US Economics Research

# Forecasting inflation: Top down, bottom up

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- We construct our inflation forecast from the top down and the bottom up. We believe that a combination of views on provides a broad understanding of underlying inflation dynamics as well as highlighting likely risks to the inflation outlook.
- Our view on inflation over the medium term is derived from an inflation-expectations–augmented Phillips curve. This top-down approach ties inflation to our broader outlook on the economy. We find that although the relationship between inflation and activity is weaker that it was prior to the financial crisis, the relationship continues to hold; the Phillips curve is flatter but has not flat-lined.
- We supplement that macro view with periodic examinations of individual price series (eg, shelter, nondurables, or motor vehicles). At this level of detail, inflation dynamics are often driven by idiosyncratic shocks or special factors. Understanding how these shocks are likely to resolve yields more consistent micro level forecasts and can substantially improve the accuracy of the overall inflation forecast.
- Using the bottom up methodology, we take a view on each individual series and then aggregate the series to form our forecast of headline inflation. By doing so we incorporate our various approaches into a clear, consistent view on inflation. Any changes in view, whether stemming from, say, idiosyncratic changes in health care laws or a shift in our view on the state of the economy, are automatically incorporated into our inflation forecast.
- Among other conclusions, we find that the forecast accuracy of alternative models varies; relationships that appear to predict inflation satisfactorily in one period often deteriorate the next. We find that using a suite of models and multiple approaches to constructing our inflation forecast substantially improves forecast performance.

## Forecasting inflation: Top down, bottom up

*Using a full suite of models and multiple angles of approach substantially improves forecast performance*

We believe that a combination of views on inflation - top down, bottom up, and the very near term - provides a broad understanding of underlying inflation dynamics and hence the likely near- and medium-term evolution of inflation, as well as highlighting likely risks to the inflation outlook. Our top-down approach takes a Phillips curve view of the world, in which the overall state of the economy drives the evolution of inflation over the long term. We find that although the relationship between inflation and activity is weaker that it was, the relationship continues to hold; the Phillips curve is flatter but has not flat-lined. We supplement that macro view with periodic examinations of individual price series (eg, shelter, nondurables, or motor vehicles). At this level of detail, inflation dynamics are often driven by idiosyncratic shocks or special factors. Understanding how these shocks are likely to resolve yields more consistent micro level forecasts and can substantially improve the performance of the overall inflation forecast. Among other conclusions, we find that the forecast accuracy of alternative models varies over time; relationships that appear to predict inflation satisfactorily in one period often deteriorate the next. We find that using a suite of models and multiple approaches substantially improves forecast performance.

## Inflation over the medium term: The Phillips curve

*Our view on inflation over the long-term is derived from an inflation expectations augmented Phillips curve*

Our view on inflation over the medium term is derived from an inflation-expectations–augmented Phillips curve. We find the Phillips curve is much flatter than it used to be but still provides a useful guideline for medium-term inflation pressures. We begin with a model of inflation based on the one used by Federal Reserve Chair Yellen (see *Inflation dynamics and monetary policy*, 24 September, 2015)[1]. Our framework, in this approach assumes that inflation is influenced by inflation expectations, past inflation, resource utilization (as proxied by the unemployment rate relative to its long-term value or by a measure of the output gap), and the relative price of imports. Our goal is to use this approach to understand the pressures that are likely to push inflation over longer periods of time. Hence, we jointly estimate the Phillips curve equation with equations that estimate the dynamic evolution of unemployment, import prices, and wages, all of which are likely to interact over time. This structure allows us a more fully specified dynamic forecast of inflation in the economy[2].

*Here we model PCE rather than CPI, which keeps us close to the Fed's views of inflation…*

In the model, we follow the Fed's lead and apply our efforts to PCE rather than CPI inflation. This approach keeps us close to the Fed's views of inflation and helps us understand how it is likely to view inflation pressures in the economy and hence how likely these are to accelerate the pace of interest rate hikes (a low probability event but one that would influence our view on medium-term inflation). The main disadvantage of this approach is that it does not speak directly to CPI inflation (see *Global Inflation-Linked Products* chapter "The drivers of the CPI/PCE inflation gap in this volume for an exposition on the gap between core CPI and core PCE inflation"). In the past we have written about our approach to CPI-based Phillips curve models in *US Core inflation: Lower now, higher later* (25 March 2015). The differences between the two measures do not greatly change our view about longer-term inflation trends; more generally, we believe this combined approach prevents us from fixating on any one definition of inflation as we try to determine the true underlying inflation trends.

*… and helps us understand how likely it is to change the monetary policy stance*

[1] For a full explanation of our approach and for implementation details please see *Target 4.0% unemployment to achieve 2.0% inflation* (November 30, 2015) and *Some unpleasant dual mandate arithmetic* (October 8, 2015).
[2] In our inflation model, we follow the Fed's lead and apply our efforts to PCE rather than CPI inflation. However, because we do not use the model output directly but rather use it to guide our view on inflation pressures, we do not see any harm in the approach and more generally we believe it keeps us from fixating on any one definition of inflation as we try to determine underlying trends.

## Our price model

From this framework, we construct a price model with four fundamental equations:

- The first equation is based on Chair Yellen's Phillips curve inflation equation. Following her specification, we write core PCE inflation as a function of its first two lags – the difference between the unemployment rate and the natural rate of unemployment – and a term that captures the relative price of imports. [3] The coefficients from this exercise are shown in Figure 1 along with Chair Yellen's results. In our model, we use the specification with coefficient restrictions as that outcome most closely aligns with her findings. We experimented with a wage term in this first equation, but econometrically, wages seem to have little to no predictive power for inflation. However, we do find that past inflation influences the evolution of wages.
- Our second equation is the evolution of wages. We model average hourly earnings as a function of lagged productivity growth, lagged PCE inflation, the difference between the unemployment rate and an estimate of the natural rate of unemployment, and lagged growth in hourly earnings.
- The third is an import price equation. We model import prices as a function of lagged import prices, the broad trade-weighted nominal dollar, and lagged PCE inflation. We find no extra explanatory power using the trade-weighted basket of exchange rates for emerging markets and advanced economies separately.
- Our fourth equation models the evolution of the unemployment rate, which in turn allows us to forecast the evolution of economic slack in the economy. We find that the change in this is reasonably well explained by lags in the change in the unemployment rate and lags in its level.

FIGURE 1

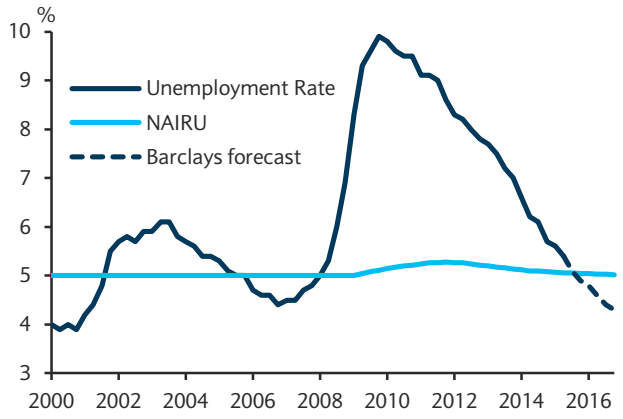
**Although the Phillips curve is relatively flat …**

| 1990Q1 to 2014Q4 | | | |
|---|---|---|---|
| | Chair Yellen's Results | Public Data | Coefficient Restriction |
| Inflation Expectations | 0.41 | 0.58 | 0.43 |
| Lag(-1) | 0.36 | 0.25 | 0.37 |
| Lag(-2) | 0.23 | NS | 0.20 |
| UR - NAIRU | -0.08 | -0.07 | -0.07 |
| Rel. Import Price | 0.57 | 0.53 | 0.55 |
| LR Inflation 1 | 2.00 | 1.55 | 2.00 |
| LR Inflation 2 | 1.63 | 1.36 | 1.66 |

Note: LR inflation 1 is equilibrium value of inflation assuming that inflation expectations are stable at 2%, the UR gap is zero, and the relative price import price is zero. LR inflation 2 uses sample average of UR gap and relative price difference. NS indicates not statistically significant at 90%.
Source: Federal Reserve, Barclays Research

FIGURE 2

**… a falling unemployment rate boosts inflation**




Note: CBO long-run NAIRU estimate. Source: BLS, CBO, Haver Analytics, Barclays Research

[3] The core inflation forecasting equation is:

$$\pi_t^c = \pi_t^e + \pi_{t-1}^c + \pi_{t-2}^c + SLACK_t \ + RPIM_t \ + \epsilon_t,$$

where core inflation ($\pi_t^c$) is modeled on long-term inflation expectations ($\pi_t^e$), lags of core inflation, economic slack ($SLACK$) in terms of the U3 unemployment rate against the CBO's measure of long-run unemployment, and the relative price of core imported goods ($RPIM$) as described in the paper.

We do not use dynamic equations for several elements of the model.

- The natural rate of unemployment and its evolution are exogenous. The model is only slightly influenced by different estimates of the natural rate 4. We use our in-house estimate but find similar results using the CBO's estimate of the long-term natural rate. We assume a slight downward drift of the natural rate between 2016 and 2020.
- We do not estimate the exchange rate. We assume the broad nominal dollar appreciates 5% in 2016 and is unchanged in 2017 and beyond. Inflation expectations are held constant over the forecast period. Following the standard established by Chair Yellen, we use the survey of professional forecasters' long-term expectations in sample. The share of goods imports in GDP is assumed constant in the forecast period.
- Finally, we treat productivity growth as an exogenous variable. As we would expect, wages are sensitive to the assumption of productivity growth. For our baseline case, we assume productivity growth remains steady at about 1.0% annual pace from Q4 15. This rate is slightly above the 0.5% average of the US economy over the past four years but is well below its long-term average of about 1.8% or the 2% pre-recession average.

## Using the model

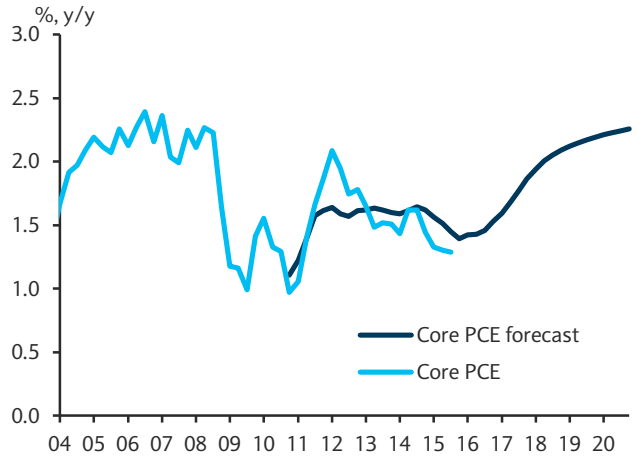
*The model always yields a concrete view on the likely rate of core inflation…*

We do not take the results of the price model directly into our inflation forecast. Rather, the results of the model inform our view on the underlying inflation pressures which may (or may not) be building in the economy. For example, at the end of 2015, the model indicated that core PCE would remain largely flat in 2016 before rising quickly in 2017 as import price inflation remain muted (Figures 3 and 4). Given that view, we forecast a slower rise in inflation than we would have otherwise, leaving the bulk of the rise in late 2016 and 2017. We think that adopting the tilt implied by the model has improved the accuracy of our forecast this year.

*… the pace at which wages will rise, and a long-term view on import price inflation.*

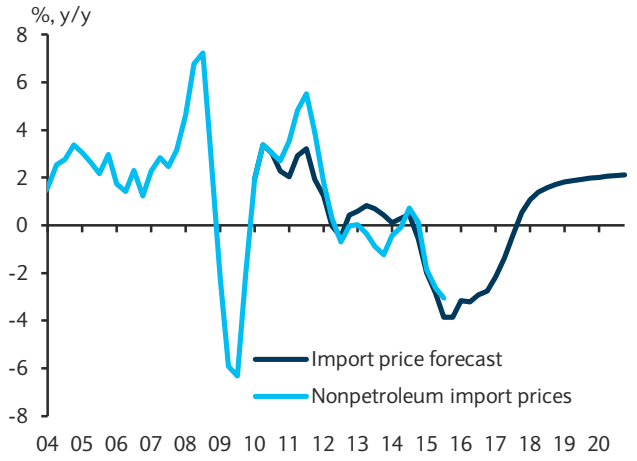
The model always yields a concrete view on the rate at which core inflation is likely to firm, the likely pace at which wages will rise, and a long-term view on import price inflation. We use this output to judge the extent to which core inflation, as an aggregate, is likely to rise. We apply the resulting tilt across individual CPI series, from which we build our forecast.

FIGURE 3
**The model predicted the flatness in inflation this year**




Source: BEA, Haver Analytics, Barclays Research

FIGURE 4
**And predicted the relative softness in import prices this year**




Source: BLS, Haver Analytics, Barclays Research

[4] Most estimates of NAIRU have low quarter-to-quarter volatility and tend to differ only in average level. The model incorporates the differences in levels in the constants within the model, attenuating the differences in estimates.

## Micro foundations: One series at a time

*The evolution of individual series is often determined by idiosyncratic economic or structural factors...*

The Phillips curve formulation cannot be used to forecast inflation in isolation. Each item in the CPI is likely to be influenced by factors beyond the amount of slack in the economy and therefore individual series' forecasts are often quite different to what would be implied from aggregate inflation pressures. The evolution of individual series is often determined by idiosyncratic economic or structural factors in specific markets that influence inflation. In these circumstances, understanding the movements in those particular series has the potential to substantially improve the performance of the overall inflation forecast.

*… and understanding the movements in those particular series can improve forecast performance significantly*

For example, after a period of rapid exchange rate appreciation, the inflation rate on goods with high import content is likely to substantially underperform other prices for some time. Failing to anticipate that "idiosyncratic" influence on inflation could lead to a substantial overshooting of the inflation forecast, especially if the forecast assumes that prices of imported goods follow the same relationship with the amount of slack in the economy as do other goods in the economy[5].

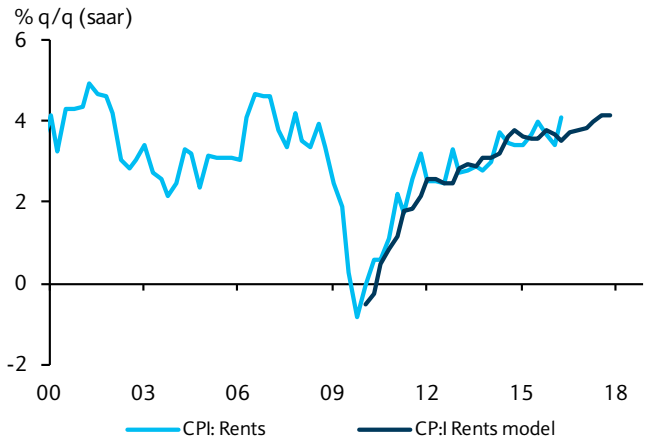
To provide context and increase understanding of our approach, we include a few specific examples of the micro data explorations we have published over the past year. However, these are just examples; we consistently examine our assumptions on individual series that we may consistently find series with anomalous behaviour or that may be subject to temporary idiosyncratic pressures. Once these are identified we use a combination of judgement and statistical models to inform our view on the near- and medium-term evolution of those series.

### Shelter

*Rent inflation is driven by economic activity, the housing market recovery and the apartment vacancy rate*

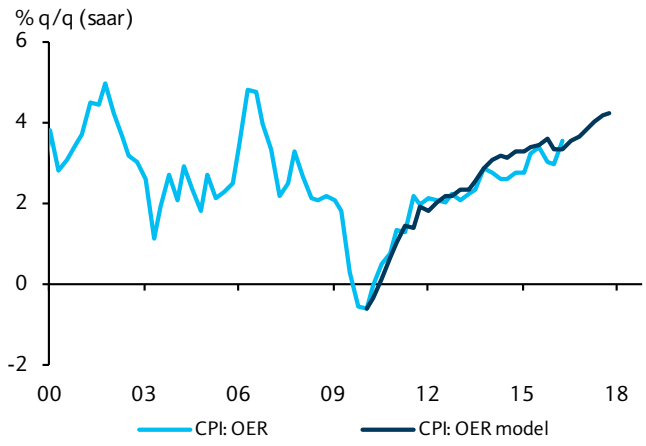
Shelter has a large weight in PCE inflation and an even larger weight in CPI. In our piece *Shelter: A domestic haven for inflation*, 20 July 2016, we conducted an examination of the drivers of shelter-specific inflation. Gains in rent are typically driven by economic recovery in general (people with jobs want places to live), the housing market recovery specifically (higher prices of owned housing stock leads to higher rents), and the chronic shortfall of housing starts relative to population growth. Nonetheless, a modest rise in the apartment vacancy rate and soft REIS data led us to conclude that rent inflation was unlikely to rise in the near term (Figure 5). Because OER inflation tends to converge toward rent inflation over time (Figure 6), we found that overall shelter inflation was likely to rise considerably over

FIGURE 5
**Our models suggest that rent inflation should stabilize …**




Source: BLS, Haver Analytics, Barclays Research

FIGURE 6
**… and OER should gradually rise to the level of rent inflation**




Source: BLS, Haver Analytics, Barclays Research

[5] Our price model, described above, incorporates import prices; however, it applies the generic influence of import prices to all items in core inflation.

our forecast period. Shelter is an example where a custom statistical model combined with our understanding of underlying market structures leads to improved forecast performance.

## Nondurable inflation

*We constructed diffusion indexes to identify the inflation components that drove the weakness earlier this year...*

Sometimes, rather than diving into individual series, we find working with different indexes of inflation can identify specific trends in underlying inflation dynamics. We wanted to understand why inflation was underperforming our forecast (see *US Inflation: Nondurable softness*, 14 September 2016). We constructed diffusion indexes of inflation to identify the broad categories of inflation (durable goods, nondurable goods or services) that were driving the weakness in prices. We found that the nondurable components of inflation were contributing substantially to the slowdown. With that background, we examined nondurable goods item by item and identified the commodity content of each good. Specifically, items high in commodity content – food not consumed in restaurants, clothing materials and footwear and recreation goods – had all been trending lower since the start of 2016. In this instance, statistical modelling failed to identify a specific relationship between inflation trends, at this disaggregated level, and commodity prices. Nonetheless, the study improved our understanding of inflation dynamics this year and reaffirmed our confidence that the weakness in prices was likely transitory.

*… and found that nondurable components of inflation contributed to the slowdown*

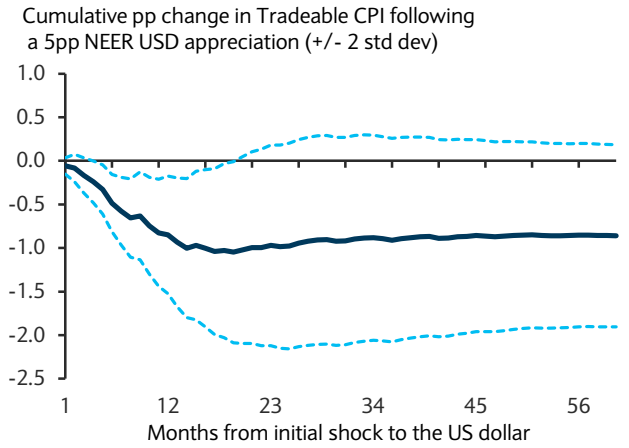
The same study led us to examine the prices of non-prescription drugs. Although the series was not especially weak relative to other price changes, the prices of these drugs was likely suppressed by an unusually large number of patent expirations. This discovery buttressed our view that prescription drug price inflation was likely to rise this year and next.

## Domestic and tradable inflation

*To better differentiate between the influence of domestic and tradable prices…*

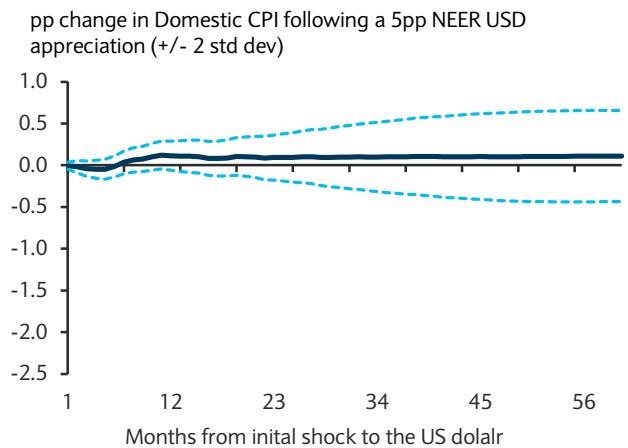
The sharp appreciation of the dollar between mid-2104 and mid-2015 combined with fundamentally weak economic conditions in most of our emerging market trading partners led to considerable import price deflation. To better differentiate between the influence of domestic and tradable prices, we constructed an inflation index weighted toward expenditure items with a high level of domestic value added – Domestic CPI (see *Creating domestic inflation*, 17 August 2015). This index allows us to better differentiate the portion of inflation driven by domestic supply and demand versus that portion driven by the evolution of supply and demand abroad. As a by-product of that work, we created a tradable CPI measure.

FIGURE 7
**Dollar appreciation leads to lower tradable CPI prices**




Source: Barclays Research

FIGURE 8
**While domestic CPI remains largely unchanged**




Source: Barclays Research

Domestic CPI helps us identify sources of inflation or deflation pressures in the US. In addition, because prices determined primarily in domestic markets tend to evolve relatively slower than tradable inflation (akin to the Atlanta Fed's sticky price measure[6]), Domestic CPI is especially useful for understanding underlying trend inflation. In addition, the index allows us to more closely follow the net influence of external shocks on overall US inflation. In other words, we can more directly measure the effect of such moves on US prices beyond their direct effect on imported goods prices.

*… we constructed an inflation index weighted toward expenditure items with a high level of domestic value added*

We find two features of these series especially useful for forecasting. First, according to our statistical models, only tradable CPI is measurably influenced by changes in the value of the US dollar (exchange rate fluctuations). A 5pp appreciation of the US dollar leads to a roughly 1pp decline in the tradable price index (Figure 7). In contrast, the same appreciation leaves the level of domestic CPI largely unchanged. This implies that assumptions on foreign exchange movements need only influence the path of our tradable index rather than aggregate inflation. Likewise, we find that US economic slack has a relatively large influence on domestic prices and has almost no effect on tradable prices. Indeed, we find that the slope of the Phillips curve when applied to domestic prices alone is considerably more stable than the traditionally measured Phillips curve, such as the one used in our price equations.

## Forecasting in the very near term

*We rely on an adaptive forecasting model to estimate inflationary pressures in the very near-term*

We acknowledge that in the very near term, the Phillips curve influence is likely to have very little effect on the evolution of prices and the particular micro idiosyncrasies only apply to a small subset of goods. Therefore, for a near-term forecast (over a period of two to three months) we rely on an adaptive forecasting model to estimate near-term inflationary pressures. There is a wide body of research arguing that univariate models, which assume a high degree of persistence in inflation, often outperform Phillips curve forecasts (at least at the four-quarter horizon). The Atkeson and Ohanian 2001 paper provides a solid foundation for this view of the world[7]. We also find support for this approach, but with the main caveat that at turning points in economic activity or when structural shocks hit particular sectors forecasting performance can be improved by using slack based models of inflation and/or a micro foundation approach to forecasting, respectively.

Nevertheless, in forecasting, we put considerable weight on these univariate adaptive forecasting approaches. Unlike regression-type models that use fixed coefficients, this method adjusts the forecast based on the distant and recent history of forecast errors. Using component exponential smoothing in this manner is effective for predicting short-term inflation, as it helps filter out noise and extract the underlying trend. We use the Holt-Winters procedure[8].

## Forecasting energy

*We believe that energy prices are determined in the global market.*

We take a different approach to forecasting energy. We believe that energy prices are determined in the global market and are thus not especially sensitive to changes in US activity. In addition, we believe that any special factors for energy are likely to be reflected in market prices. Therefore, for our near-term forecast, we use oil and gasoline futures contracts. These futures contracts are especially useful for forecasting the NSA series as they reflect market prices of deliverable energy on that date rather than seasonally adjusted data. Over the medium term, as futures contracts become less liquid, we use Barclays forecast for oil prices in the energy portion of our inflation forecast.

[6] *Atlanta Fed's sticky prices measure*
[7] Atkeson, A. and L. Ohanian (2001) *Are Phillips Curves Useful for Forecasting Inflation?* Quarterly Review, Federal Reserve Bank of Minneapolis.
[8] For a discussion on the various exponential smoothing procedures we suggest consulting Yar and Chatfield *Prediction intervals for the Holt-Winters forecasting procedure* (1990), Eviews User's Guide among other resources

## Pulling it together

We construct our actual forecast of inflation from the bottom up. We take a view, as described above, on each individual series and then aggregate the series to find our forecast of headline inflation. In this manner, incorporating our various approaches into a consistent view on inflation is straightforward. Any changes in view, whether stemming from, say, idiosyncratic changes in health care laws or a shift in our view on the state of the economy, are automatically incorporated into our inflation forecast. Our bottom-up aggregation approach allows us to seamlessly incorporate specific idiosyncrasies and the broader macro outlook into our inflation forecast. We believe that this combination is key to a well-founded view on inflation.

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