Inflation Risk Premium: Evidence from the TIPS Market

Olesya V. Grishchenko and Jing-zhi(Jay) Huang

Penn State University

18th Annual Derivatives Securities and Risk Management Conference
April 11-12, 2008

Motivation

- In this paper, we focus on estimating the magnitude of the Inflation Risk Premium (IRP)
- Estimating Inflation Risk Premium is important for
  - managing risk on the bond market
    - IRP provides a measure that compensates investors for the risk that the actual inflation rate over the life of the Treasury may be higher than expected

Motivation

- In this paper, we focus on estimating the magnitude of the Inflation Risk Premium (IRP)
- Estimating Inflation Risk Premium is important for
  - managing risk on the bond market
    - IRP provides a measure that compensates investors for the risk that the actual inflation rate over the life of the Treasury may be higher than expected
  - policymakers. In particular, Bernanke (2004) emphasized that *"inflation-indexed securities would appear to be the most direct source of information about inflation expectations and real interest rates"*.
    - Recently, monetary policymakers have monitored several measures of market expectations of future inflation. One of these measures, *a breakeven inflation*, is based on the yield differential between nominal and Treasury inflation-protected securities (TIPS)

Breakeven Inflation and Inflation Risk Premium

- By definition, Breakeven Inflation is the difference between nominal and real rates:

$$BEI_t(\tau) = y_t^n(\tau) - y_t^r(\tau) \tag{1}$$

Breakeven Inflation and Inflation Risk Premium

- By definition, Breakeven Inflation is the difference between nominal and real rates:

$$BEI_t(\tau) = y_t^n(\tau) - y_t^r(\tau) \tag{1}$$

- This measure is constantly watched by policymakers as an indicator of the expected inflation
- But how much of it is due to expected inflation and how much to the inflation risk premium?

Breakeven Inflation and Inflation Risk Premium

- By definition, Breakeven Inflation is the difference between nominal and real rates:

$$BEI_t(\tau) = y_t^n(\tau) - y_t^r(\tau) \tag{1}$$

- This measure is constantly watched by policymakers as an indicator of the expected inflation
- But how much of it is due to expected inflation and how much to the inflation risk premium?
- The inflation risk premium is defined as

$$IRP_t(\tau) = BEI_t(\tau) - E_t\pi_{t+\tau}(\tau) \tag{2}$$

- Separating the two represents a challenge

Literature Review

- Studies that estimate explicitly IRP (none involves information from TIPS market):
  - Campbell and Shiller (1996): nominal term premium –between 50 and 100 bps
  - Buraschi and Jiltsov (2005): structural model (monetary version of RBC model) – 20 to 140 bps
  - Ang, Bekaert, Wei (2007): regime-switching term structure(TS) model – around 1.15% (5-year IRP)

Literature Review

- Studies that estimate explicitly IRP (none involves information from TIPS market):
  - Campbell and Shiller (1996): nominal term premium –between 50 and 100 bps
  - Buraschi and Jiltsov (2005): structural model (monetary version of RBC model) – 20 to 140 bps
  - Ang, Bekaert, Wei (2007): regime-switching term structure(TS) model – around 1.15% (5-year IRP)
- Studies that use information from TIPS market:
  - D'Amico, Kim and Wei (2007): 3-factor TS model with nominal and TIPS data – IRP can be positive or negative - depends on series used in estimation
  - Jarrow and Yildirim (2003) and Chen, Liu and Cheng (2005): use TIPS to estimate TS, but not IRP
  - Shen (2006): focus on liquidity premium

Main Findings

- IRP is time-varying: negative in the first half of the sample (2000-2003) and positive in the second half of the sample (2004-2006)

Main Findings

- IRP is time-varying: negative in the first half of the sample (2000-2003) and positive in the second half of the sample (2004-2006)
- The negative estimated inflation risk premium appears to be due to liquidity problems on the TIPS market in the first half of the sample

Main Findings

- IRP is time-varying: negative in the first half of the sample (2000-2003) and positive in the second half of the sample (2004-2006)
- The negative estimated inflation risk premium appears to be due to liquidity problems on the TIPS market in the first half of the sample
- In the second half od the sample, inflation risk premium is between 2 and 63 bps depending on the measure of the expected inflation and maturity of the debt (5 and 10-year horizon)

Main Findings

- IRP is time-varying: negative in the first half of the sample (2000-2003) and positive in the second half of the sample (2004-2006)
- The negative estimated inflation risk premium appears to be due to liquidity problems on the TIPS market in the first half of the sample
- In the second half od the sample, inflation risk premium is between 2 and 63 bps depending on the measure of the expected inflation and maturity of the debt (5 and 10-year horizon)
- Net of the liquidity premium, IRP is 14 bps for 10-year horizon in the second half of the sample: reasonable result by Bernanke (2004)

TIPS Example

- Nominal bond: nominal coupon rate = 5.5%, par = \$1,000
- Expected rate of inflation = 2%
- Indexed bond: real coupon rate = 3.5%, par = \$1,000
- Then the payments of nominal and indexed bonds are as follows:

TIPS Example

- Nominal bond: nominal coupon rate = 5.5%, par = \$1,000
- Expected rate of inflation = 2%
- Indexed bond: real coupon rate = 3.5%, par = \$1,000
- Then the payments of nominal and indexed bonds are as follows:

Year	Dollar Payments of a nominal bond	Dollar payments of the linker under 3 different inflation scenarios			Real payments of a linker
		$\pi = 0\%$	$\pi = 2\%$	$\pi = 4\%$	
1	**55**	**35**	**35.70**	**36.40**	**35**
(Adjusted par)		1,000	1,020.00	1,040.00	
2	**55**	**35**	**36.41**	**37.86**	**35**
(Adjusted par)		1,000	1,040.40	1,081.60	
3	**55**	**35**	**37.14**	**39.37**	**35**
(Adjusted par)		1,000	1,061.21	1,124.86	
4	**55**	**35**	**37.89**	**40.95**	**35**
(Adjusted par)		1,000	1,082.43	1,169.86	
5	**55**	**35**	**38.64**	**42.58**	**35**
(Adjusted par)	**1,000**	1,000	1,104.08	1,216.65	**1,000**

TIPS and Nominal Bonds Data

- Sample: Jan 2000 - Dec 2006, monthly frequency
- Maturities: 5, 7 and 10 years
- Both TIPS and nominal yields are zero-coupon yields
- Source:
  - TIPS: Barclays Capital
  - Nominal: Federal Reserve

TIPS and Nominal Bonds Data

- Sample: Jan 2000 - Dec 2006, monthly frequency
- Maturities: 5, 7 and 10 years
- Both TIPS and nominal yields are zero-coupon yields
- Source:
  - TIPS: Barclays Capital
  - Nominal: Federal Reserve
- Descriptive Statistics:

	Central Moments				Autocorrelations		
	Mean	Stdev	Skew	Kurt	Lag1	Lag2	Lag3
	Panel A: TIPS Yields						
$y^{TIPS}(60)$	2.2262	1.0061	0.4774	2.0740	0.9714	0.9443	0.9212
$y^{TIPS}(84)$	2.4385	0.8989	0.5282	2.0138	0.9755	0.9521	0.9320
$y^{TIPS}(120)$	2.6231	0.8077	0.5046	1.8903	0.9786	0.9583	0.9406
	Panel B: Nominal Bond Yields						
$y(60)$	4.2265	1.0187	0.4823	2.7584	0.9771	0.9552	0.9349
$y(84)$	4.5481	0.8374	0.6299	2.9097	0.9797	0.9605	0.9430
$y(120)$	4.9194	0.6724	0.6670	2.7653	0.9823	0.9657	0.9507

Inflation Data

- Realized inflation
  - CPI, seasonally-unadjusted (index for TIPS)
  - Core CPI, seasonally adjusted

Inflation Data

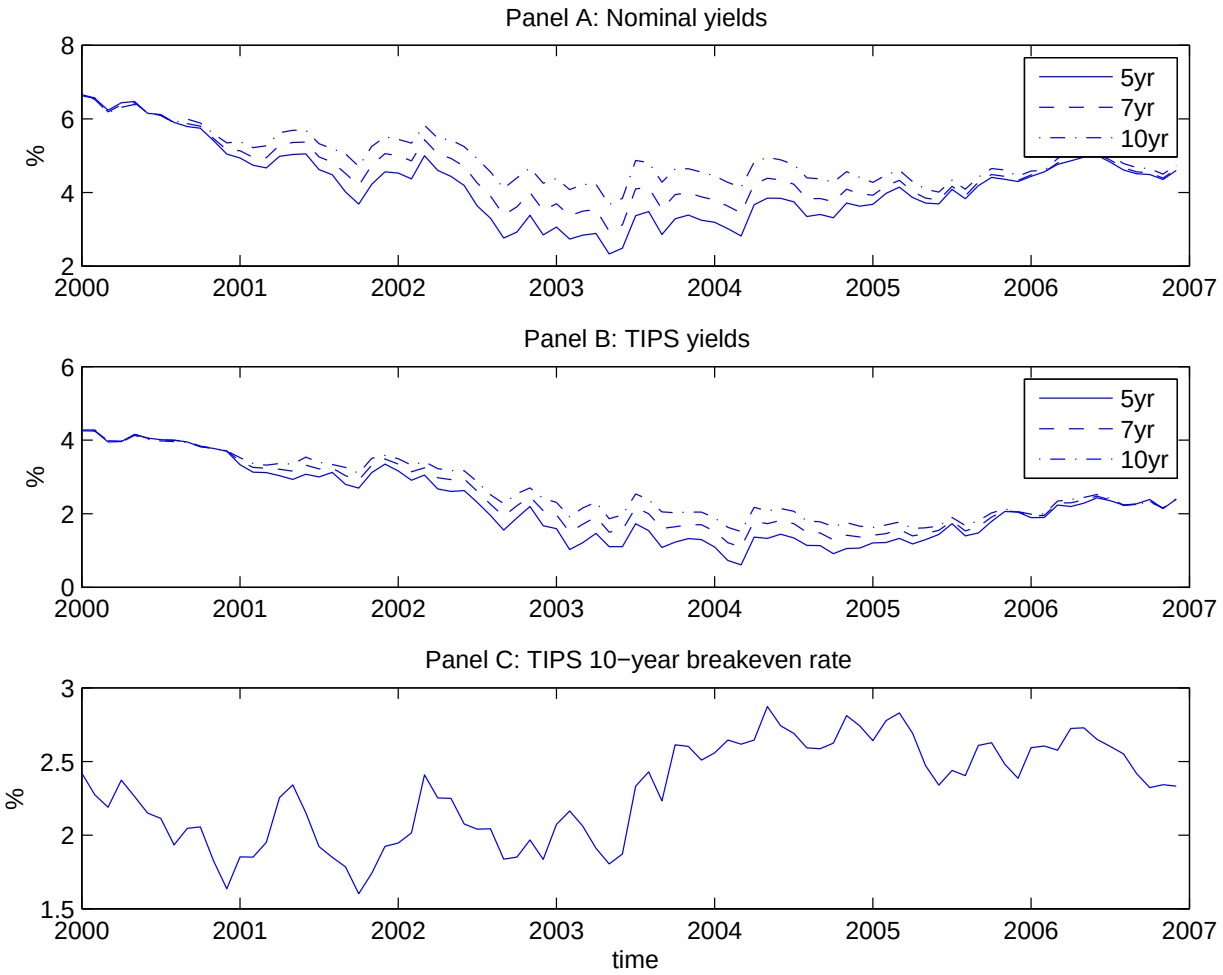
- Realized inflation
  - CPI, seasonally-unadjusted (index for TIPS)
  - Core CPI, seasonally adjusted
- Expected Inflation
  - Survey of Professional Forecasters
    - GDP 1-year ahead forecast
    - CPI 1 and 10-year ahead forecast
  - Blue Chips
    - CPI 1-year ahead forecast

Inflation Data

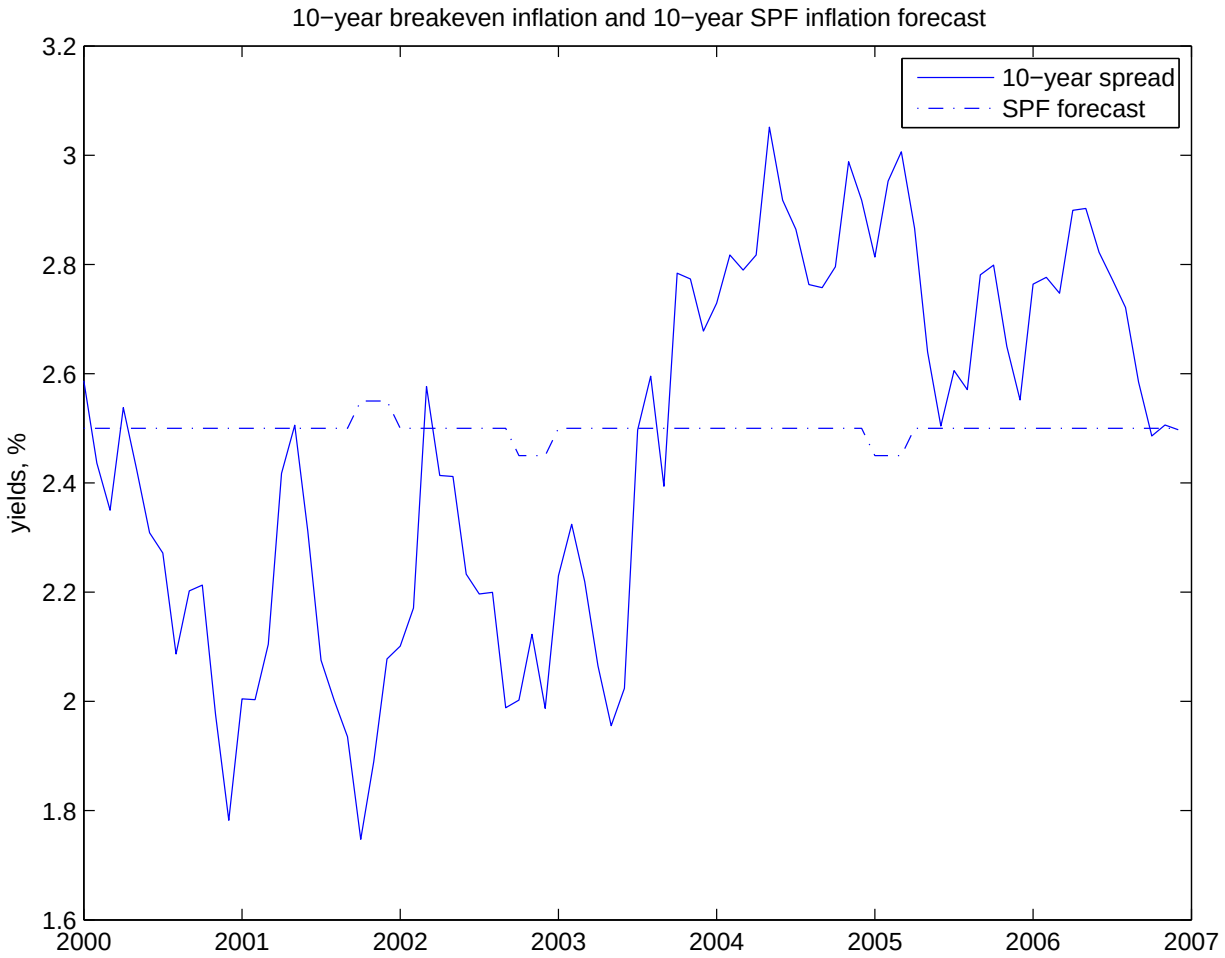
- Realized inflation
  - CPI, seasonally-unadjusted (index for TIPS)
  - Core CPI, seasonally adjusted
- Expected Inflation
  - Survey of Professional Forecasters
    - GDP 1-year ahead forecast
    - CPI 1 and 10-year ahead forecast
  - Blue Chips
    - CPI 1-year ahead forecast

	Central Moments				Autocorrelations		
	Mean	Stdev	Skew	Kurt	Lag1	Lag2	Lag3
	Panel C: Inflation Variables						
CPI	2.5933	4.3513	-0.1780	3.0736	0.5215	0.1012	0.0737
Core CPI	2.1759	1.0260	0.0757	2.6381	0.8118	0.8498	0.8195
SPF, GDP 1yr forecast	2.0278	0.2220	-0.1878	1.9757	0.9583	0.9104	0.8642
SPF, CPI 1yr forecast	2.3299	0.2513	-0.7662	3.6846	0.9544	0.9092	0.8660
SPF, CPI 10yr forecast	2.4982	0.0166	-0.7062	9.1771	0.9642	0.9284	0.8927
Blue Chips, CPI 1yr forecast	2.4550	0.4140	-0.3937	2.0438	0.9882	0.9733	0.9567

TIPS and Nominal Zero-coupon Yields Curves



10-year Breakeven Inflation and Expected Inflation



- We follow the methodology of Evans(1998) in estimating real yields

- We follow the methodology of Evans(1998) in estimating real yields
- Because of the 3-month lag in TIPS indexation, we have 3 TS: nominal $(q_t(h), y_t(h))$, TIPS $(q_t^+(h), y_t^+(h))$, and real $(q_t^*(\tau), y_t^*(\tau))$

- We follow the methodology of Evans(1998) in estimating real yields
- Because of the 3-month lag in TIPS indexation, we have 3 TS: nominal $(q_t(h), y_t(h))$, TIPS $(q_t^+(h), y_t^+(h))$, and real $(q_t^*(\tau), y_t^*(\tau))$
- There is an additional risk of covariance between future nominal and future inflation rate

- We follow the methodology of Evans(1998) in estimating real yields
- Because of the 3-month lag in TIPS indexation, we have 3 TS: nominal $(q_t(h), y_t(h))$, TIPS $(q_t^+(h), y_t^+(h))$, and real $(q_t^*(\tau), y_t^*(\tau))$
- There is an additional risk of covariance between future nominal and future inflation rate
- So, the TS of real rates is given by nominal and TIPS TS in addition to the covariance risk mentioned above

- Relationship for prices in 3 TS (in terms of log prices q_t):

$$q_t^+(h) = q_t^*(\tau) + [q_t(h) - q_t(\tau)] + \gamma_t(\tau), \qquad (3)$$

where $\tau = h - l$ and

- Relationship for prices in 3 TS (in terms of log prices q_t):

$$q_t^+(h) = q_t^*(\tau) + [q_t(h) - q_t(\tau)] + \gamma_t(\tau), \tag{3}$$

where $\tau = h - l$ and

$$\gamma_t(\tau) \equiv CV_t(q_{t+\tau}(l), \Delta^\tau p_{t+\tau}). \tag{4}$$

- Relationship for prices in 3 TS (in terms of log prices q_t):

$$q_t^+(h) = q_t^*(\tau) + [q_t(h) - q_t(\tau)] + \gamma_t(\tau), \tag{3}$$

where $\tau = h - l$ and

$$\gamma_t(\tau) \equiv CV_t(q_{t+\tau}(l), \Delta^\tau p_{t+\tau}). \tag{4}$$

- Therefore, real yields are:

$$y^*(\tau) = \frac{h}{\tau} y_t^+(h) - \frac{l}{\tau} f_t(\tau, l) + \frac{1}{\tau} \gamma_t(\tau). \tag{5}$$

Real Yields

- We observe $y_t^+(h)$, $y_t(h)$ and f_t, but we need to estimate covariance $\gamma_t(\tau)$ in order to compute $y_t^*(\tau)$

Real Yields

- We observe $y_t^+(h)$, $y_t(h)$ and f_t, but we need to estimate covariance $\gamma_t(\tau)$ in order to compute $y_t^*(\tau)$
- To estimate $\gamma_t(\tau)$, we use VAR methodology. Let $z_t' \equiv [\Delta p_t, q_t(l), x_t]$, where $x_t = \mathbf{1}$. Then estimate VAR:

$$z_{t+1} = Az_t + e_{t+1} \tag{6}$$

Real Yields

- We observe $y_t^+(h)$, $y_t(h)$ and f_t, but we need to estimate covariance $\gamma_t(\tau)$ in order to compute $y_t^*(\tau)$
- To estimate $\gamma_t(\tau)$, we use VAR methodology. Let $z_t' \equiv [\Delta p_t, q_t(l), x_t]$, where $x_t = \mathbf{1}$. Then estimate VAR:

$$z_{t+1} = Az_t + e_{t+1} \tag{6}$$

- As a result of estimated (6),

$$\gamma_t(\tau) = i_1' \left[\sum_{i=1}^{\tau} A^{\tau-i} \left(\sum_{j=1}^{i} A^{i-j} V(e_{t+j}|z_t) A^{i-j'} \right) \right] i_2, \tag{7}$$

where i_k, $k = 1, 2$ is the selection vector such that $\Delta p_t = i_1' z_t$ and $q_t(l) = i_2' z_t$.

TIPS and Real Yields Statistics

Table 3:

Sample period	Horizon, τ months	TIPS Yields		Real Yields	
		Mean	Stdev	Mean	Stdev
2000-2006	57	**2.226**	1.006	**2.032**	1.031
	81	2.438	0.899	2.255	0.917
	117	2.623	0.808	2.432	0.821
2000-2003	57	**2.685**	1.036	**2.495**	1.064
	81	2.916	0.876	2.734	0.901
	117	3.107	0.728	2.919	0.747
2004-2006	57	**1.614**	0.533	**1.415**	0.561
	81	1.802	0.394	1.616	0.411
	117	1.977	0.292	1.783	0.301

Inflation Risk Premium

- The following equation defines the $IRP_t(\tau)$:

$$y_t(\tau) = y_t^*(\tau) + E_t\pi_{t+\tau}(\tau) + IRP_t(\tau), \tag{8}$$

where $\pi_{t+\tau} \equiv (1/\tau)\Delta^\tau p_{t+\tau}$

Inflation Risk Premium

- The following equation defines the $IRP_t(\tau)$:

$$y_t(\tau) = y_t^*(\tau) + E_t\pi_{t+\tau}(\tau) + IRP_t(\tau), \tag{8}$$

  where $\pi_{t+\tau} \equiv (1/\tau)\Delta^\tau p_{t+\tau}$
- $E_t\pi_{t+\tau}(\tau)$ is either constructed as historical averages of 1,3,5,7, and 10-year backward-looking horizon or from survey forecasts

Inflation Risk Premium

- The following equation defines the $IRP_t(\tau)$:

$$y_t(\tau) = y_t^*(\tau) + E_t\pi_{t+\tau}(\tau) + IRP_t(\tau), \tag{8}$$

  where $\pi_{t+\tau} \equiv (1/\tau)\Delta^\tau p_{t+\tau}$
- $E_t\pi_{t+\tau}(\tau)$ is either constructed as historical averages of 1,3,5,7, and 10-year backward-looking horizon or from survey forecasts
- We also estimate Fisher hypothesis:

$$IRP_t(\tau) = \alpha_0 + \alpha_1 \left[y_t(\tau) - y_t^{real}(\tau) \right] + u_{t+\tau}. \tag{9}$$

  If $\alpha_1 \neq 0$, then IRP covaries with yield spreads, and Fisher does not hold (if IRP were zero, then it would not covary with yield spreads)

Expected Inflation: Realized Historical Average

Table 4:

Horizon, τ months	Estimation period, T years				
	1	3	5	7	10
	Panel A: Based on CPI				
57	2.429	2.414	2.444	2.531	2.783
81	2.456	2.445	2.531	2.671	2.924
117	2.543	2.636	2.778	2.921	3.124
	Panel B: Based on Core CPI				
57	2.214	2.293	2.398	2.549	2.863
81	2.300	2.396	2.548	2.736	3.051
117	2.509	2.673	2.859	3.049	3.327

IRP and yield spreads (based on CPI)

Table 5:

Horizon, τ months	α_0	α_1	R^2
	$E_t\pi_{t+\tau}(\tau)$ is 1-year historical average		
57	-0.023	0.930	0.978
	(-33.146)	(30.167)	
81	-0.024	0.997	0.896
	(-12.807)	(10.445)	
117	-0.031	1.214	0.920
	(-15.888)	(17.662)	
	$E_t\pi_{t+\tau}(\tau)$ is 10-year historical average		
57	-0.034	1.271	0.874
	(-16.096)	(13.095)	
81	-0.039	1.426	0.876
	(-17.529)	(14.307)	
117	-0.043	1.491	0.874
	(-17.567)	(15.124)	

$\alpha_1 \neq 0 \Rightarrow IRP_t(\tau) \neq 0$!

Inflation Risk Premium: *based* on Historical Average Realized CPI

Table 7:

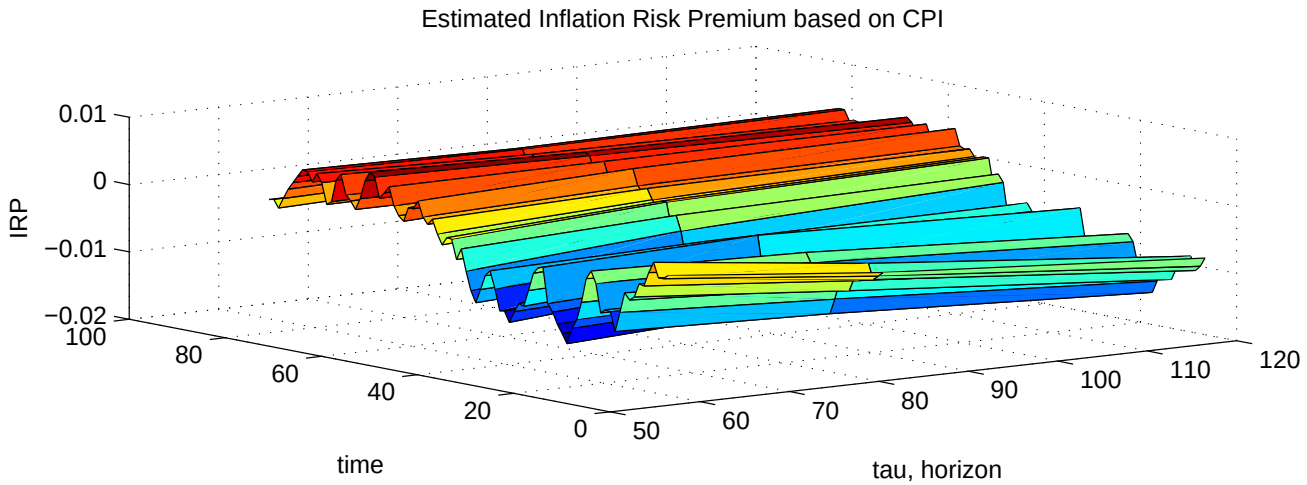
Year	Horizon,	Estimation period, T years				
	τ months	1	3	5	7	10
2000-2006	57	-0.281	-0.266	-0.296	-0.383	-0.635
	81	-0.201	-0.191	-0.276	-0.416	-0.669
	117	-0.083	-0.176	-0.318	-0.461	-0.664
2000-2003	57	-0.577	-0.586	-0.656	-0.813	-1.178
	81	-0.463	-0.511	-0.640	-0.863	-1.160
	117	-0.382	-0.546	-0.744	-0.901	-1.076
2004-2006	57	0.112	0.160	**0.183**	0.189	0.089
	81	0.149	0.236	0.209	**0.180**	-0.014
	117	0.315	0.316	0.251	0.126	**-0.116**

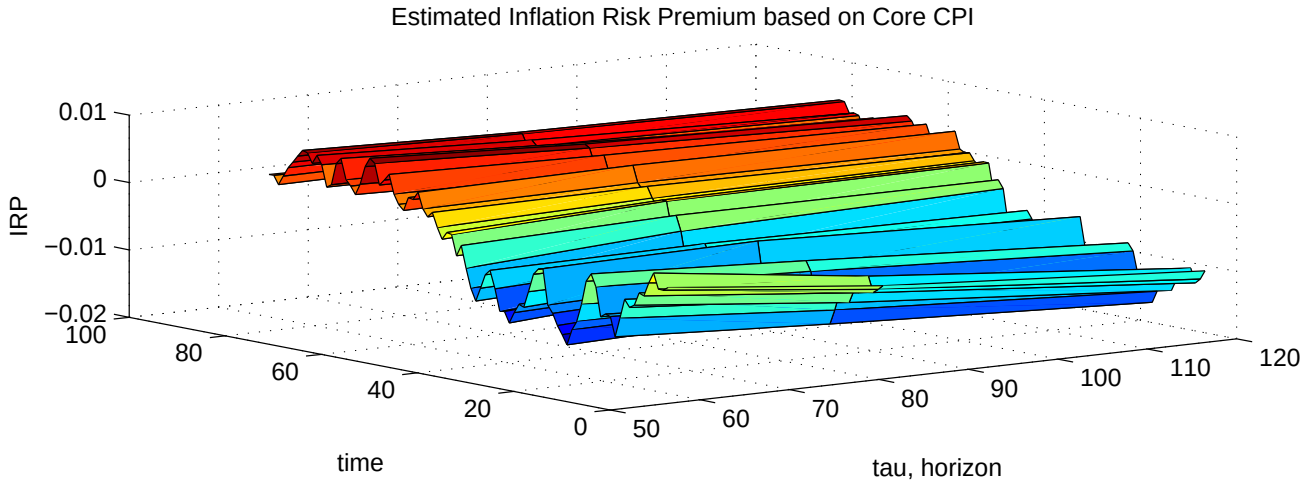
Inflation Risk Premium : *based* on Historical Average Realized Core CPI

Table 9:

Sample period	Horizon, τ months	Estimation period, T years				
		1	3	5	7	10
2000-2006	57	-0.066	-0.146	-0.250	-0.401	-0.715
	81	-0.045	-0.141	-0.293	-0.481	-0.796
	117	-0.049	-0.213	-0.400	-0.589	-0.867
2000-2003	57	-0.520	-0.591	-0.721	-0.934	-1.334
	81	-0.453	-0.567	-0.762	-1.014	-1.356
	117	-0.478	-0.684	-0.903	-1.098	-1.362
2004-2006	57	0.539	0.448	**0.379**	0.310	0.110
	81	0.500	0.427	0.332	**0.230**	-0.050
	117	0.523	0.413	0.272	0.089	**-0.207**

Term Structure of the Inflation Risk Premium





Inflation Risk Premium: *based* on Survey Forecasts

Table 11:

Sample period	Horizon τ months	Forecast Variable			
		SPF			Blue Chips
		GDP, 1yr	CPI,1yr	CPI,10yr	CPI,1yr
2000-2006	57	0.087	-0.215	-0.383	-0.307
	81	0.191	-0.111	-0.279	-0.200
	117	0.403	0.100	-0.068	0.005
2000-2003	57	-0.205	-0.575	-0.738	-0.553
	81	-0.037	-0.407	-0.570	-0.383
	117	0.231	-0.139	-0.302	-0.127
2004-2006	57	0.477	0.266	0.090	0.021
	81	0.496	0.285	0.109	0.044
	117	0.631	0.420	0.244	0.180

Estimating Liquidity Premium

Table 12:

To control for liquidity problems on the TIPS market, we regress $IRP_t(\tau)$ on the bid-ask spread and the log trading volume, and use residual as IRP net of liquidity effects:

$$IRP_t(\tau) = \alpha_0 + \alpha_1 spread_t(\tau) + \alpha_2 volume_t(\tau) + u_t(\tau) \qquad (10)$$

Estimating Liquidity Premium

Table 12:

To control for liquidity problems on the TIPS market, we regress $IRP_t(\tau)$ on the bid-ask spread and the log trading volume, and use residual as IRP net of liquidity effects:

$$IRP_t(\tau) = \alpha_0 + \alpha_1 spread_t(\tau) + \alpha_2 volume_t(\tau) + u_t(\tau) \qquad (10)$$

Regression Models	α_0	α_1	α_2	R^2	Average residual	
					First half	Second half
Model I	-1.653	29.160		0.335	-0.161	**0.161**
	(-3.747)	(3.621)				
Model II	0.195		0.244	0.283	-0.176	**0.176**
	(1.958)		(3.207)			
Model III	-1.036	20.350	0.128	0.383	-0.141	**0.141**
	(-1.668)	(2.004)	(1.385)			

To conclude ...

- In this paper, we estimate the inflation risk premium from directly observable TIPS market data
  - We find that the IRP has been negative in the early years of the TIPS market's existence
  - We estimate that in the second half of the sample, the IRP is between 2 and 63 bps, with upward-sloping TS of IRP
  - We find that the inflation risk premium contains a significant liquidity component.
  - Net of liquidity component, 10-year IRP drops to 14bps

To conclude ...

- In this paper, we estimate the inflation risk premium from directly observable TIPS market data
  - We find that the IRP has been negative in the early years of the TIPS market's existence
  - We estimate that in the second half of the sample, the IRP is between 2 and 63 bps, with upward-sloping TS of IRP
  - We find that the inflation risk premium contains a significant liquidity component.
  - Net of liquidity component, 10-year IRP drops to 14bps
- Future research
  - Dynamic latent model for expected inflation
  - Regime-switching model for IRP
  - More factors measuring liquidity premium