior to a CPI announcement date. Period II runs from 21 days to 1 day before a CPI announcement date. In period II, Bureau of Labor Statistics processes price data collected from the survey period. The CPI announce date is the period III. Period IV covers the five days after a CPI announcement date.

Given the structure of the TIPS contract with the investor, we expect that the holding period return has a positive correlation with realized inflation reflected in the change in the reference CPI, and that it has a negative correlation with the change in real

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[1] A typical chronology of monthly CPI announcement cycle is presented in Schwert (1981), p. 21.

[2] The observation window covers 51 days around a CPI announcement date, i.e., 45 days before and 5 days after a CPI announcement date. The study window is 3 days shorter than the observation window, i.e., 42 days before and 5 days after a CPI announcement date.

return. The Treasury security market requires one business day to settle a transaction. The HPR on Friday includes at least 3-day accrual interest yield until the first business day in the following week. The TIPS daily HPRs are expected to have a weekly pattern in which Friday is expected to have a larger HPR. After controlling for these three factors, we design a regression model to reveal when TIPS prices adjust to inflation information. Specifically, we are asking how much of the TIPS holding period returns are associated with unexpected inflation during each of the four observation periods.

3. Literature Review

There is a small body of research that has used market securities to investigate the market's ability to aggregate information about inflation. Schwert (1981) addressed the information aggregation of inflation into the stock prices, and found a weak support for the hypothesis that composite stock prices adjust to new inflation information during the price measurement period. Huberman and Schwert (1985) used Israeli bonds indexed to its CPI to test whether announcements of CPI were already reflected in the indexed bond prices. They find that 85 percent of the reaction to inflation information occurs from 2 to 5 weeks before the announcement, i.e., when the inflation is occurring. They found no significant relationship between unexpected inflation and indexed bond returns during the two weeks after the month is ended and before the announcement is made. On the day after the announcement they made the final 15% adjustment. Their conclusion is that index-linked bond prices do absorb most of the information as the price level is changing, but there is some portion which is missed and is assimilated only after public announcement.

Chu (1991) used the short-lived inflation futures prices (1985-1986) to examine the timing and speed with which inflation futures prices absorb inflation information. The research measures the expected and unexpected components of the inflation rate by identifying a time series inflation rate model based on past inflation rates. The time-series model is used to predict inflation of the next month. Any difference between the predicted inflation and the actual inflation which was subsequently announced is treated as the unexpected inflation. Chu (1991) found that inflation futures prices reflect 71 percent of unexpected inflation about 25 business days prior to the CPI announcement, which coincides with the end of the inflation measurement period. The remaining 29 percent occurs on and shortly after the CPI announcement date.

Both studies conclude that while the markets involved are not perfectly aggregating information, they are efficient in absorbing a great deal of inflation information into the price of the underlying security far in advance of the announcement date.

Previous studies using Israeli indexed bond price data have several problems. Some of the Israeli bonds are only partially indexed with respect to principal and none of the coupon payments are indexed, rendering the bonds less effective as an inflation hedge security. Also there is a default premium in the Israeli bonds' returns which may bias results of the test. Moreover, the Israeli government does intervene in the bond market (Huberman and Schwert, 1985), with indexed bonds representing the 67% of government bonds outstanding in 1976. The inflation futures contract used by Chu (1991) overcomes these problems, but the contract had a relatively short trading history and never enjoyed a large trading volume.

Our study is the first attempt to document when TIPS prices adjust to inflation information. In a survey paper, Thomas (1999) indicates that proxies for expectations of inflation are problematic, and that there is no consensus on whether surveys or time series models or macroeconomic models are the best estimator. This study uses a market-generated measure of inflation expectations just as Kandel, Ofer, and Sarig (1993) did. The expected inflation on a specific date is measured by the breakeven inflation rate, i.e. the nominal yield to maturity on a constant five-year conventional Treasury bond minus the real yield to maturity on a constant five-year TIPS.

4. The Regression Model and Hypotheses

The dependent variable in the regression model is the time-series of daily holding period return (HPR) from three individual TIPS issues. To fully utilize all three maturing TIPS issues (TIPS2007, TIPS2008, and TIPS2009), the regression model analyzes a pooling of time-series cross-section data. Table 1 summarizes the time-series cross-section HPRs. The study covers a time span of 1,268 trading days starting September 2, 2003 through September 12, 2008. TIPS2007 has 767 trading days covering September 2, 2003 through September 15, 2006. TIPS2008 has 765 trading days covering September 1, 2004 through September 14, 2007. TIPS2009 has 763 trading days covering September 1, 2005 through September 12, 2008. In total, the pooling data set has 2,295 trading day records.

The total 1,268 trading days are separated into five cross-section periods. TIPS2007 was the sole TIPS security traded in period 1 (September 2, 2003 through August 31, 2004, 252 trading days). Two TIPS securities, TIPS2007 and TIPS2008 were traded in period 2 (September 1, 2004 through August 31, 2005, 253 trading days). All three TIPS issues were traded in period 3 (September 1, 2005 through September 15, 2006, 262 trading days). TIPS2008 and TIPS2009 were traded in period 4 (September 18, 2006 through September 14, 2007, 250 trading days). Finally, TIPS2009 was the sole TIPS issue traded in period 5 (September 17, 2007 through September 12, 2008, 251 trading days).

The following regression model is used to identify the timing of TIPS price adjustment to inflation information.

$$HPR_{Yr,t} = \alpha + \beta(\mathrm{DRY_t}) + \gamma(\mathrm{DRATIO_t}) + \sum_{i=1}^{4} \theta_i (DumDay_{i,t}) + \sum_{k=-45}^{5} \delta_k U_{k,t} + \mu_{Yr,t}$$

$$t = 1, 2, \ldots, 1268, \quad Yr = 2007, 2008, 2009. \qquad (1)$$

where

$\mathrm{HPR}_{Yr,t}$: the daily nominal holding period return for TIPS Yr issue on the t-th date;

$\mathrm{DRY_t}$: daily change in real interest rate, a control variable;

$\mathrm{DRATIO_t}$: daily change in the ratio of reference CPI over base CPI, a control variable;

$\mathrm{DumDay}_{i,t}$: dummy variables to indicate weekday for the t-th date, a control variable;

$U_{k,t}$: the monthly inflation surprise if the t-th date is k days away from a CPI announcement date; zero otherwise;

k: a negative number means $|k|$ days prior to a CPI announcement date; a positive number means k days after a CPI announcement date; and zero means a CPI announcement date;

$\mu_{Yr,t}$: a disturbance term for the TIP Yr issue on the t-th date;

$\alpha, \beta, \gamma, \theta_i$'s: the regression coefficients for control variables;

δ_k's: the regression coefficients revealing the adjustment of TIPS prices to inflation information.

Holding period return measures daily realized return if an investor purchases TIPS on day t-1 and sell the same TIPS on day t. Daily HPR for an issue of TIPS is computed as follows:

$$\text{HPR}_t = \frac{P_t - P_{t-1} + (\text{nomial coupon payment on ex - coupon day, zero otherwise})}{P_{t-1}} \tag{2}$$

where

$$P_t = \left[\begin{array}{l} \text{reported clean price} + \\ \left(\frac{c}{2}\right) \frac{\text{days between settlement date and the last coupon payment date}}{\text{days between coupon payment dates}} \end{array} \right] \frac{I_t}{I_B} \tag{3}$$

P_t is nominal invoice price of a TIPS issue on observation date *t*; *c* is annual coupon in teal term; I_t is the reference CPI for the observation date; and I_B is the reference CPI for the original dated issue date. DRY is measured by daily change in 5-year constant maturity real rate.

The monthly unexpected inflation rate is obtained by subtracting the monthly expected rate from the actual monthly rate. The monthly expected rate is measured by the breakeven inflation rate divided by 12. The breakeven inflation rate is defined as the yield spread between 5-year constant maturity nominal and real rates.

We use observation date July 20, 2007 for TIPS issue maturing on January 15, 2008 as an example to explain the 51-day observation window and the structure of independent variables $U_{k,t}$'s. The observation date on July 20, 2007 is 42 trading days before the announcement of August 2007 CPI on September 19, 2007. The $U_{-42,t}$ for observation date on July 20, 2007 is the actual monthly inflation rate for August 2007 minus the expected inflation measured by the one twelfth of the breakeven inflation rate observed on July 20, 2007. Similarly, July 20, 2007 is 18 trading days before the announcement of July 2007 CPI and 2 trading days after the announcement of June 2007 CPI. $U_{-18,t}$ and $U_{2,t}$ are computed according to the same procedure for observation date on July 20, 2007. According to the definition of unexpected inflation, the rest of 48 $U_{k,t}$'s. for observation date on July 20, 2007 are set to zero.

We examine a observation window of 45 days before and 5 days after a CPI announcement date. The regression coefficients for the three control variables are expected to be significantly different from zero. The regression coefficient for the control variable DRY_t is expected to be significantly less than zero, i.e., $\beta < 0$. The TIPS HPR is negatively related to changes in the real interest rate. An increase in the real interest rate results in a decrease in real and nominal prices of TIPS and subsequently a negative HPR. The nominal price of TIPS increases as the reference CPI increases. HPR is expected to be positively related to an increase in the ratio of reference CPI over base CPI. The regression coefficient for the control variable $DRATIO_t$ is expected to be significantly greater than zero, i.e., $\gamma > 0$. The regression coefficients for the set of dummy weekday variables ($DumDay_i$'s) are used to reflect weekday effect due to the settlement procedure used in the TIPS market.

The specification of the regression model enables us to test timing hypotheses linked to the four study periods. First, if the TIPS HPR reflects new flow of information about inflation during the retail price survey period, the summation of regression coefficients for unexpected inflation over the price survey period should be significantly different from zero. The monthly price survey period covers around 22 to 42 business days prior to the announcement date. The priori hypothesis of the timing of TIPS price adjustment states that $\sum_{(k=-42\ to\ -22)} \delta_k$ is greater than zero.

Second, the time period between 21 days to one day before a CPI announcement date, Bureau of Labor Statistics processes retail price data collected from the survey period. In a market that processes inflation information efficiently, a priori hypothesis states that $\sum_{(k=-21\ to\ -1)} \delta_k$ is insignificantly different from zero.

Third, the regression coefficient δ_0 measures the reaction of TIPS price to the CPI announcement. Except for the case of perfect foresight about inflation, the CPI announcement is expected to carry new inflation information and TIPS price adjustment. A priori hypothesis states that δ_0 is greater than zero. Finally, in an efficient market, no additional TIPS price adjustment is expected after the CPI announcement. We hypothesize that $\sum_{(k=1\ to\ 5)} \delta_k$ is insignificantly different from zero. Table 2 summarizes the four priori hypotheses.

5. Econometric Issues and Methodology

Two econometric issues are in order. First, the regression model uses time-series cross-section data to estimate regression coefficients and perform hypothesis tests. For each trading day, there may be one, two, or three TIPS issues in the panel data. If the number of TIPS issues are greater than one, TIPS prices are subject to contemporaneous market disturbance across TIPS issues and their regression disturbance terms at an observation date t, $\mu_{Yr,t}$'s, are highly correlated. Ordinary least squares estimators are unbiased but their variance-covariance matrix is inefficient. In estimating an efficient covariance structure, White (1980) heteroscedasticity consistent estimator is applied to control for both contemporaneous correlation and heteroscedasticity. The correlation among various TIPS residual terms on an observation date is allowed to change over time. The variance-covariance matrix is estimated by $(X'X)^{-1}\sum_t (X_t^{'}\hat{\mu}_t\hat{\mu}_t^{'}X_t)(X'X)^{-1}$, where X is the regression design matrix, X_t is the cross-sectional explanatory variables for the t-th date, and $\hat{\mu}_t$ is residual vector estimated from separate autoregressive model applied to individual TIPS time series data.

Second, after controlling for the presence of cross-sectional correlation among TIPS issues, the time-series cross-section data are still subject to the autocorrelation problem. We apply nonparametric bootstrapping methods to examine the robustness of hypothesis tests using White heteroscedasticity consistent variance-covariance estimator. Davison and Hinkley (2006) describe the details of bootstrapping method to resample regression error terms. To maintain the original structure of time-series cross-section data, the resampling error terms are restricted to same weekday and same time period specified in Table 1 panel B.

6. Data and Results

We investigate three maturing issues of TIPS with maturities on January 15 2007 (TIPS 2007), January 15 2008 (TIPS 2008), and January 15 2009 (TIPS 2009). When the three Treasury securities were issued, all of them had 10 years maturity. Daily real clean price series for TIPS, 5-year constant maturity real and nominal interest rates are retrieved from Datastream database.[3] Historical time series CPI and announcement dates are available at the Bureau of Labor Statistics website. Reference CPI and base CPI for a specific issue of TIPS are retrieved from the TreasuryDirect website.

Our study periods include three years of trading history before each TIPS maturity dates. The TIPS have a three-month lag in indexing their coupon and principal payments. The inflation hedging property of a TIPS issue expires three months before the maturity date. To avoid the last few months when a TIPS issue gradually transforms from an inflation hedge security into a Treasury bill, the study periods end four months before maturity dates.

Table 3 summarizes the mean and standard deviation values for the variables used in the regression models. The average daily HPRs for the three TIPS issues are 0.0148%, 0.0136%, and 0.0198%. In terms of nominal annual yields, the three average HPRs are equivalent to 3.73%, 3.43%, and 4.99%, respectively. The average 5-year constant maturity real rates for the three TIPS study periods are 1.49%, 1.89%, and 1.84%. The average real rates are relatively low compared with conventional estimates between 3% and 4% using annual growth rate of real gross national product. The average 5-year constant maturity nominal rates for the three TIPS issues are 3.93%, 4.35%, and 4.19%. We also report summary statistics for daily changes in real rates (DRY), daily changes in the ratio of reference CPI over base CPI (DRATIO), and actual monthly percentage change in CPI.

The HPR is calculated based on TIPS nominal invoice price and the accrued nominal coupon payment. Figure 1 shows the time series pattern of holding period return

[3] Federal Reserve compiles and publishes daily 5-year constant maturity real and nominal interest rates. Datastream includes the time series in its database.

for the three maturing TIPS during their respective time spans. Similar to other risky securities, the HPR for TIPS fluctuates over time to reflect the changes in real rate and inflation information. As a general trend, the fluctuation in HPR attenuates as a TIPS issue approaches its maturity date. The attenuation patterns reflect the decrease in duration as the time to maturity of a TIPS issue decreases.

Table 4 reports regression coefficients for control variables. For an individual TIPS, SAS AUTOREG procedure is applied to estimate regression coefficients for controlling variable. The AUTOREG procedure specifically recognizes the presence of autocorrelation in individual TIPS time-series residual terms. Consistent with our prior expectation the β coefficient for the control variable *DRY* is significantly less than zero. The TIPS HPR is negatively related to changes in the real interest rate. An increase in the real interest rate leads to a decline in TIPS prices and subsequently a negative HPR. On the other hand, TIPS nominal price increases as reference CPI increases and vice versa. Consistent with our expectations, we found a positive and statistically significant relationship between TIPS prices and reference CPI. The coefficient estimates for the control variable *DRATIO* varies from 0.344 to 0.605. The statistically significant regression coefficients for β and γ are observed for all three issues.

The estimated regression coefficients for weekday dummy variables show that Friday consistently has the highest HPRs, which reflect the settlement procedure used in the TIPS market. The estimated first order autoregressive parameter, $\hat{\phi}_1$, is significantly greater than zero for all three TIPS time-series regression models. After adjusting for the first order autocorrelation, the regression models for individual TIPS issues are free from autocorrelation problem as indicated by the reported Durbin-Watson statistics in Table 4.

Table 4 also reports the pooling time-series cross-section results for control variables. Ordinary least squares method is used to estimate regression coefficients for control variables. The estimated standard errors are selected from White (1980) heteroscedasticity consistent variance-covariance estimator to control for both contemporaneous correlation and heteroscedasticity. The results for pooling data are robust with respect to results from individual TIPS time-series data. TIPS HPRs are negatively related to change in real interest rate, positively related to the daily change in the ratio of reference CPI over base CPI, and a larger HPR on Friday due to the TIPS settlement procedure

Four priori hypotheses summarized in Table 2 test when TIPS prices reflect new flow of information about inflation during the four study periods. We calculate a time series of the cumulative sum of the estimated regression coefficients $\hat{\delta}'s$ over a 51-day observation window. The window runs from 45 days before through 5 days after a CPI announcement date. Figure 2 plots the cumulative sum of the estimated coefficients for the 2007, 2008, and 2009 maturing TIPS and the pooling time-series cross-section data with the horizontal axis representing number of days before or after an announcement day. All four time-series of cumulative sum of coefficients show similar pattern. The pattern reveals a significant portion of the unexpected inflation has been reflected in TIPS prices 22 days prior to CPI announcement.

The sum of estimated coefficients for δ_{-42} through δ_{-22} reflects new flow of information about information during the price survey period. A statistically significant positive $\sum_{(k=-42\ to\ -22)} \hat{\delta}_k$ indicates new information about inflation is being incorporated into TIPS prices as they occur. Our pooling data show that the estimated

$\sum_{(k=-42\ to\ -22)} \hat{\delta}_k$ is 0.408. The *t*-statistics for testing the null hypothesis $\sum_{(k=-42\ to\ -22)} \delta_k = 0$ is 4.79, which is significantly greater than zero at the 1% level. Similar sum of coefficient estimates and student-t statistics are computed to test priori hypotheses for the other three study periods. The estimated $\sum_{(k=-21\ to\ -1)} \hat{\delta}_k$, $\hat{\delta}_0$, and $\sum_{(k=1\ to\ 5)} \hat{\delta}_k$ are −0.034, 0.092, and −0.009, respectively. The corresponding student-*t* statistics for Period II, III, and IV are −0.43, 4.50, and −0.24, respectively.

The error terms used to compute the White heteroscedasticity consistent variance-covariance matrix are extracted from individual autoregressive regression models for three TIPS issues. As the Durbin-Watson statistics reported in Table 4, the extracted error terms from the first order autoregressive regression model are free from the autocorrelation problem. As an alternative approach to examine the robustness of the reported *t*-statistics for testing the four hypotheses, we apply bootstrap method by resampling regression residual terms with replacement. The bootstrap resampling procedure permutes the regression error terms. Ordinary least squares method is used to compute regression residual terms and subsequently the estimation of the variance-covariance matrix. Based on 1,000 simulation runs, Table 5 shows the comparison between sample estimates and bootstrap results. The sample estimates are close to the benchmark results derived from the bootstrap method. Our empirical results are robust with respect to autocorrelation problem observed in the TIPS regression models.

7. Conclusions

We analyze the timing to incorporate inflation information into TIPS prices. Four or five weeks after the change in consumer price for a particular month has been measured, the CPI is announced. The cash flow of the TIPS is impacted by the inflation, and this security provides a rare opportunity to observe directly, through a market-based daily measurement, when the TIPS prices adjust to inflation information. The timing of adjustment of TIPS prices to monthly update of CPI was revealed for maturing TIPS prices once we control for changes in the real rate, changes in the reference CPI and the weekday effect. Three overlapping three-year study periods are drawn from three maturing issues of TIPS, and a regression model identifies when TIPS holding period returns are correlated with daily inflation surprise. The inflation surprise is measured by the actual inflation minus the expected inflation. Previous research in this area has used time series models to predict the expected inflation series. In contrast, this study obtains inflation expectations from the yield spread between the nominal Treasury securities and the TIPS of the same maturity, i.e. breakeven inflation using actual market prices.

Our results indicate that the TIPS market is efficient in aggregating inflation information. Using the pooling time-series cross-section data from three matured TIPS issues, TIPS prices start reacting to inflation during the price survey period. A significant portion of unexpected inflation has been incorporated into TIPS prices by the end of the price survey period. TIPS prices adjust any misinterpretation about inflation on the CPI announcement date. Bootstrap results are used as a benchmark to gauge the robustness of *t*-statistics for hypothesis tests. This paper presents the empirical evidence and contributes to the understanding of when information about inflation is incorporated into TIPS whose future cash flows are linked to inflation. The empirical evidence presented in this paper is consistent with a TIPS market where TIPS price adjustment is concurrent with the change in consumer price.

References

Chu, C., 1991, Futures prices and inflation information. *Review of Quantitative Finance and Accounting* 1, 281-291.

Davison, A. C. and Hinkley, D. 2006 Bootstrap methods and their applications, *Cambridge*: Cambridge Series in Statistical and Probabilistic Mathematics.

Huberman, G. and G. W. Schwert, 1985, Information aggregation, inflation, and the pricing of indexed bonds. *Journal of Political Economy* 93, 92-114.

Kandel, Shmuel, A. R. Ofer, and Oded Sarig, 1993, Learning from trading, *The Review of Financial Studies*, 6:3, 507-526.

Schwert, G. W., 1981, The adjustment of stock prices to information about inflation. *Journal of Finance* 36, 1, 15-29.

Thomas, L. B., Jr., 1999, Survey measures of expected U.S. inflation. *Journal of Economic Perspectives* 13, 4, 125-144.

White, H. 1980 A heteroscedasticity consistent covariance matrix estimator and a direct test for heteroscedasticity. *Econometrica*, 48, 817-838.

Table 1. Time-Series Cross-Section Holding Period Returns		
Panel A: Time-Series Data		
TIPS Issue	Time Span	Number of Trading Day
TIPS2007	09/02/2003 ~ 09/15/2006	767
TIPS2008	09/01/2004 ~ 09/14/2007	765
TIPS2009	09/01/2005 ~ 09/12/2008	763
Total		**2,295**

Panel B: Cross-Section Periods				
Time Period	Time Span	Number of Trading Days	Number of Records	Trading TIPS Issues
1	09/02/2003 ~ 08/31/2004	252	252	TIPS2007
2	09/01/2004 ~ 08/31/2005	253	506	TIPS2007, and TIPS2008
3	09/01/2005 ~ 09/15/2006	262	786	TIPS2007, TIPS2008, and TIPS2009
4	09/18/2006 ~ 09/14/2007	250	500	TIPS2008, and TIPS2009
5	09/17/2007 ~ 09/12/2008	251	251	TIPS2009
Total		**1,268**	**2,295**	

Table 2. Summary of Hypotheses			
Study Period	Time span relative to a CPI announcement date	Description	Prior hypothesis
I	22 days to 42 days prior to a CPI announcement date	CPI retail price survey period	$\sum_{(k=-42\ to\ -22)} \delta_k > 0$
II	1 day to 21 days prior to a CPI announcement date		$\sum_{(k=-21\ to\ -1)} \delta_k = 0$
III	Day zero	CPI announcement date	$\delta_0 > 0$
IV	1 day to 5 days after a CPI announcement date		$\sum_{(k=1\ to\ 5)} \delta_k = 0$

Table 3. Summary Statistics (All numbers are in percentage.)

Panel A: TIPS 2007 (Maturity date January 15, 2007; Real coupon rate 3-3/8%)
Study Period: 09/02/2003 through 09/15/2006, 767 Trading Days

	Mean	Standard Deviation	Maximum	Minimum
HPR	0.0148	0.1159	0.6188	-0.5492
DRY	0.0013	0.0496	0.2400	-0.1800
DRATIO	0.0160	0.0285	0.1515	-0.1303
Real Rate	1.49	0.51	2.64	0.39
Nominal Rate	3.93	0.63	5.23	2.65
Monthly change in CPI	0.27	0.40	1.22	-0.80

Panel B: TIPS 2008 (Maturity date January 15, 2008; Real coupon rate 3-5/8%)
Study Period: 09/01/2004 through 09/14/2007, 765 Trading Days

	Mean	Standard Deviation	Maximum	Minimum
HPR	0.0136	0.0930	0.4399	-0.3083
DRY	0.0014	0.0432	0.1700	-0.1600
DRATIO	0.0151	0.0310	0.1486	-0.1278
Real Rate	1.89	0.55	2.79	0.78
Nominal Rate	4.35	0.50	5.23	3.25
Monthly change in CPI	0.25	0.44	1.22	-0.80

Panel C: TIPS 2009 (Maturity date January 15, 2009; Real coupon rate 3-7/8%)
Study Period: 09/01/2005 through 09/12/2008, 763 Trading Days

	Mean	Standard Deviation	Maximum	Minimum
HPR	0.0198	0.1014	0.4583	-0.2852
DRY	0.0001	0.0591	0.2500	-0.2200
DRATIO	0.0198	0.0329	0.1522	-0.1259
Real Rate	1.84	0.67	2.79	0.01
Nominal Rate	4.19	0.74	5.23	2.23
Monthly change in CPI	0.33	0.45	1.22	-0.80

Table 4. Regression Coefficients for Control Variables

Individual TIPS Time-Series Model: $$HPR_t = \alpha + \beta(\mathrm{DRY}_t) + \gamma(\mathrm{DRATIO}_t) + \sum_{i=1}^{4}\theta_i(DumDay_{i,t}) + \sum_{k=-45}^{5}\delta_k U_{k,t} + \mu_t$$
$$\text{where } \mu_t = \phi_1\mu_{t-1} + \varepsilon_t, \qquad t = 1,2,...,T.$$

Pooling Time-Series Cross-Section Model: $$HPR_{Yr,t} = \alpha + \beta(\mathrm{DRY}_t) + \gamma(\mathrm{DRATIO}_t) + \sum_{i=1}^{4}\theta_i(DumDay_{i,t}) + \sum_{k=-45}^{5}\delta_k U_{k,t} + \mu_{Yr,t}$$
$$t = 1,2,...,1268, \quad Yr = 2007,\ 2008,\ 2009.$$

	Individual TIPS Time-Series Model†						Pooling Time-Series Cross-section Model‡	
Coefficient	2007 Estimate	Standard Error	2008 Estimate	Standard Error	2009 Estimate	Standard Error	Panel Estimate	Standard Error
α	0.012*	0.006	-0.002	0.006	0.004	0.007	0.003	0.004
β	-2.018**	0.044	-1.680**	0.050	-1.237**	0.045	-1.564**	0.035
γ	0.605**	0.086	0.558**	0.075	0.344**	0.084	0.509**	0.055
θ_1 (Tuesday)	-0.010	0.008	0.007	0.007	-0.000	0.009	0.001	0.005
θ_2 (Wednesday)	-0.011	0.007	0.007	0.007	0.004	0.009	0.002	0.004
θ_3 (Thursday)	-0.015	0.007	0.011	0.007	0.016	0.009	0.006	0.005
θ_4 (Friday)	0.004	0.008	0.013	0.007	0.016	0.009	0.013**	0.005
Num. of Records	767		765		763		2,295	
ϕ_1	0.083**	0.037	0.084**	0.037	0.101**	0.037		
R^2	0.759		0.649		0.561			
Durbin-Watson	2.010		2.018		1.983			

** Significantly different from zero at the 1% level.
* Significantly different from zero at the 5% level.
† The coefficient estimates and their standard errors are based on time-series regression models with autoregressive error terms.
‡ The coefficient estimates are estimated from the ordinary least squares method. The standard errors come from White (1980) heteroscedasticity consistent estimator to control for both contemporaneous correlation and heteroscedasticity.

Table 5. Sample Estimates and Bootstrap Results

Study Period	Sample t-statistics	Bootstrap Results (1,000 simulation run)		
		Mean	Median	Standard Deviation
I	4.79	5.15	5.16	1.10
II	−0.43	−0.53	−0.52	1.06
III	4.50	5.97	5.96	1.46
IV	−0.24	−0.08	−0.10	1.07

Figure 1. Holding Period Returns

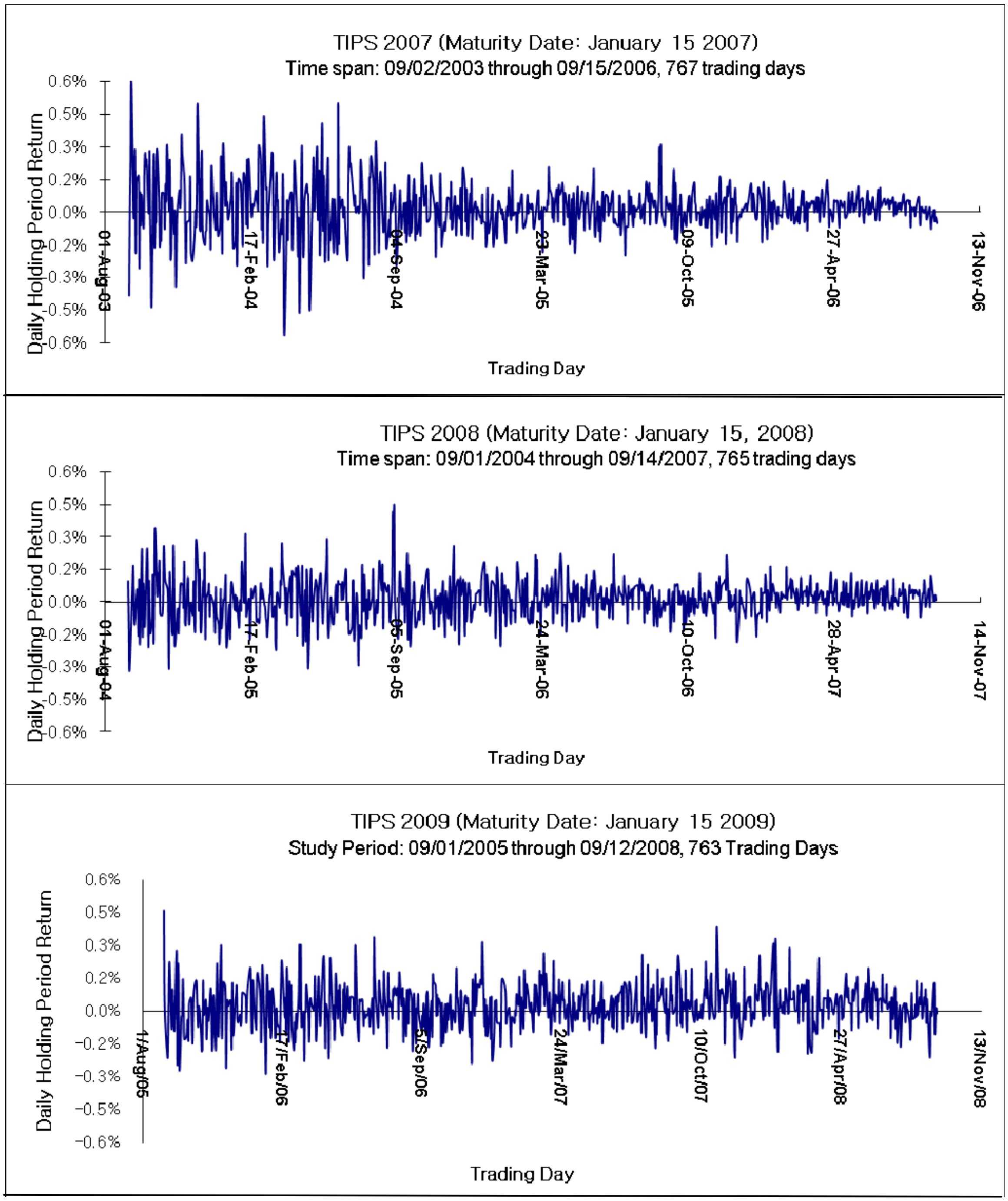

Figure 2. Cumulative Sum of Coefficients