John E. Silvia, Chief Economist
john.silvia@wellsfargo.com • (704) 410-3275
Azhar Iqbal, Econometrician
azhar.iqbal@wellsfargo.com • (704) 410-3270
Blaire Zachary, Economic Analyst
blaire.a.zachary@wellsfargo.com • (704) 410-3359

Predicting the Probability of Inflation/Deflation: An Ordered Probit Approach

Talk of deflation has entered everyday discussion in capital markets. What is the inflation outlook? How likely is deflation? This report provides an ordered probit approach that estimates the six-months-ahead probability of three distinct scenarios for prices: inflationary pressure, deflationary pressure and price stability. The traditional way of forecasting inflation is to predict a single level and/or growth rate of the PCE deflator (or other measure of price); however, this approach suffers two problems. First, it is not useful for the option/risk facing decision-makers. As trading/investment strategies are far more focused on the alternatives of inflation and deflation then if the inflation rate is 2.2 or 2.4 percent. Second, point estimates of inflation convey a sense of overconfidence. Our method is different and more practical for decision-makers who must hedge their portfolios, but it is also useful for policymakers, investors and consumers who can attach a probability with each more-likely scenario of future price trends: inflationary, deflationary or price stability.

One key result from our ordered probit model is that since 2010 the probability of deflationary pressure has been persistently higher than the other two scenarios. We find that a persistently higher probability for a particular price scenario can highlight a looming threat. In fact, in the 1980s the model consistently predicted a relatively higher probability for inflationary pressure and that prediction matched a period of higher inflation. Today, we find the risk of deflationary pressure is more likely, with the model forecasting a 66 percent chance of deflationary pressure.

One application of our results can be seen in the case of the recent path of U.S. monetary policy. That is, the recent years' surge in the deflationary pressure probabilities may offer a justification for the highly accommodative monetary policy followed by the FOMC.

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Importance of Predicting Inflation/Deflation Probability

There are several inflation forecasts available in the market place from both the public and private sectors. In particular, The Federal Open Market Committee (FOMC), The Congressional Budget Office (CBO), The Office of Management and Budget (OMB) and Blue Chip, to name a few, provide inflation forecasts regularly. Furthermore, the inflation forecast from the FOMC is important because the FOMC utilizes its inflation estimate in forming monetary policy decisions but also as a reason to influence market expectations.

To be sure, an indirect effect of the FOMC inflation forecast is that it is used in the application of simple policy rules like the Taylor rule. That is, the federal funds rate is an essential determinant of borrowing costs, and an inflation forecast provides a likely path of the future Fed funds rate. Monetary policy rules, or what are now commonly referred to as Taylor rules, have become popular ways to conceptualize monetary policy decision making and evaluate the appropriate tenor of monetary policy against a consistent set of benchmarks. The Taylor rule suggests that the Fed funds rate, which is the Fed's primary policy interest rate and a good proxy of the nominal short-term interest rates, depends on inflation expectations and the output gap.[1] Bernanke (2010)

[1] **Taylor, John B. (1993). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy*, 39 (1993), pages 195-214.**

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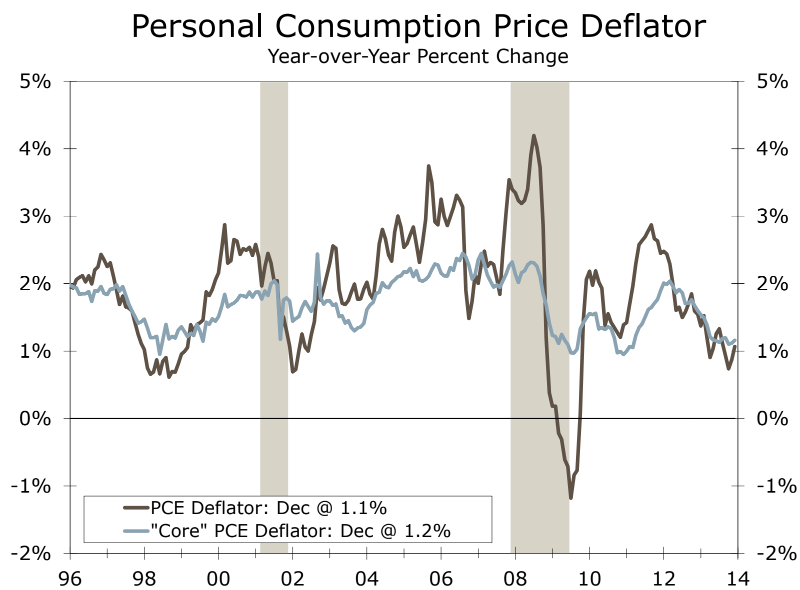
suggested utilizing an inflation forecast, as a proxy for inflation expectations, to estimate the likely future path of the Fed funds rate.[2]

The majority of inflation forecasting sources predict a future inflation rate for a certain period ahead, e.g., the FOMC provides a two-year out forecast for the inflation rate (PCE deflator as a proxy for the inflation rate, Figure 1). Our thesis is that it would be beneficial for decision makers to assign a probability to each likely inflation scenario for the near future. One major reason is that budgetary planning and policy implications would be different for a deflationary outlook, for instance, than those of positive inflation expectations. The FOMC tends to follow a contractionary monetary policy during inflationary periods and, usually, an expansionary policy is associated with deflationary expectations. Similarly, all else equal, a firm or a household would need more (nominal) monetary resources for a given quarter during an inflationary period than a deflationary time period.

Therefore, instead of generating a specific single number for future inflation (a prediction of 3.0 percent for one-year ahead PCE deflator, for example), it would be much better to generate probabilities of each prices scenario (55 percent chances for an inflationary, 30 percent probability of deflationary and 15 percent chances of price stability, for instance). This would also help decision makers to make appropriate decisions to allocate limited resources according to the probabilities of alternative inflation outcomes.

Figure 1



Source: U.S. Department of Commerce and Wells Fargo Securities, LLC

Econometrics of Ordered Probit Modeling[3]

This report utilizes an ordered probit framework to generate probabilities of three distinct scenarios for inflation, deflation and price stability.

This report utilizes an ordered probit framework to generate probabilities of three distinct scenarios for inflation (or inflationary pressure), deflation (or deflationary pressure) and price stability. In the ordered probit modeling, a dependent variable can take a finite number of values possessing a natural ordering.[4]

We employ the PCE deflator as a measure of the U.S. prices. The reason to utilize the PCE deflator as a measure of inflation (instead of CPI, PPI etc.) is that it is the preferred inflationary gauge for the FOMC. In addition, the FOMC provides a long-run target of 2 percent as a stable inflation

[2] Bernanke, Ben S. (2010). Monetary Policy and the Housing Bubble. *The Annual Meeting of the American Economic Association*, Atlanta, Georgia, January 2010. Available at: http://www.federalreserve.gov/newsevents/speech/bernanke20100103a.htm
[3] Initial draft of this paper was presented at the *76th International Atlantic Economic Conference*, October 11-13, 2013, Philadelphia, PA. The complete conference paper is available upon request.
[4] For more detail about the ordered Probit modeling, see the Appendix of this report.

goal. This inflation target, provided by an influential decision maker, helps us to categorize the PCE deflator time series into periods of inflation (or inflationary pressure), deflation (or disinflation/deflationary pressure) and stable prices and thereby the dependent variable for the ordered probit model.

In the next step, using the FOMC inflation target, we create a dependent variable for the ordered probit model. Furthermore, the FOMC stated that it may tolerate half of a percentage point above the long-run inflation target of 2 percent (for more detail, see FOMC's statement for the Jan. 29, 2014 meeting). That is, an inflation rate higher than 2.5 percent would alter the concept of stable inflationary expectations and may influence FOMC decisions. We can assume the similar downward spread, a half percentage point below 2 percent, may caution a disinflation (or deflationary expectations) signal. Therefore, a PCE deflator rate between 1.5 percent and 2.5 percent may be seen as stable pace of inflation, above 2.5 percent as inflationary and below 1.5 percent as deflationary.

An inflation rate higher than 2.5 percent could alter the concept of stable inflationary expectations and may influence FOMC decisions.

Specifically, we utilize year-over-year percent change (YoY) in the PCE deflator as a proxy for general price level. A categorical-variable (Y= -1, 0, 1) is created; Y equals minus-one (-1) if the year-over-year change in the PCE deflator is below 1.5 percent (assuming that a less than 1.5 percent growth rate will bring to light a deflation-averted strategy), Y equals zero if PCE inflation remains between 1.5 percent and 2.5 percent and Y equals one (1) if PCE inflation is greater than 2.5 percent (assuming that higher than 2.5 percent growth rate of PCE deflator will alter the inflation outlook).[5] In sum, the dependent variable (Y_t) contains all three possibilities of price trends and it also possesses a natural ordering (-1, 0, 1) and thereby can be utilized in the ordered probit modeling. The final model includes the following four predictors; the unemployment rate, the S&P 500 index, the 10-year Treasury yield and the index of leading indicators (LEI).[6]

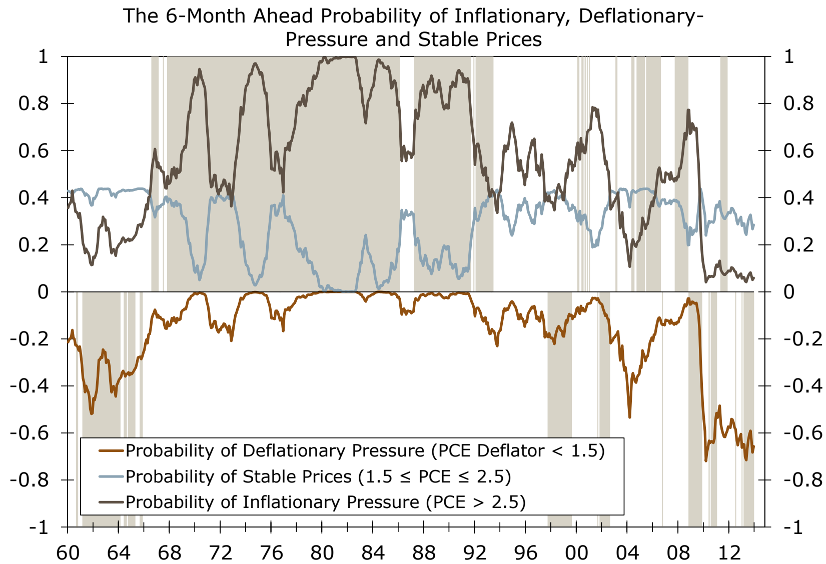
Probabilities of Inflationary-Deflationary Pressure Based on the Ordered Probit Model

The simulated real-time out-of-sample probabilities are plotted in Figure 2. The bars (shaded area) above zero represent actual periods of inflationary experience. That is, the bars (shaded area) above the zero-line indicate that the PCE deflator growth rates (YoY) were greater than 2.5 percent during those time periods. Similarly, the bars (shaded area) below the zero-line are attached to the periods of deflationary pressure, i.e., when PCE deflator growth rates (YoY) were below 1.5 percent. The blank area, between July 1993 and September 1997 for instance, shows prices were in the stable zone (PCE growth rates (YoY) between 1.5 and 2.5 percent).

In Figure 2, the brown line represents a six-month ahead probability of inflationary pressure, the blue line indicates the probability of stable inflation and the red line attaches to the probability of deflationary pressure. We converted probabilities of deflationary prices into a negative series (probabilities multiplied by minus one) and probability closer to -1 (minus one), the red line, indicates a significant risk of deflationary pressure within the next six months. Similarly, a probability closer to 1 (one), the brown line, shows a significant risk of an inflationary pressure. Finally, if the blue line, probability of stable prices, is close to one then it indicates a significant chance of stable inflation during the next six months.

[5] Typically, we face non-stationary issue when we deal with a time series dataset. However, in the present case, our dependent variable is a categorical variable (-1, 0, 1) and predictors are in growth rates (first difference) and therefore, we do not face non-stationary issues.
[6] These predictors are selected based on a data mining approach, which is described in the complete conference paper, ibid footnote 4.

Figure 2



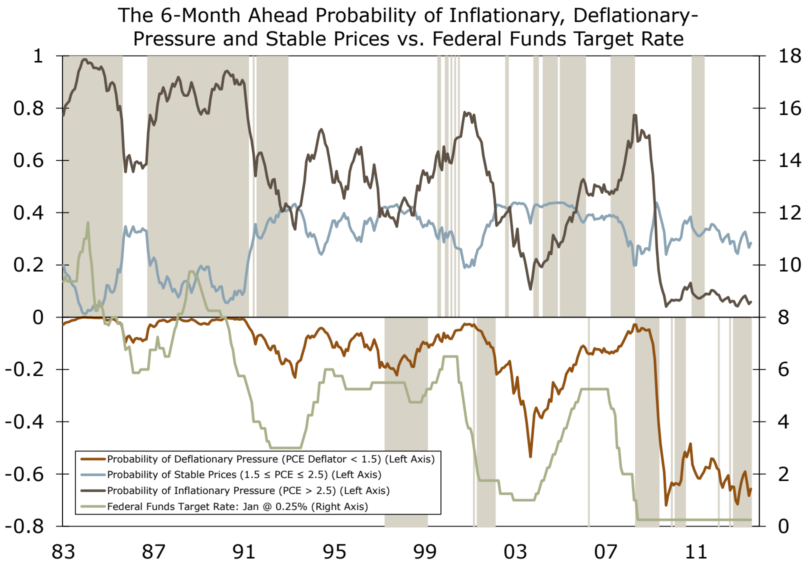
Source: Wells Fargo Securities, LLC

The brown line, the probability of an inflationary pressure, is very consistent with the actual inflationary periods. The probabilities for the inflationary pressure stay above 50 percent (or 0.5) for most of the 1983—1991 time period when actual inflation was also above 2.5 percent, except for the June 1986—June 1987 period when prices were in the stable zone. During the 1991—1997 period, the red line, the probability for deflationary period was lowest (in absolute terms), which is consistent with the actual prices pattern (prices were either in the inflationary zone or stable but not in deflationary period). Furthermore, the October 1997—August 1999 period was a deflationary era as actual inflation was below 1.5 percent, and it was the first time in our simulated out-of-sample period that this occurred (which starts from July 1983). The deflationary pressure probabilities were in the double-digits for the May 1997—May 1999 period, which suggests a chance of deflationary pressure. The 2000s decade (2000—2010) was very volatile for prices as prices moved frequently from one regime (inflationary pressure, for instance) to another (deflationary pressure, for example) and prices did not stay in a specific zone (inflationary or deflationary, for instance) for any consecutive two years. That is another example of price volatility. It is also evident from the three probability lines as none of them show persistently higher probabilities of a particular price scenario. There are a few spikes, such as relatively higher probabilities, during the early and late periods of the last decade. Similarly, relatively higher (absolute) probabilities of deflationary pressure were seen during the 2003—04 period.

There is a significant risk of deflationary pressure compared to inflationary pressure in the near future.

One noticeable observation, which may be crucial for decision makers, is that for the past several years (since January 2010), the probability of deflationary pressure is persistently high, above 50 percent (in absolute terms) except for one month which is April 2011 (the probability was 0.48). This pattern implies that there is a significant risk of deflationary pressure compared to inflationary pressure in the near future. In addition, a persistently higher probability for a particular inflation scenario is consistent with the 1980s episode when the model predicted a relatively higher probability for several years for a particular inflation scenario. During that period, the model predicted relatively higher probabilities for inflationary pressure and, in reality; the U.S. economy did experience a period of higher inflation. Based on December 2013 data, a risk of deflationary pressure is more likely (66 percent chance of deflationary scenario) than the other two scenarios.

Figure 3



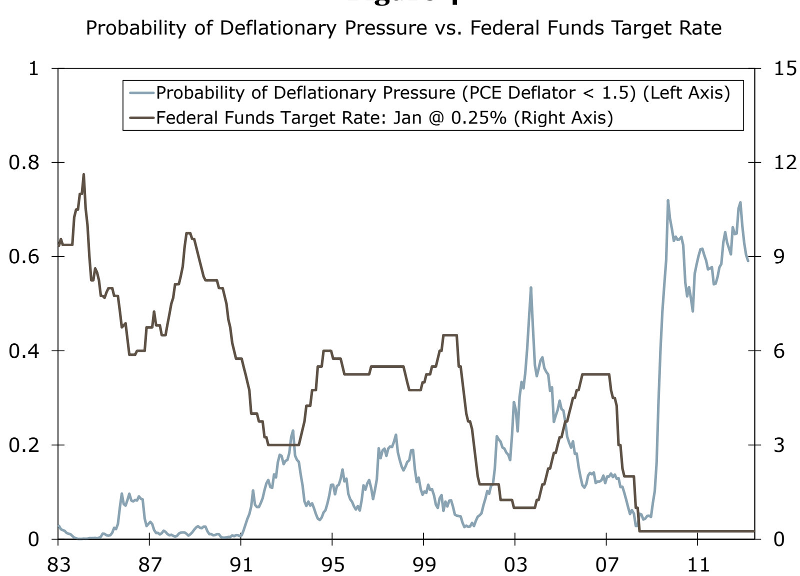
Source: IHS Global Insight and Wells Fargo Securities, LLC

Inflation/Deflation Probabilities and the Federal Funds Target Rate

One application of our results can be seen in the case of U.S. monetary policy. The Great Recession officially ended in June 2009 but the Federal Reserve continued its expansionary monetary policy by keeping the federal funds target rate in the 0.00--0.25 percent range for much longer. For example, while the Fed funds rate is still in the 0.00--0.25 percent range, several rounds of quantitative easing (QE) have been introduced. Furthermore, it was widely expected that the FOMC would announce at its September 2013 meeting a move toward "tapering" its QE program. The FOMC decision was a surprise for many, but given the ordered probit model results it makes sense. That is, our model suggests that the risk of deflationary pressure is much higher since January 2010 than the inflationary scenario and during a deflationary period the FOMC tends to follow an expansionary monetary policy.

During a deflationary period the FOMC tends to follow an expansionary monetary policy.

Figure 4



Source: IHS Global Insight and Wells Fargo Securities, LLC

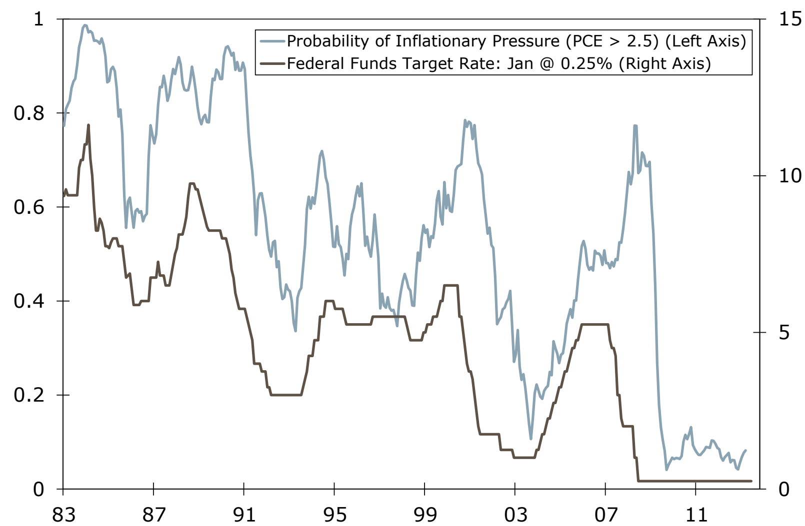
For a visual inspection, we plotted the federal funds target rate (green line) along with probabilities of deflationary pressure (red line), stable inflation (blue line) and inflationary pressure (brown line) in Figure 3. Figure 4 shows probabilities of deflationary pressure and the Fed funds target rate. The probabilities of inflationary pressure along with the Fed funds rate are displayed in Figure 5.

The Fed funds rate has a consistent pattern with the inflationary and deflationary probabilities.

Typically, the FOMC tends to raise the Fed funds rate to combat inflation and reduce the rate during deflationary periods. The visual inspection does suggest that, most of the time, the fed funds rate line has a consistent pattern with the inflationary/deflationary probabilities. For instance, during the early 2000s the fed funds rate has a decreasing trend and that is consistent with a downward inflationary probability line and upward trending (in absolute terms) deflationary probability line. The FOMC started raising the fed funds rate during the 2004--2006 period and that period also experienced a rising inflationary probability line along with a declining deflationary risk. In addition, the recent years' surge in deflationary pressure probabilities (as it is above 50 percent for the past several years) states why the FOMC keeps the door open to continue its highly accommodative monetary policy.

Figure 5

Probability of Inflationary Pressure vs. Federal Funds Target Rate



Source: IHS Global Insight and Wells Fargo Securities, LLC

Concluding Remarks

One key result from our ordered probit model is that for the last several years (since January 2010), the probability of deflationary pressure is relatively high, above 50 percent (in absolute terms) except for April 2011 (the probability was 0.48). This result suggests that there is a significant risk of deflationary pressure compared to inflationary pressure.

One application of our ordered probit model results can be seen in the case of the recent path of the U.S. monetary policy. That is, the recent years' surge in the deflationary pressure probabilities may justify why the FOMC continued the stance of the highly accommodative monetary policy. In sum, we suggest decision makers consider using an ordered probit model to generate probabilities of different inflation scenarios.

Appendix

In the ordered probit modeling, the dependent variable is a latent (unobservable) continuous variable, say Y_t^*, and the conditional mean of Y_t^* is a linear function of explanatory variables (Z_t). Furthermore, a discrete variable, say Y_t, can be generated based upon the Y_t^* values and then Y_t can be utilized as a dependent variable in the ordered probit model. One of the ordered probit modeling conditions is that the dependent variable only contains integers with natural order (for instance, 0, 1, 2,... so on). [7]

The following ordered probit model is built and estimated to generate probabilities of inflationary pressure, deflationary pressure and stable inflation. We begin by assuming an ordered probit model of the form:

$$Y^*_{T+h|T} = \beta' \; Z_t + \varepsilon_t \qquad (1)$$

where $Y^*_{T+h|T}$ is an unobserved variable that determines, at time T, if U.S. prices experience inflationary pressure, deflationary pressure or price stability within the next h periods (in this case h=6 because we are interested in 6-month ahead probability). Z_t is a vector of independent variables; β is a vector of coefficients including an intercept; and ε_t is a normally distributed error term. Y_t^* is an unobservable continuous variable and an ordered probit model requires a discrete observable dependent variable for the estimation. Therefore, using the equation (2), a discrete dependent variable, Y_t, is generated.

$$\begin{aligned} Y_t &= -1 && \text{if } Y_t^* < r_1 \\ Y_t &= 0 && \text{if } r_1 \le Y_t^* \le r_2 \qquad (2) \\ Y_t &= 1 && \text{if } Y_t^* > r_2 \end{aligned}$$

$$Y_{T+h/T} = \beta' \; Z_t + \varepsilon_t \qquad (3)$$

In order to generate Y_t, two threshold parameters, r_1 and r_2, are created and $r_1 < r_2$. Furthermore, if $Y_t^* < r_1$ then Y_t= -1 and it considers prices are in a deflationary zone. Y_t is equal to zero if $r_1 \le Y_t^* \le r_2$ and that is attached with a stable prices scenario. If $Y_t^* > r_2$ then Y_t=1 and it shows inflationary pressure. Given historical data on the U.S. inflation (changes in the PCE deflator as a measure of inflation, for instance), three scenarios (inflationary, deflationary pressure and price stability) are captured in Y_t and with a set of predictor variables represented by Z_t, a six-months-out probability of these three scenarios can be generated by estimating equation (3).

[7] **For more detail see Maddala, G.S. (1983). *Limited-Dependent and Qualitative Variables in Econometrics*. Cambridge University Press, Cambridge, UK**

Wells Fargo Securities, LLC Economics Group

Diane Schumaker-Krieg	Global Head of Research, Economics & Strategy	(704) 410-1801 (212) 214-5070	diane.schumaker@wellsfargo.com
John E. Silvia, Ph.D.	Chief Economist	(704) 410-3275	john.silvia@wellsfargo.com
Mark Vitner	Senior Economist	(704) 410-3277	mark.vitner@wellsfargo.com
Jay H. Bryson, Ph.D.	Global Economist	(704) 410-3274	jay.bryson@wellsfargo.com
Sam Bullard	Senior Economist	(704) 410-3280	sam.bullard@wellsfargo.com
Nick Bennenbroek	Currency Strategist	(212) 214-5636	nicholas.bennenbroek@wellsfargo.com
Eugenio J. Alemán, Ph.D.	Senior Economist	(704) 410-3273	eugenio.j.aleman@wellsfargo.com
Anika R. Khan	Senior Economist	(704) 410-3271	anika.khan@wellsfargo.com
Azhar Iqbal	Econometrician	(704) 410-3270	azhar.iqbal@wellsfargo.com
Tim Quinlan	Economist	(704) 410-3283	tim.quinlan@wellsfargo.com
Eric Viloria, CFA	Currency Strategist	(212) 214-5637	eric.viloria@wellsfargo.com
Michael A. Brown	Economist	(704) 410-3278	michael.a.brown@wellsfargo.com
Sarah Watt House	Economist	(704) 410-3282	sarah.house@wellsfargo.com
Michael T. Wolf	Economist	(704) 410-3286	michael.t.wolf@wellsfargo.com
Zachary Griffiths	Economic Analyst	(704) 410-3284	zachary.griffiths@wellsfargo.com
Mackenzie Miller	Economic Analyst	(704) 410-3358	mackenzie.miller@wellsfargo.com
Blaire Zachary	Economic Analyst	(704) 410-3359	blaire.a.zachary@wellsfargo.com
Peg Gavin	Executive Assistant	(704) 410-3279	peg.gavin@wellsfargo.com
Cyndi Burris	Senior Admin. Assistant	(704) 410-3272	cyndi.burris@wellsfargo.com

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