J.P.Morgan

North America Fixed Income Strategy
15 August 2019

Revising our fitted TIPS curve

- We revise our seasonally and option-adjusted TIPS curve, making a number of improvements versus our previous model. We can use our revised curve to identify cheap TIPS along the curve, which is timely given that the Fed will conduct its first secondary market TIPS purchase operation on September 9
- We first discuss our basic curve fitting approach to build a smooth, unadjusted TIPS curve, and then review the methodology to adjust for the seasonal component of CPI and the value of the floor option on the principal amount
- The new model shows smaller yield errors and demonstrates a better yield error distribution. Our enhanced adjusted, fitted TIPS curve will be rolled out in our Treasury analytics reports available on JPMM

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Earlier this week the Fed released its first schedule of Treasury purchase operations that will be conducted over the next month, until the next schedule is released. Of the 11 operations announced, there will be one conducted in the TIPS market, on September 9, in maturities from 0 to 7.5 years. From month to month, the Desk will alternate between transacting in shorter-dated and longer-dated maturity ranges in TIPS (see "History doesn't repeat itself, but it often rhymes," 7/30/19). After determining a range of securities eligible for purchase, it will evaluate offers based on proximity to prevailing market prices, as well as relative value measures—such as yield errors versus a real fitted curve. While we have produced an option-adjusted, seasonality-adjusted TIPS par curve on a daily basis since 2005, until now, a number of drawbacks with the model have made it challenging to use the model-implied yield errors to assess relative value. In the following sections, we discuss the methodology used to construct our revised curve, highlighting recent improvements we have made.

Before turning to methodology, we can use the results of our revised curve model to isolate cheap TIPS that could be candidates for purchase by the Fed. **Exhibit 1** shows securities that that are less than 30% owned by SOMA and that appear cheap based on yield errors relative to our revised seasonally-adjusted par curve model as well as our rich/cheap (R/C) measure, calculated as the yield error less its 3-month average.

Exhibit 1: We can use our par curve model to identify securities that appear cheap and that could be candidates for purchase by the Fed

TIPS with positive yield errors (bp) and rich/cheap measures* (bp) and that are less than 30% owned by SOMA as of 8/13/19; units as indicated

Coupon (%)	Maturity	Yield error (bp)	R/C (bp)	Asset swap spd (bp)	SOMA ownership
1.125	1/15/2021	1.0	5.2	17.5	13%
0.625	7/15/2021	1.7	0.2	18.0	2%
0.375	7/15/2023	1.8	0.1	19.1	0%
0.125	7/15/2024	1.0	1.0	22.4	0%
2.375	1/15/2025	1.9	1.1	22.1	23%
0.375	7/15/2025	2.3	0.5	25.4	0%
0.375	7/15/2027	1.2	0.4	29.0	5%
1.75	1/15/2028	0.6	0.9	27.2	11%
0.75	7/15/2028	2.3	0.4	29.9	5%
0.75	2/15/2045	0.6	0.1	70.8	0%
1	2/15/2048	0.9	0.1	71.9	9%
1	2/15/2049	0.7	0.2	70.4	5%

*Yield error = Actual yield - par fitted yield for each securities; Rich/Cheap = Yield error – 3-month moving average of yield error

Source: J.P. Morgan

Modeling a smooth, unadjusted curve

While this note focuses on revisions to our seasonally and option-adjusted curve, we first discuss the basic methodology for fitting our unadjusted TIPS yield curve, to which we have also made some small improvements. Similar to the construction of our nominal yield curve, we first consider three basic steps. First, we specify the exact basket of securities used in the estimation of our real yield curve. Second, we

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specify a parametric model for the curve. Finally, we estimate model parameters such that the resulting discount factor function results in a "best fit" relative to observed real prices of securities in the basket. While our existing fitted TIPS curve minimizes the sum of squared price errors, we revise our objective function to minimize yield errors (see "The new and improved Treasury par curve model," 7/16/18 for a discussion of why we revise our objective function). When building our nominal Treasury par curve, we filter out securities that trade with a liquidity premium, but we include the universe of existing TIPS to construct our real yield curve given the limited number of outstanding securities.

The discount factor function $d(t)$ for any time t is defined as the present value of \$1 cash flow occurring at time t. Suppose a TIPS has real cash flows C_j at corresponding times $t_j, j = 1, \ldots, n_i$. Then for the construction of our unadjusted real yield curve, we can consider the theoretical real price as $\widehat{P_i} = \sum_{j=1}^{n_i} C_j d(t_j)$, where the same discount factor function is used to relate the dirty price of any given security in the basket to its future cash flows. Similarly, we can calculate a theoretical real yield on each security, using the bond's modified duration.

We use a cubic spline to model the discounting factor function $d(t)$, which is fully specified by 10 model parameters $x_0, \ldots, x_9$ and 6 knots $t_4, \ldots, t_9$ with below functional form:

$$d(t) = x_0 + \sum_{i=1}^{3} \frac{x_i}{10^i} t^i + \sum_{i=4}^{9} \frac{x_i}{10^3} (t - t_i)^3 1_{t>t_i}$$

where

$$1_{t>t_i} = \begin{cases} 0, & t < t_i \\ 1, & t \geq t_i \end{cases}$$

and knots $t_i, i = 4, \ldots, 9$ are determined such that there is roughly the same number of cash flows between neighboring knots.

Next, we can estimate parameters that minimize the sum of squared yield errors, based on the difference between model-implied real yields and observed real yields of our basket of TIPS, to produce a simplified, unadjusted fitted TIPS curve. The New York Fed also produces its own model using a similar methodology.[1] While this model produces a smooth curve, is fairly simple to execute, and achieves a number of objectives, it does not account for CPI seasonality and the value of the embedded floor option on the principal amount, and thus it is a less useful representation of the richness or cheapness of specific securities.

Exhibit 2 shows the yield errors for securities for 2021-2029 maturities based on our unadjusted fitted real yield curve and illustrates that July issues tend to trade rich to the curve, while Jan and April-maturity issues tend to trade cheap to the curve. This pricing pattern of course reflects the predictable variations in the seasonally unadjusted CPI. Inflation tends to be firmer in the first few months of the year, more moderate in the middle of the year, and weak in the last quarter of the year. **Exhibit 3** shows the multiplicative seasonal adjustment factors for the last four years, published by the BLS (found here). Because of the lag in the indexation process, this means that July TIPS mature after several months of positive seasonals, while January and April TIPS mature when CPI seasonals are negative.

[1] See Refet S. Gürkaynak, Brian Sack, and Jonathan H. Wright, "The TIPS Yield Curve and Inflation Compensation," May 2008.

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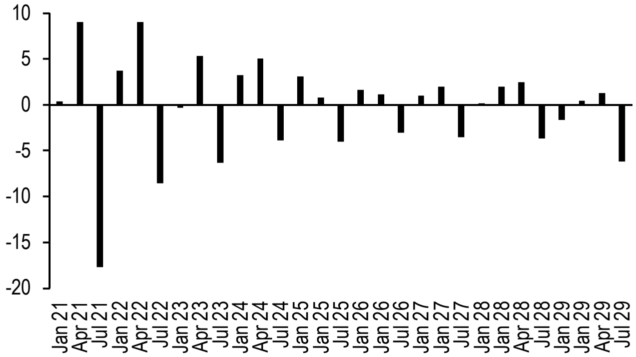
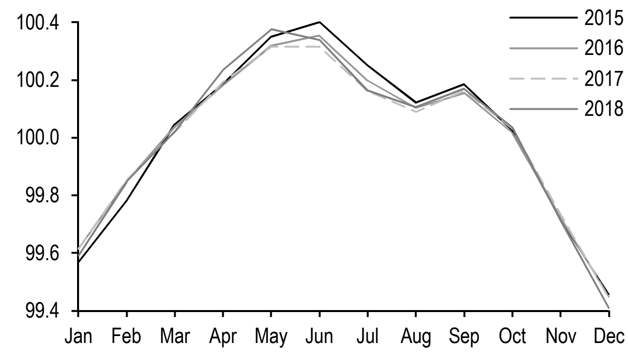
Exhibit 2: A smooth real yield curve that does not adjust for seasonality is not very informative for assessing relative value
Yield errors versus parametric real yield model that does not adjust for seasonality, shown for 2021-2029 maturities, as of 8/13/19; bp



Source: J.P. Morgan

Exhibit 3: Headline CPI exhibits predictable seasonality, with inflation firmer early in the year and weakest late in the year
Seasonal adjustment factor by month, for the last four years; unitless



Source: BLS

Modeling a seasonally and option-adjusted fitted curve

In order to assess whether a security appears cheap versus surrounding TIPS, we aim to adjust for the seasonality component as well as the value of the floor option. The option adjustment is straightforward: we model the value of the option via standard swaption pricing models with OIS discounting and subtract it from the observed real market price for each TIPS in our basket. The seasonal adjustment is more complex.

Since future inflation incorporates an expected seasonal bias, the seasonal timing of buying a security relative to the timing of future cashflows matters. Buying the same inflation-protected security when the inflation-adjusted principal reflects CPI at a seasonal high will not price with the same real yield as buying it at a seasonal low.[2] Thus the predictable seasonal component of CPI should be reflected in the theoretical real price.

Using the monthly multiplicative seasonal factors $s_i, i = 1, \ldots, 12$, we can calculate daily seasonal adjustment factors $A(t)$ for time t in month M, based on linear interpolation between monthly factors s_{M-2} and s_{M-3}. On settlement date d_s, the seasonality adjustment factor for each cashflow at time t_j is then computed as

$$\alpha(t) = \frac{A(t)}{A(d_s)}$$

Based on this, we arrive at our seasonally-adjusted theoretical real price, $\widehat{P_i^a} = \sum_{j=1}^{n_i} C_j d(t_j)\, \alpha(t_j)$, where $d(t)$ shares the same cubic spline functional form as in the unadjusted model described above. From this, we can once again derive model parameters for our adjusted real zero curve, such that we achieve a "best fit" between the theoretical seasonally adjusted real yields for the basket of securities and their option-adjusted, observed real yields.

[2] For more on the theoretical basis for why CPI's seasonal bias causes distortions in the TIPS real yield curve, see, e.g., George M. von Furstenberg and Michael Gapen, "Conditional Indexation Bias in Yields Reported on Inflation-Indexed Securities with Special Reference to UDIBONOS and TIPS," September 1998.

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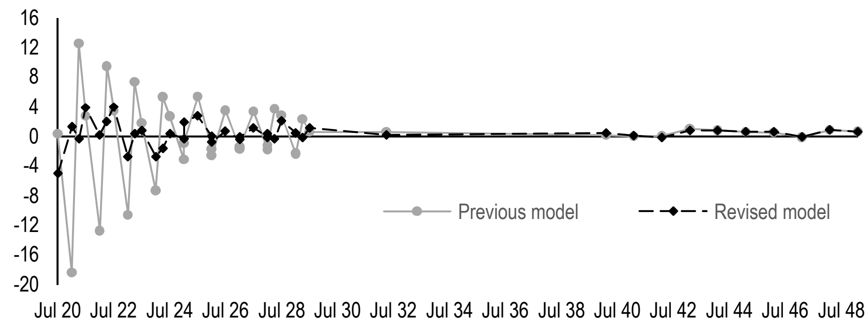
Results

The modifications made to our adjusted TIPS par curve improve the fit in a number of ways. First, yield errors are no longer correlated with the maturity month. Second, **Exhibit 4** shows that when compared with the legacy model, yield errors are lower on average, especially at the front end. We will be rolling out these changes for the "TIPS Fitted Curve Relative Value Report" which can be found in our *US Cash Interest Rate Products Analytics Package* on JPMM. Historical curve data as well as yield errors for individual Treasury securities will be made available in our DataQuery analytical tool.

Exhibit 4: Yield errors at the front end are smaller in the new par curve model than under the legacy model

Yield errors for previous versus revised seasonally and option-adjusted model, as of 8/13/19; bp



Source: J.P. Morgan

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