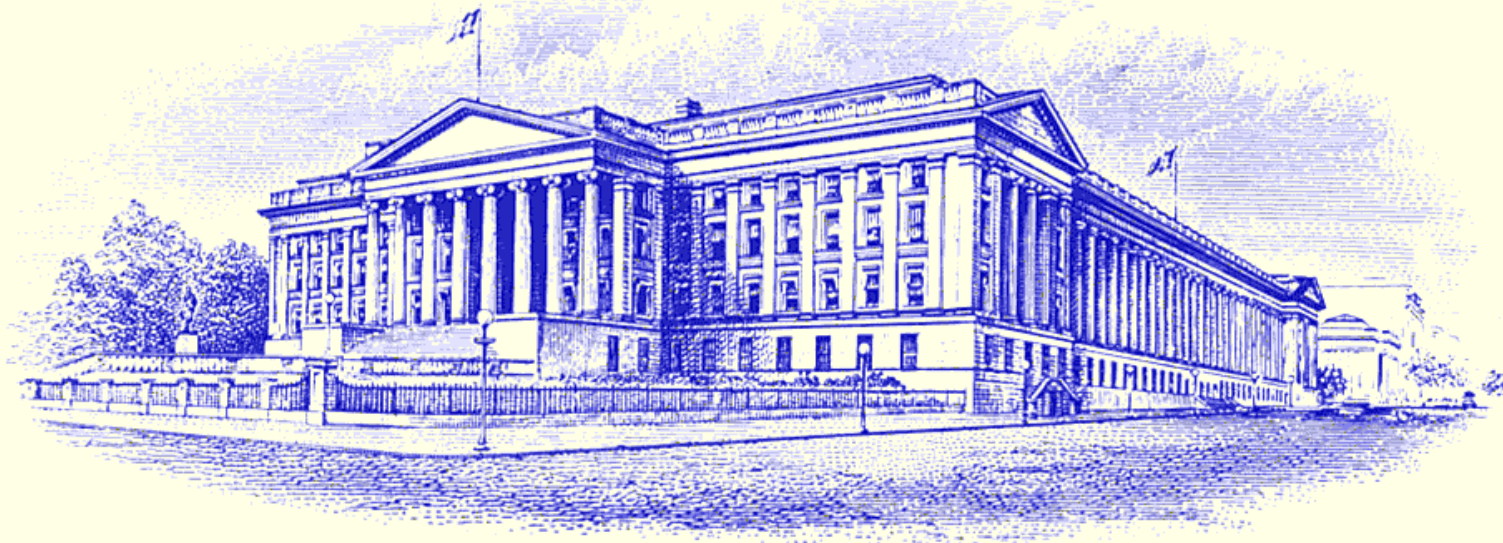


THE TREASURY BREAKEVEN INFLATION CURVE



James A. Girola

U.S. Department of the Treasury

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Introduction

- This presentation describes the Treasury Breakeven Inflation (TBI) Curve, which provides breakeven inflation rates derived from nominal Treasury notes and bonds and TIPS.
- Breakeven inflation rates are future inflation rates embedded in the Treasury securities market. Breakeven rates pertain to inflation of the (not seasonally adjusted) Consumer Price Index for All Urban Consumers (CPI-U).
- The Treasury TBI curve uses methodology that overcomes deficiencies in other approaches.

Introduction

- Although TBI rates can be influenced by a variety of short-term factors, on balance over time they are reliable indicators of market expectations for future inflation. Therefore, they can be used to compute projections of inflation into the future which are in accord with markets.
- Inflation projections have many uses, including economic forecasting, pension trust funds, and conversion of future nominal cash flows to real payments, as in the Blended Retirement System.
- Moreover, when combined with projected real interest rates based on the structure of the economy, projected inflation can forecast future nominal interest rates.

Treasury Yield Curves

- The TBI curve is one of a set of yield curves done by Treasury. Data generated by these curves are already used by the Defense Department.
- The first Treasury curve is the Treasury Nominal Coupon-Issue (TNC) Yield Curve, which pertains to Treasury nominal coupon issues.
- The second is the Treasury Real Coupon-Issue (TRC) Yield Curve for Treasury Inflation-Protected Securities (also known as TIPS).
- And the third is the High Quality Market (HQM) Corporate Bond Yield Curve, which pertains to U.S. high quality corporate bonds.
- The following discussion summarizes these curves and their methodology. The last slide contains links for more information.

The HQM Yield Curve

- The HQM corporate bond yield curve is produced as mandated by the Pension Protection Act of 2006 (PPA). This curve pertains to high quality corporate bonds, that is, bonds in the top three qualities AAA, AA, and A.
- To meet the requirements of the PPA, it was necessary to invent a new yield curve methodology at Treasury for the HQM curve. The methodology is sketched out below.
- The HQM curve data are disseminated by IRS and by the Treasury Office of Economic Policy, and include spot rates and related yields that are used by single-employer pension plans to discount future liabilities. HQM yield curve data are available back through 1984.
- The HQM yield curve is also used in the Blended Retirement System.

The TNC Yield Curve

- The HQM methodology was subsequently applied to the Treasury market to produce the TNC yield curve, which pertains to Treasury nominal coupon issues, both notes and bonds.
- The TNC curve includes both on-the-run issues (securities most recently issued of each maturity) and older off-the-run issues. However, in this presentation the focus is on spot rates from off-the-run issues.
- The initial application of the TNC yield curve was to discount future liabilities of various federal agencies including the Defense Department, such as pension and other postemployment liabilities, for the agencies' audited financial statements and for the annual Financial Report of the U.S. Government.
- The TNC curve goes back through 1976, and is the most extensive Treasury yield curve dataset currently available.

The TRC Yield Curve

- The HQM and TNC methodology was subsequently used to produce the TRC yield curve. The TRC yield curve is the real yield curve derived from Treasury Inflation-Protected Securities or TIPS, and includes both real notes and real bonds.
- And the nominal TNC and real TRC yield curves are combined to derive the Treasury Breakeven Inflation (TBI) Curve.
- The TRC yield curve and the TBI curve are both available back through 2003.

Yield Curve Data

- These yield curves each provide several sets of data, including spot rates, selected par yields, and forward rates. The TNC curve provides off-the-run and on-the-run data.
- The curves are calculated late in the day on each business day, and the results are disseminated each month. The spot rate data, which are of particular interest for breakeven inflation, include monthly averages of daily spot rates, as well as end of month spot rates from the TNC and TRC curves and the TBI curve as a combination of these.

Yield Curve Data, continued

- Spot rates are available for each maturity at half-year intervals starting at $\frac{1}{2}$ year up through 100 years, for a total of 200 maturities. Rates beyond 30 years maturity are projected as described below.
- All spot rates are semiannually compounded, except, following convention, TBI rates are annually compounded.

Yield Curves for January 2019

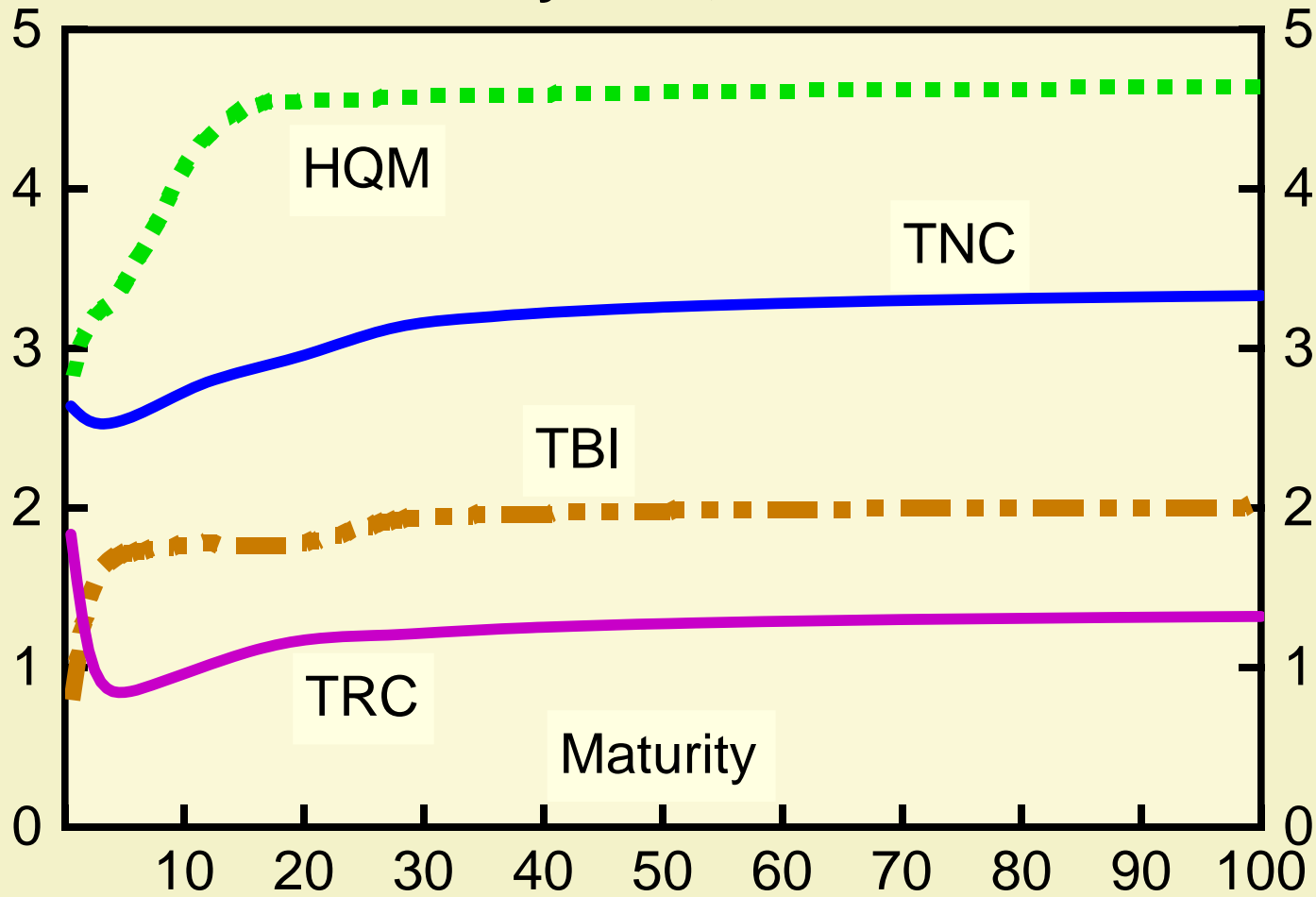
- Slide 12 contains the average TNC, TRC, and HQM spot yield curves for January plus the TBI breakeven curve. All curves are projected out through 100 years maturity.
- The HQM spot rate is 4.58 percent at 30 years maturity, compared to 3.16 percent and 1.22 percent for the TNC and TRC spot rates, respectively. The TBI rate is 1.95 percent at 30 years maturity.
- The HQM rate exceeds the TNC rate largely because of corporate bond default risk, and the TNC rate exceeds the TRC rate with positive inflation.

Yield Curves for January 2019, continued

- The spot yield curves rise gradually throughout the projection range from 30 years maturity through 100 years maturity, which is typical. At 100 years maturity, the HQM spot rate is 4.64 percent, the TNC rate is 3.33 percent, the TRC rate is 1.32 percent, and the TBI rate is 2.01 percent.

SPOT YIELD CURVES

January 2019, Percent



Methodology Features

The methodology used for the yield curves contains features and capabilities that do not appear in other yield curve approaches:

- The methodology makes use of established bond market characteristics to generate a stable yield curve that captures market movements.
- The methodology projects yields beyond 30 years.
- The methodology combines regression variables with the yield curve.

Methodology Features, continued

- The requirements of the PPA made necessary the invention of this methodology, which is new and more extensive.
- In particular, this methodology is grounded in established bond market characteristics, which generate and justify the mathematical form of the yield curve.

The following slides summarize details of this methodology.

Maturity Ranges

- A central feature of the methodology is that it breaks the yield curve into maturity ranges.
- This is because trading in securities tends to divide into maturity ranges, such that the trading activity in each range on average reflects similar purposes, similar views of risk, and similar expectations about securities in that range.
- Because market views can be considered similar for securities in the same range, yields in each maturity range are related to each other in a simple fashion.
- Consequently, this methodology models yields, and in particular forward rates, in each maturity range as a smooth (cubic) function, and joins the functions together smoothly across ranges (as a cubic spline).

Maturity Ranges, continued

- At the present time five maturity ranges are used for the yield curves, delineated by the maturity points 0, 1.5, 3, 7, 15, and 30 years maturity. These points provide separate ranges for the critical maturities of 2 years, 5 years, the benchmark 10 years, and 30 years.
- The choice of fixed maturity ranges increases significantly the stability of the yield curve estimates over time.
- In addition, the methodology is statistically straightforward to estimate, generating statistical equations that are well conditioned.

The Long-Term Forward Rate

- The methodology must also be able to project yields and inflation rates beyond 30 years maturity out through 100 years.
- First of all, the long-term forward rate at and beyond 30 years maturity is set to a constant, because there are not enough data to estimate accurately movements in the forward rate beyond 30 years maturity.
- Then this constant is taken to be the average forward rate in the 15- to 30-year maturity range.
- Therefore, using the long-term forward rate, spot rates can be projected beyond 30 years maturity out to 100 years maturity. The projected spot rates provide discount rates for long-dated cash flows, and also enable projection of inflation 100 years forward.

Methodology: Regression Variables

- This methodology also has the special capability of combining regression variables with the yield curve. The regression variables adjust for various features of the market and particular attributes of individual securities.
- The TNC and TRC yield curves use regression to measure the hump in yields that is sometimes seen around 20 years maturity. The TNC curve also uses regression to measure price effects of on-the-run securities.
- The HQM yield curve uses regression variables to combine AAA, AA, and A rated bonds into a single average curve.
- Given this summary of the yield curves, the next topic is the definition and examination of breakeven inflation.

Definition: Breakeven Inflation

- The most useful way to define breakeven inflation is as follows: the breakeven inflation rate over a future period is the future inflation rate during that period that, if realized, would equate for the period the dollar return gotten from nominal Treasury securities and the dollar return gotten from TIPS.
- Put another way, investing in nominal Treasury notes and bonds for a period, say 10 years, provides a future return in dollars received at the end of the 10 years. Similarly, investing in TIPS provides a real return after 10 years, which is then converted to dollars by the CPI-U. The breakeven inflation rate is the CPI-U inflation rate over the 10 years that, if realized, would make these two returns equal.

Definition: Breakeven Inflation, continued

- It follows from this definition that the breakeven inflation rate is an indicator of inflation expectations by market participants: if expectations were different, returns would not be equal, and traders would buy or sell securities to make them equal.
- However, the use of breakeven inflation to show inflation expectations is subject to qualifications. First, the breakeven rate must be derived from suitable data, and must be calculated correctly. This is done for the TBI curve by using spot rates from the TNC and TRC yield curves.
- But even when this is done, there are short periods when the demand for nominal Treasuries vs TIPS is distorted by factors that are more important than equating returns, such as temporary movements in liquidity in times of economic crisis.
- The following slides discuss these issues.

Use of Spot Rates

- The biggest problem with most computations of breakeven inflation rates is that they use yields rather than spot rates.
- Following the definition, breakeven rates are derived from returns received at the end of future periods from nominal Treasuries vs TIPS. The spot rate on securities, nominal or TIPS, gives the correct amount received at the end of each period.
- In contrast, yields do not give returns received at the end of periods because yields include streams of coupon payments received throughout the periods before the end. Spot rates are the same as zero coupon rates: that is, rates on securities that pay a single amount at the end of the investment period.

Use of Spot Rates, continued

- Consequently, use of yields significantly biases down the calculation of breakeven inflation. Perhaps yields are typically used because many analysts do not have spot rates. The TBI curve uses spot rates from the TNC and TRC yield curves.
- Another way to view the problem of yields is that at any maturity the duration of TIPS in nominal terms is longer than that of nominal Treasuries, with the result that the two types of securities are mismatched for the purpose of calculating the breakeven rate. In contrast, for a given maturity, the duration of nominal and TIPS spot rates are the same and equal to the maturity.
- It should be noted that spot rates computed from the TNC and TRC yield curves are estimated from coupon-issue securities. Therefore, they may not match market returns exactly at any time.

Liquidity Bias

- The use of breakeven inflation for inflation expectations has also been questioned because it has been argued that nominal Treasuries are more liquid than TIPS. If so, this implies that nominal Treasuries are more desirable and have lower returns, which would bias down the calculation of breakeven inflation.
- However, this argument typically assumes the use of yields for the on-the-run, that is, the most recently issued, Treasury securities. In contrast, spot rates in the TBI curve pertain to older off-the-run nominal Treasuries whose liquidity is much closer to that of TIPS, thereby eliminating any such bias.

Additional Sources of Bias

- Another source of bias in the usual computations of breakeven inflation rates comes from the fact that the rates are taken to be simply the subtraction of TIPS rates from nominal rates. Although not reproduced here, the correct formula employs compounding rather than subtraction, as done for TBI rates.
- In addition, breakeven computations often assume semiannual compounding as in the bond market. In contrast, inflation is conventionally measured as annual, and consequently, TBI rates are annual too.
- All these biases need to be taken into account: if breakeven inflation is under consideration for inflation projections, it first has to be calculated correctly.

Inflation Risk Premium

- A final source of possible bias in breakeven inflation, often thought to be the largest, is the inflation risk premium in nominal Treasury notes and bonds.
- Because future inflation is uncertain, there is a risk associated with real returns on nominal Treasuries that is not in TIPS. To compensate for this risk, holders of nominal Treasuries are said to demand returns that are on average above the returns for TIPS based on expected inflation. This pushes up the returns on nominal Treasuries and thereby biases up the breakeven inflation rate as an indicator of inflation expectations.

Inflation Risk Premium, continued

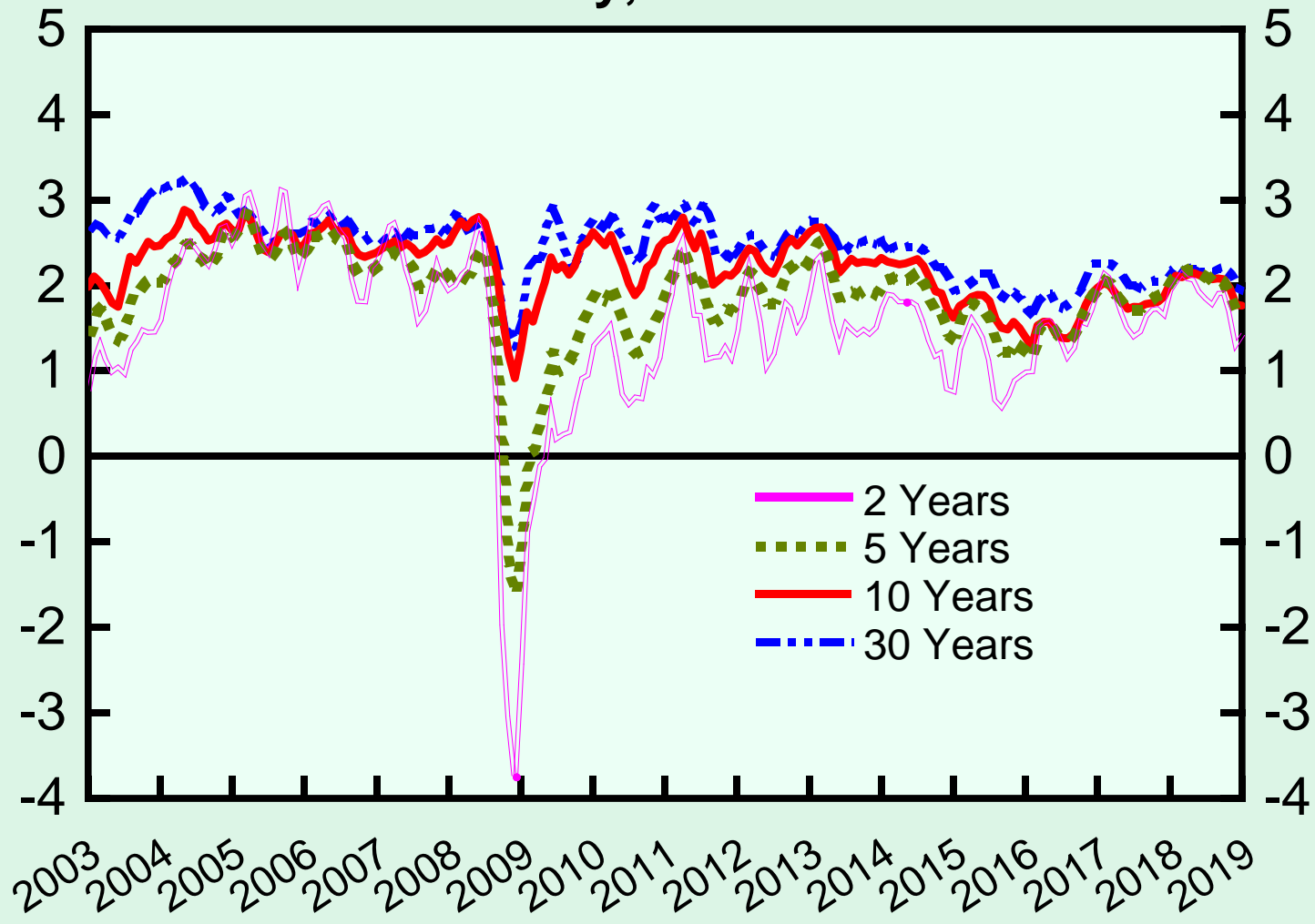
- Of course, just as future inflation may be unexpectedly high, it may also be unexpectedly low, thereby boosting real returns on nominal Treasuries. So the inflation risk premium assumes a risk aversion by security holders toward inflation surprises that may not actually exist, especially for institutional investors.
- The data in the rest of the slides provide evidence about the inflation risk premium. The data are consistent with the view that the risk premium is small at most.

Breakeven Inflation over Time

- The following chart in slide 28 shows TBI breakeven inflation at selected maturities for January 2003 through January 2019.
- The breakeven rates in the chart are somewhat higher at higher maturities earlier in the period but not so much lately. This may indicate that inflation expectations rose for more distant future periods, but it may also reflect some inflation risk premium.
- It is not possible to assess the premium from these data, and more data are considered in the following slides.
- The chart also shows sharp declines in breakeven inflation in the crisis at the end of 2008. The declines came from high TIPS yields stemming largely from TIPS liquidity concerns. The declines show that over short periods, breakeven inflation may be influenced by special factors and may not be a good indicator of expected inflation.

BREAKEVEN INFLATION RATES AT SELECTED MATURITIES

Monthly, Percent

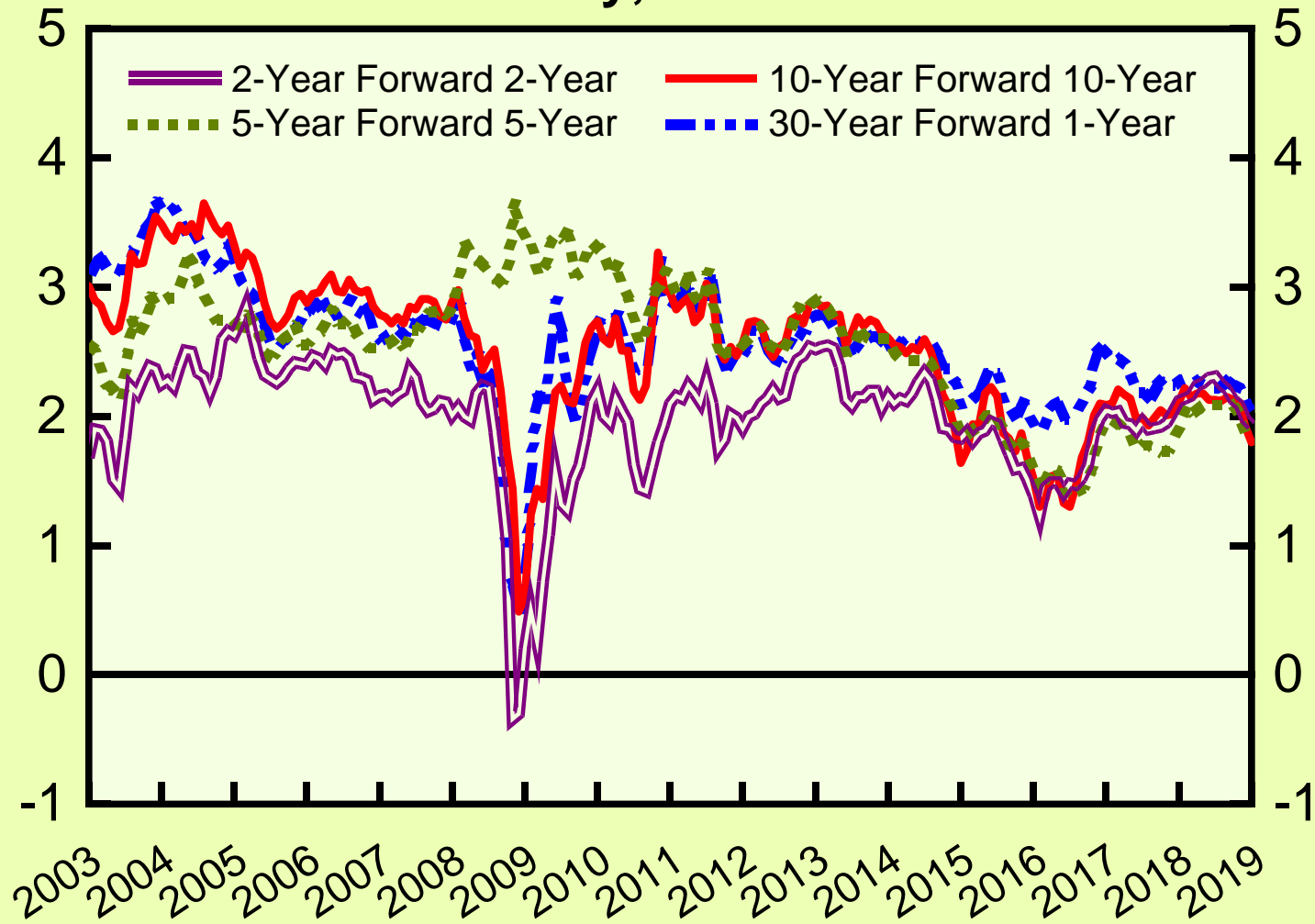


Forward Breakeven Inflation

- The chart in slide 30 shows selected forward breakeven inflation rates, also for January 2003 through January 2019.
- Forward breakeven inflation is the inflation rate over a given horizon for a future time. It is computed from regular breakeven inflation rates. The series included in the chart are common measures of future inflation expectations.
- All the breakeven rates converge near 2 percent at the end, similar to the breakeven rates on slide 28.

SELECTED FORWARD BREAKEVEN INFLATION RATES

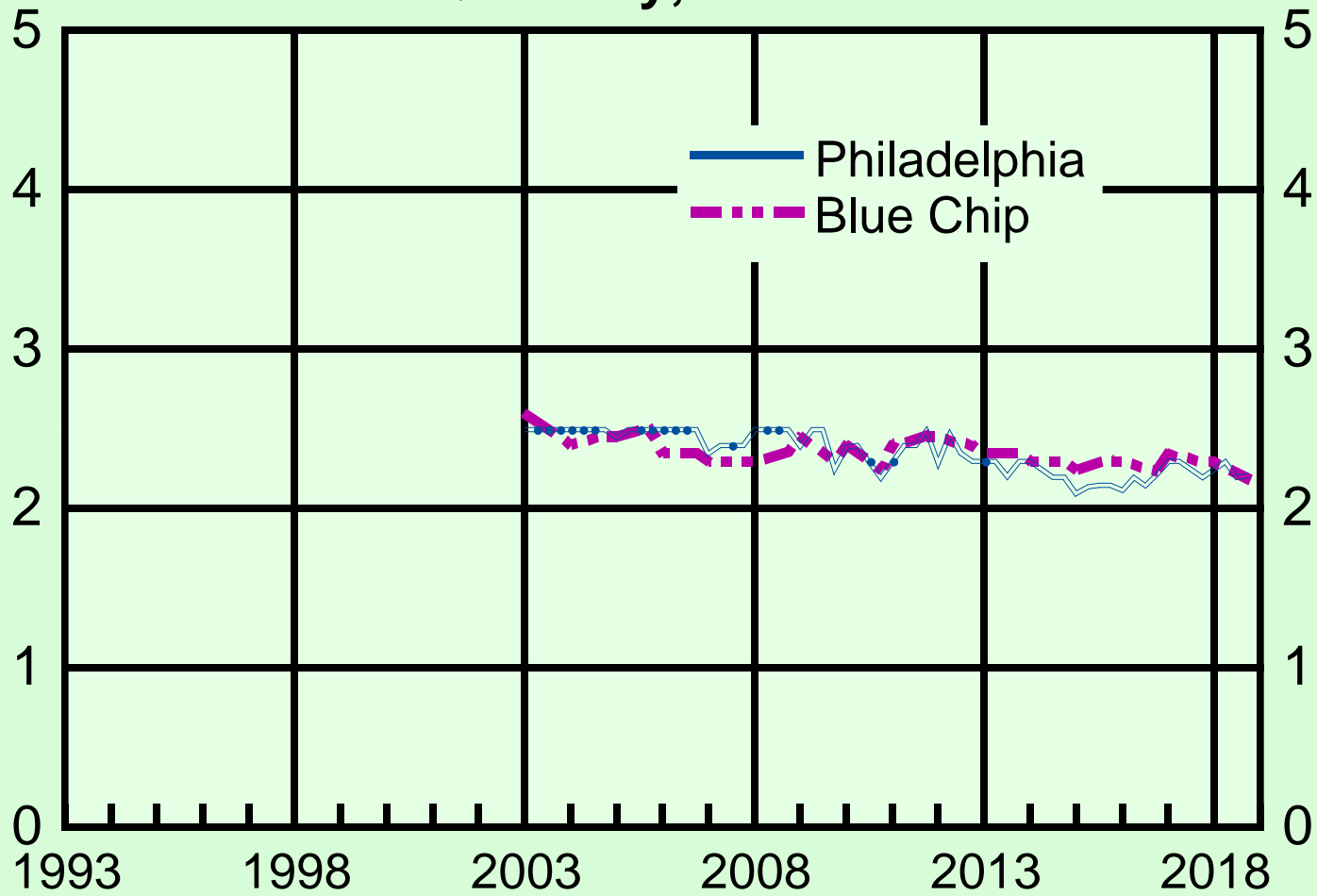
Monthly, Percent



10-Year CPI Inflation Forecasts

- The next charts compare TBI 10-year forecasts to survey 10-year forecasts and actual inflation over 10 years for the 16 years 2003-2018.
- The chart on slide 32 has the quarterly 10-year forecast from the Survey of Professional Forecasters at the Federal Reserve Bank of Philadelphia and the semiannual 10-year forecast from the long-range consensus in Blue Chip Economic Indicators (derived the successive 5-year forecasts).
- The two forecasts vary little throughout the period and are also very close to each other. They both start out around 2.5 percent and end around 2.2 percent in 2018.

10-YEAR INFLATION: FORECAST AND ACTUAL Quarterly, Percent



10-Year CPI Inflation Forecasts, continued

- The chart on slide 34 adds the TBI 10-year forecast (quarterly averages) to the survey forecasts.
- The TBI forecast is near both survey forecasts (allowing for the drop in the financial crisis) but there are differences: the TBI forecast starts somewhat higher than the surveys at the beginning and then falls below them at the end.
- However, the important point to note in this chart is that there is no evidence of any bias in the TBI forecast line. In particular, there is no evidence that the TBI rates are biased up by a risk premium.

10-YEAR INFLATION: FORECAST AND ACTUAL

Quarterly, Percent

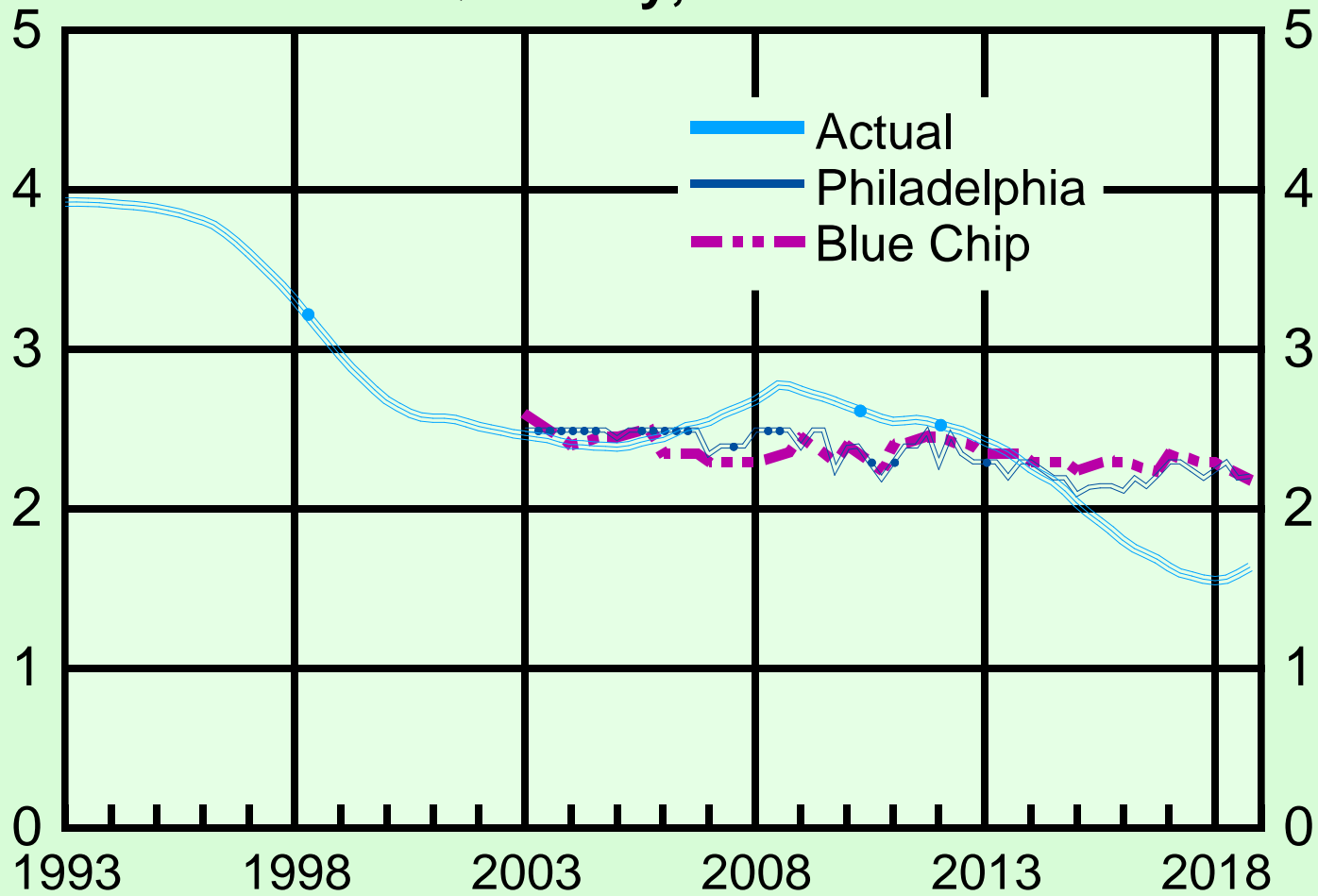


10-Year CPI Inflation Forecasts, continued

- The chart on slide 36 removes the TBI line but adds the actual average CPI inflation rate 10 years back for each quarter (inflation rates are computed by log regressions on time trends which smoothly depict underlying inflation).
- Actual 10-year inflation rates accelerated to 2.78 percent in 2008 and then showed steady deceleration to the present, falling to around 1.64 percent by the end of 2018.
- The survey forecasts did not pick up the inflation changes in advance. In particular, except for a belated small decline the last few years, these forecasts missed the recent deceleration in inflation.

10-YEAR INFLATION: FORECAST AND ACTUAL

Quarterly, Percent

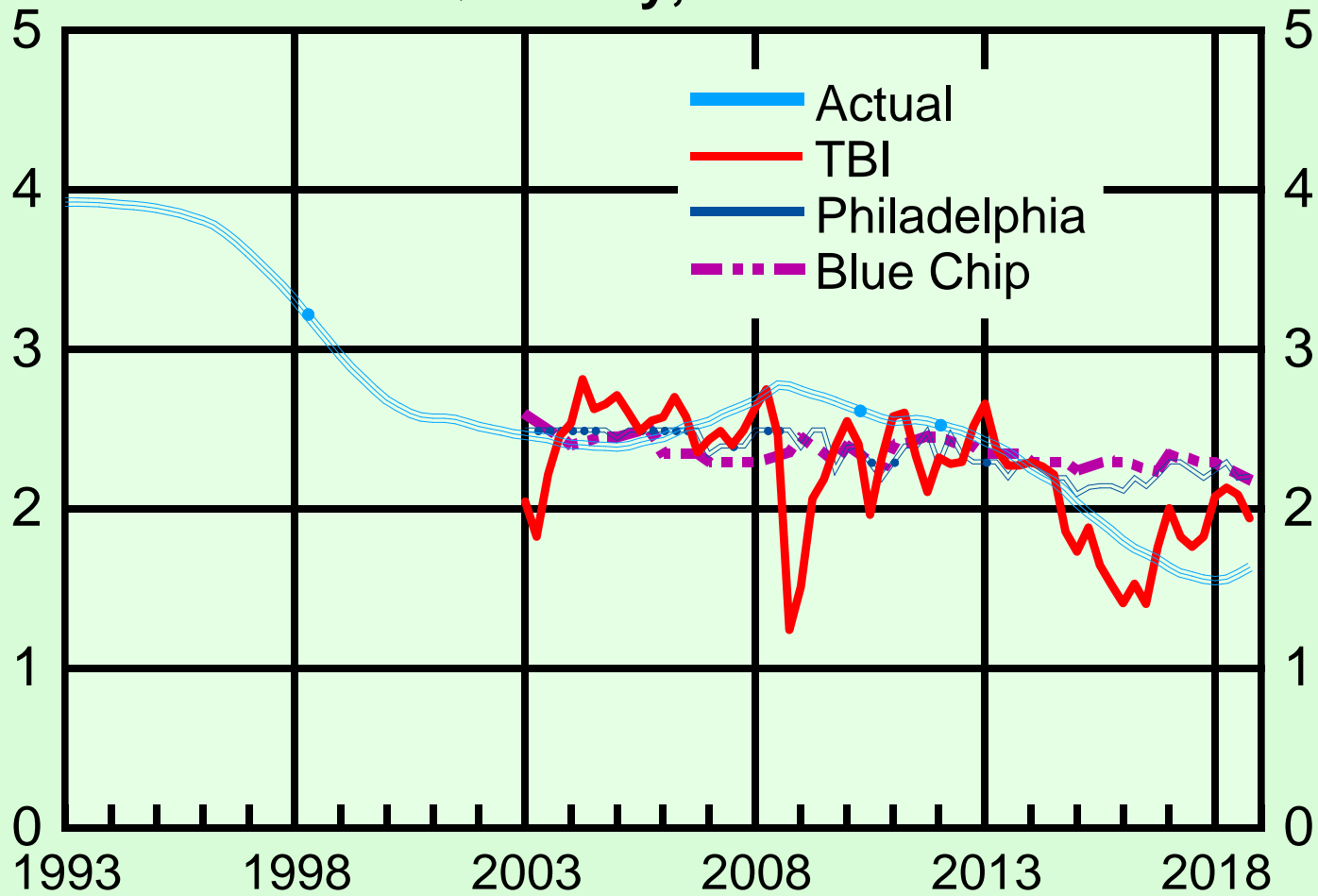


10-Year CPI Inflation Forecasts, continued

- The last chart on slide 38 adds back the TBI line to the survey forecasts and actual 10-year inflation.
- The chart shows that the TBI forecasts do better than the survey forecasts. The higher TBI rates in 2004-2006 pick up the ensuing inflation acceleration, while the lower TBI rates in 2015-2018 track the inflation deceleration. This is much better than the surveys which moved little over the period.
- Nevertheless, TBI forecasts were still very slow to pick up changes in actual inflation: they did not foresee changes 10 years in advance and they mostly moved simultaneously with actual inflation.

10-YEAR INFLATION: FORECAST AND ACTUAL

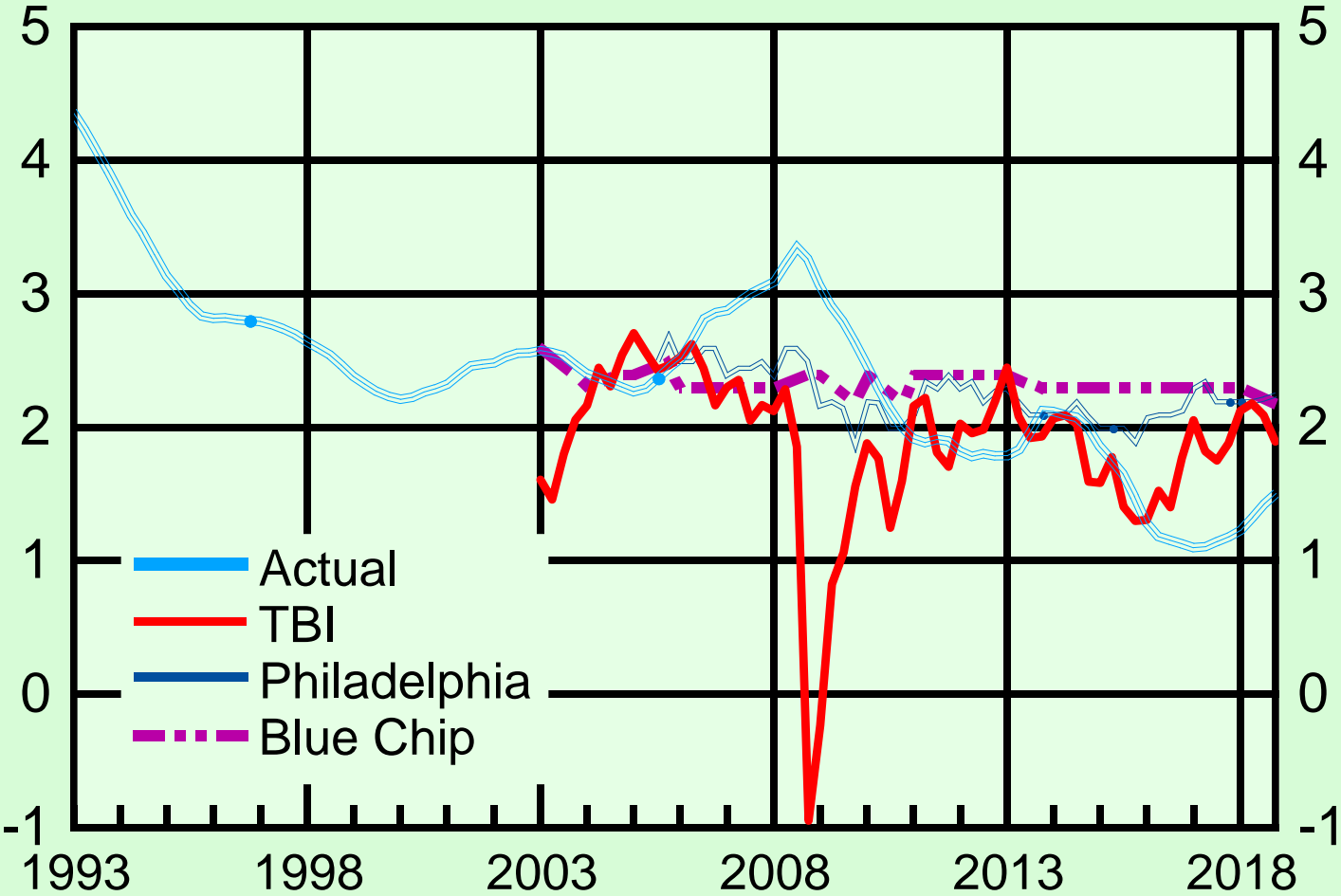
Quarterly, Percent



5-Year CPI Inflation Forecasts

- The chart on slide 40 is the same as slide 38 except it is done for 5-year periods.
- This chart confirms the same conclusions: there is no bias in TBI rates and no noticeable inflation risk premium, and TBI forecasts do better than surveys in capturing actual changes in inflation, although they are still very late in foreseeing such changes in advance.

5-YEAR INFLATION: FORECAST AND ACTUAL Quarterly, Percent

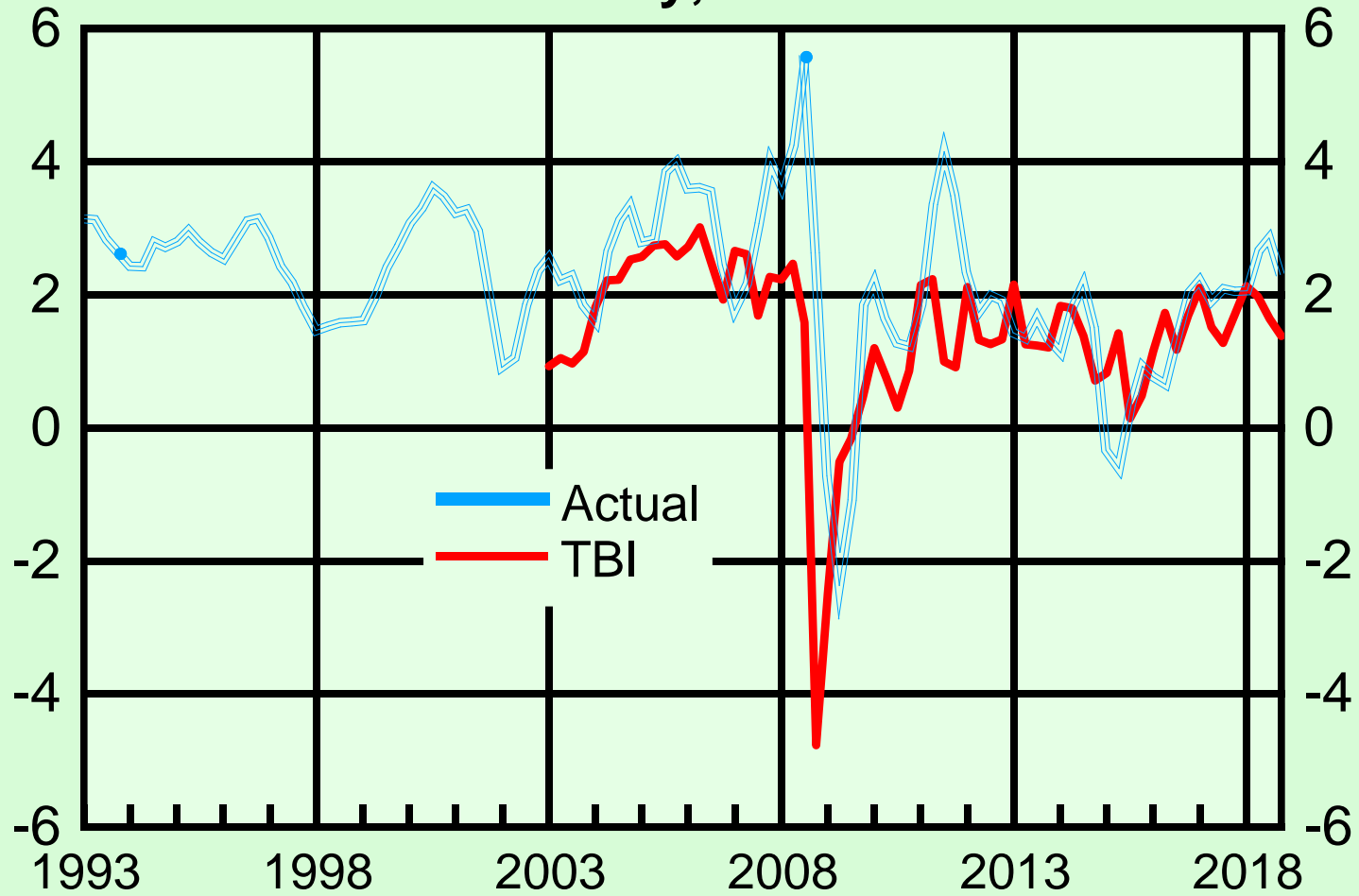


1-Year CPI Inflation Forecasts

- Finally, the chart on slide 42 shows 1-year TBI inflation forecasts compared with 1-year back inflation rates.
- This chart indicates that 1-year TBI forecasts track actual inflation, with some evidence that the forecasts anticipate 1-year inflation changes.
- It is notable that the big dip in the 1-year TBI forecast in 2008 was followed shortly by a dip in actual 1-year inflation. This indicates that the TBI dip was influenced both by liquidity concerns in the crisis and by anticipation of actual deflation in the CPI over 1-year periods.

1-YEAR TBI INFLATION FORECAST

Quarterly, Percent



Alternative TBI Projections

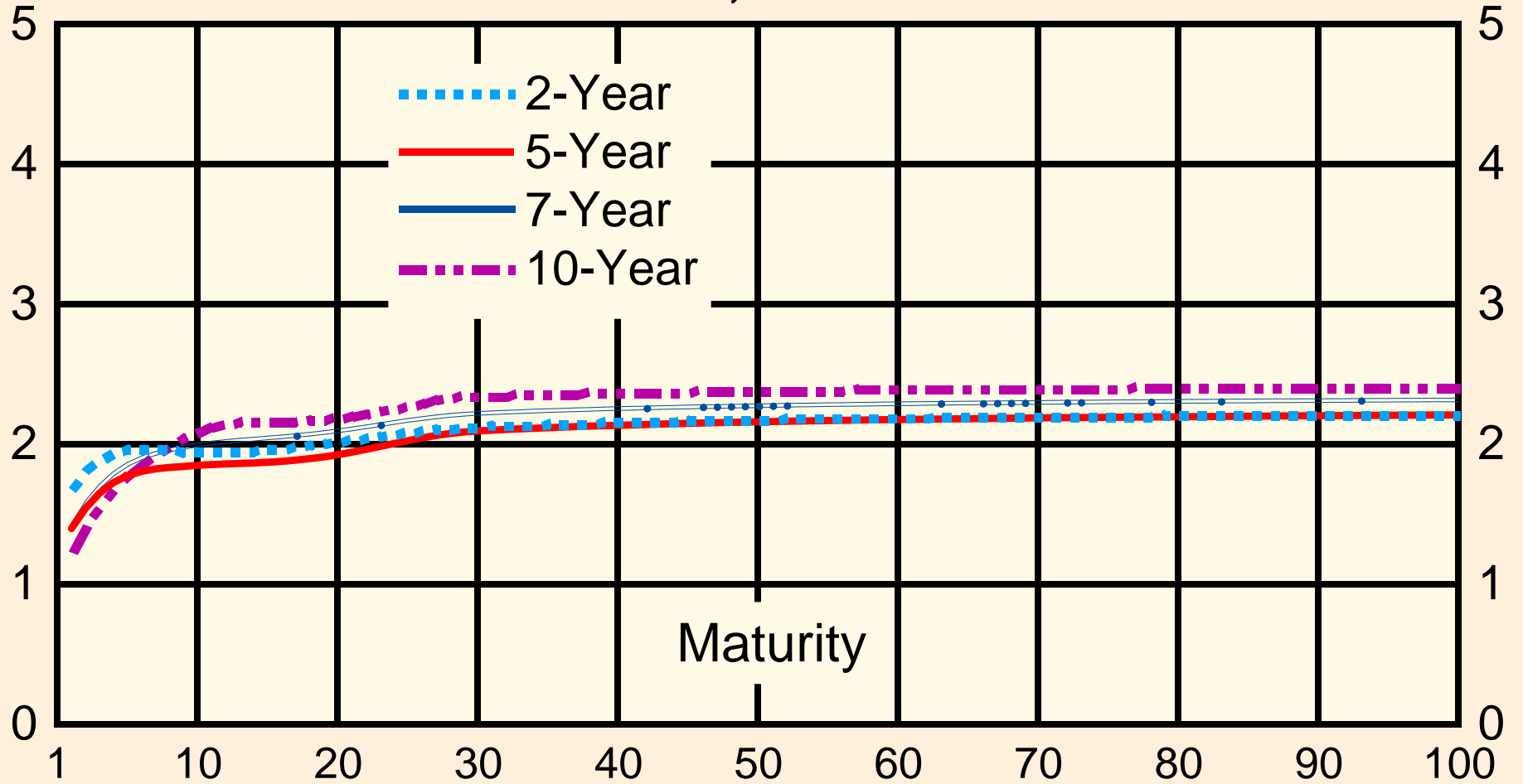
- The next step is to use the TBI rates to project expected future inflation.
- The projection can be done from a single recent month's data such as in slide 12, but as has been shown, TBI rates can be distorted by special factors over short periods. Therefore, the projection should use averages of TBI rates over a span of time.
- In particular, because the focus is on inflation over the long-term, market expectations averaged over longer periods provide settled market views about the long term, as opposed to shorter periods which may be influenced by recent inflation behavior.

Alternative TBI Projections, continued

- The chart on slide 45 shows TBI rates averaged over various time spans. For each projection, the value at each maturity is the projected average inflation rate from the present through that maturity.
- The chart includes the 2-year average, analogous to the segment rates in the Pension Protection Act, as well as the 5-year and 7-year averages, and the 10-year average which is used by government agencies including Defense for discount rates for future liabilities.
- The chart shows that the averages are close, especially at shorter maturities. Therefore, the expected future pattern of inflation has been stable over the last decade.

ALTERNATIVE TBI PROJECTIONS

Annual, Percent

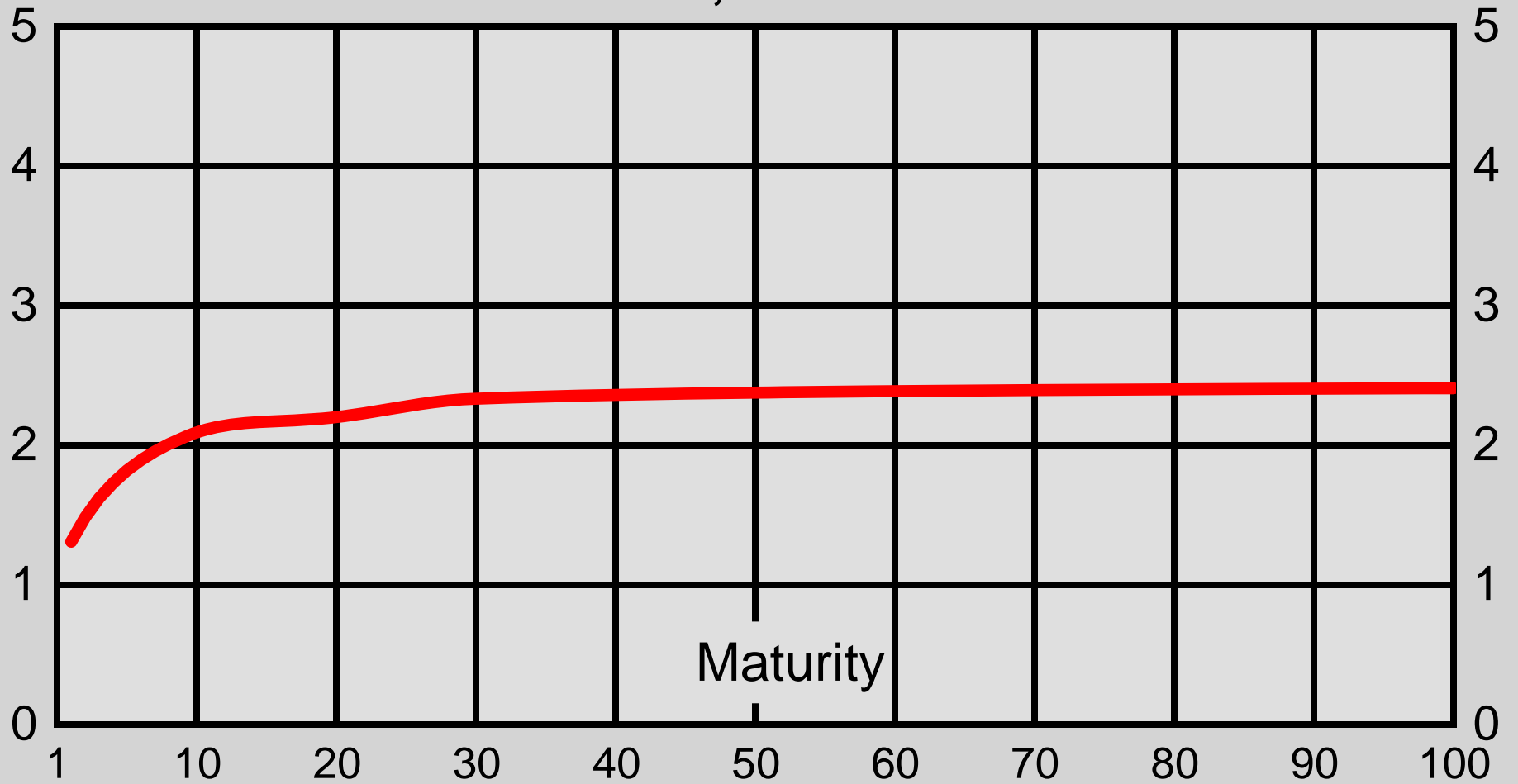


TBI Inflation Projection

- In view of this stability, the full 10-year average provides a projection that captures recent market views, especially for long-term inflation, and minimizes the influences of short-term effects. However, the 10-year average extends back into the recession period, which may affect the results. Therefore, the average chosen is the 115 months from the first month of recovery July 2009 through January 2019.
- The projection using this average is depicted in the chart on slide 47. The chart shows that average inflation rises from values around 1-1/2 percent to 2.09 percent at 10 years maturity, 2.33 percent at 30 years, 2.38 percent at 50 years, and 2.41 percent at 100 years maturity.

TBI INFLATION PROJECTION

Annual, Percent

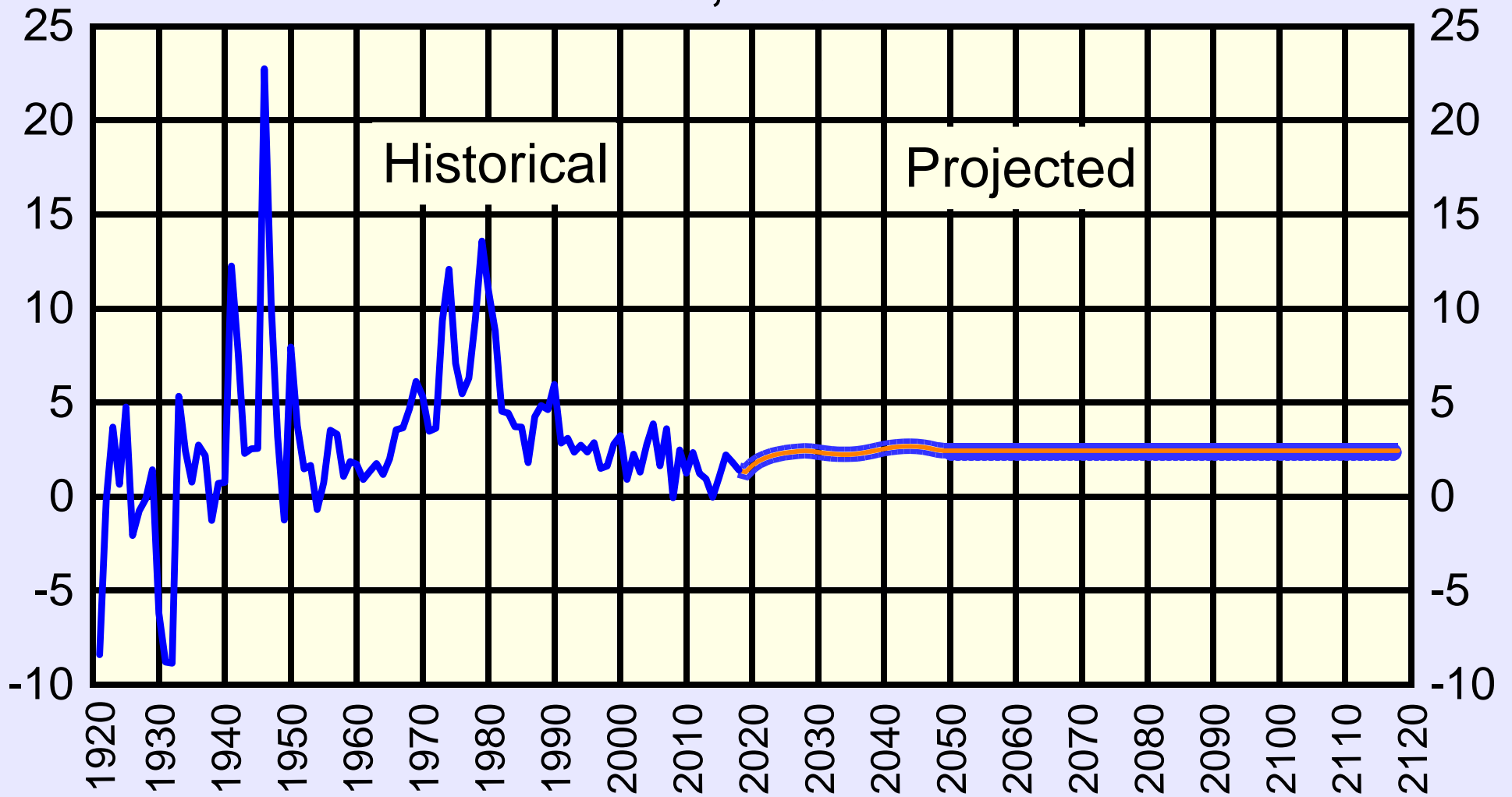


Yearly Inflation

- The projection in the previous chart provides average inflation over increasingly long time spans. The next chart on slide 49 converts this to projected inflation rates per year for the 100 years 2019 – 2118, and adds the actual yearly CPI inflation rates for the 98 years 1921 – 2018. (Actual rates are calculated from January of each year through January of the following year using log regressions on time.)

YEARLY INFLATION

Annual, Percent



Yearly Inflation, continued

- The historical line shows the movement of inflation over the last century. The line illustrates the sharp deflation in the Great Depression and the surge in inflation in World War II, followed by a period of stability. Inflation then accelerated in the 1960s with the Vietnamese War and continued to rise in the 1970s, reaching a peak of 13.59 percent in 1979. The ensuing monetary tightness brought inflation down, and for the last 30 years, inflation has been relatively stable around 2.40 percent.
- The projection line shows that inflation is expected to accelerate from its current rate of 1.41 percent, and after some variation, reach a steady rate of 2.44 percent around 2050. Therefore, the inflation rate is projected to settle down in the future to the same rate as it has been in the last several decades.

Yearly Inflation, continued

- It is clear from all these charts that the TBI curve provides much more information for inflation projections than other sources. Survey data are not nearly rich enough for these kinds of projection computations, and even though it is possible crudely to extrapolate past inflation rates forward, the results are not nearly as refined as are gotten from TBI rates. Therefore, the TBI curve provides an important data source for projecting inflation.

For More Information

- Data and documentation for the TNC and TRC yield curves are available on the Treasury Economic Policy website at:

<https://www.treasury.gov/resource-center/economic-policy/corp-bond-yield/Pages/TNC-YC.aspx>

- The HQM corporate bond yield curve for the PPA is published by the IRS each month. Data and documentation are also available on the Treasury Office of Economic Policy website at:

<https://www.treasury.gov/resource-center/economic-policy/corp-bond-yield/Pages/Corp-Yield-Bond-Curve-Papers.aspx>

- Previous applications of the methodology presented here to TIPS yield curves can be found in papers 0601 and 0501 in the Economic Policy Research Paper Series on the Office of Economic Policy website.