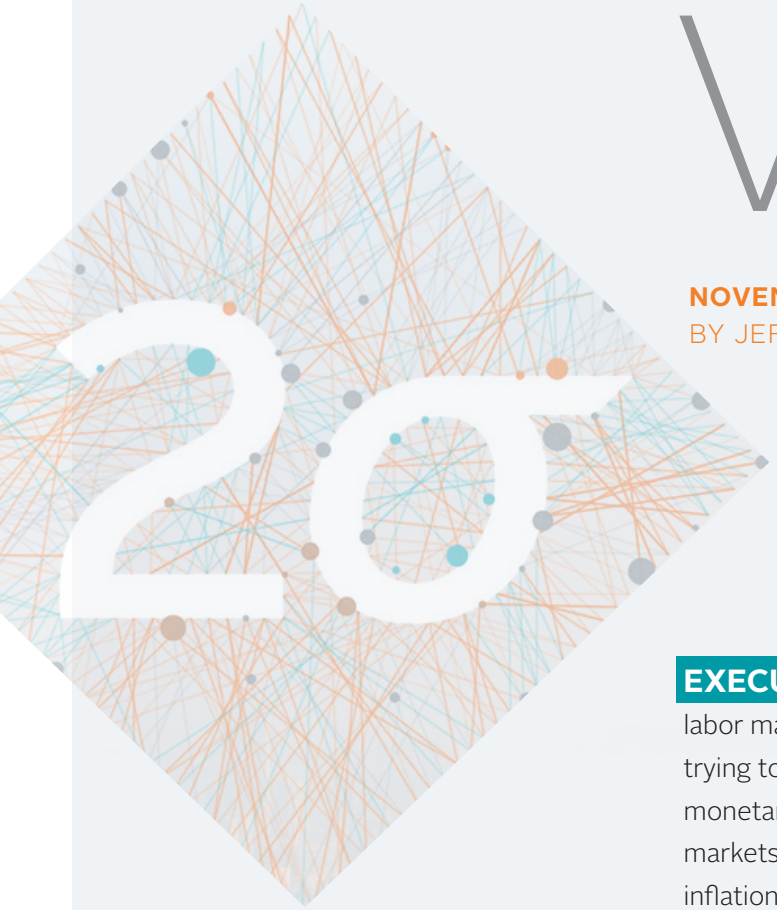
TWO SIGMA

Street View



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EXECUTIVE SUMMARY The link between inflation and the labor market has cracked. This makes life challenging for anyone trying to formulate a 360 degree view of the relationship between monetary policy and economic outcomes (not to mention financial markets). The Phillips Curve, which plots unemployment levels and inflation, offers one well-known albeit controversial lens through which one can analyze this relationship. An alternative lens, and the focus of this Two Sigma Street View, considers the empirical relationship between wages and inflation. Between 1970 and 2008, there existed a statistically significant, causal relationship between US wages and consumer prices. Since 2008, that has not proven true. As a result, market participants should expect more uncertainty in terms of both monetary policy decisions and the effects of those decisions.

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CRACK IN THE US INFLATION AND LABOR MARKET

AFTER A. W. PHILLIPS discovered the eponymous "Phillips Curve" in 1958 when comparing UK inflation rates to unemployment levels (Phillips, 1958), the relationship between inflation and the labor market became a central tenet of macroeconomic orthodoxy and monetary policy.[1] The US Federal Reserve's dual-mandate reflects that tenet. In order for the Federal Reserve to simultaneously target price stability and maximum employment, monetary policy needs to influence both. As a result, market participants tracking changes in future economic states, as well as future monetary policy, have looked to the labor market as a signpost carved in stone.

However, the relationship between inflation and the labor market has cracked. Depending on the economist, and perhaps on the day, the fissure emerged during the Great Recession that started in 2008, it emerged during the Great Inflation that afflicted the 1970s, or perhaps it never really existed.[2] Whether that crack fatally condemns the intellectual underpinning of the Phillips Curve remains a topic hotly debated in the academic literature. Google Scholar, for example, recognizes nearly 1,800 articles on the topic since the beginning of 2015.[3]

In lieu of offering another perspective through the widely viewed Phillips Curve lens to look at unemployment and inflation, this Two Sigma Street View takes a slightly different approach. The empirical analysis below estimates a vector autoregression model (VAR) to identify the relationship between wage growth and inflation. Between 1970 and 2008, there existed a statistically significant, causal relationship between US wages and consumer prices. Since 2008, that relationship seems to have dissolved. As a result, market participants should expect more uncertainty in terms of both monetary policy decisions and the effects of those decisions. The once perceived "rock solid" signpost seems to have lost much of its signalling value.

1 Samuelson and Solow (1960) named the curve for Phillips after a similar analysis for the US yielded results consistent with the U.K.

2 See, for example, Lucas (1972), Williams (2010), and Gordon (2011).

3 Google Scholar search for "Phillips Curve" since 2015 identifies 1,790 references globally.

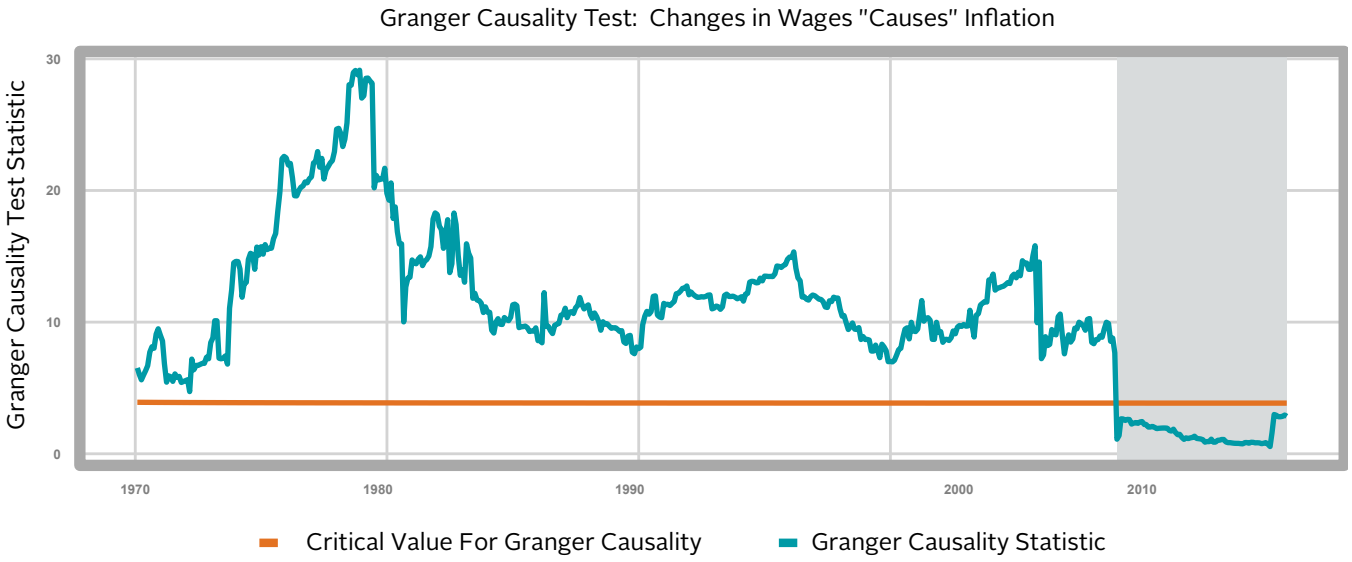
EMPIRICALLY, CHANGES IN WAGES CEASED TO PREDICT CHANGES IN US PRICES BEGINNING IN 2008

The US Bureau of Labor Statistics (BLS) publishes data on both wages and prices. The wage data comes from the Current Employment Statistics survey, a monthly measurement since 1964 of the hourly wages for production and non-supervisory employees. The price data comes from the monthly Consumer Price Index for all Urban Consumers, commonly referred to as CPI-U. First differencing each observation renders the two time series stationary.

Standard time series econometrics techniques can test the relationship between wages and inflation.[4] A vector autoregression (VAR) serves as the functional form. The VAR uses monthly expanded windows (i.e., the January 1970 model uses 5 years and 11 months of data, the February 1970 model uses 6 years and 0 months of data, the March 1970 model uses 6 years and 1 month of data, etc.). The test begins in January 1970 to ensure that the first window includes sufficient data to formulate a meaningful test. A Granger causality

4 A vector autoregression (VAR) is like an ordinary least squares regression for time series data in which the variables have some sort of feedback relationship. In this case, the VAR model is an n-equation, n-variable model in which each variable is regressed (using math almost identical to ordinary least squares) against its own lagged values, plus past values of the remaining n-1 variables (Greene 2003). In this case, the model regresses changes in wages against its own lagged values and lagged values of inflation. Similarly, the model regresses inflation against its own lagged values and lagged values of changes in wages.

FIGURE 1



Notes: Monthly data from the US Bureau of Labor Statistics.

test evaluates whether changes in wages can explain changes in inflation (and vice versa).[5] Figure 1 depicts the results of that Granger causality test.

Figure 1 plots both the Granger causality test statistic (blue line) and the critical value of that test (orange line). Both change over time, because the underlying data set grows by one month (i.e., expanding window) for each point in the chart. Where the test statistic exceeds the critical value (i.e., where the blue line is higher than the orange line), the Granger causality test implies that changes in wages can explain some of the changes in inflation with statistical confidence. Where the test statistic falls short of the critical value, the Granger causality test implies that no relationship exists between wages and inflation.

Simply stated, between 1970 and December 2008, there existed a statistically significant, causal relationship between US wages and prices. Since 2008, that has not proven true.[6]

MARKET PARTICIPANTS SHOULD EXPECT MORE UNCERTAINTY IN TERMS OF BOTH MONETARY POLICY DECISIONS AND THE EFFECTS OF THOSE DECISIONS

Whether the breakdown in the relationship between wages and inflation represents a temporary crack or a fatal breach remains anyone's guess. Perhaps, as in the case of the Phillips Curve, some might argue that the relationship existed only in theory but not in practice. Such a debate would fit better in an academic seminar than a market commentary.

There are other, more relevant, implications for market participants: where once policy makers and market observers could reliably lean on wage and other labor market data to guide or inform future US monetary policy, greater uncertainty may now exist. The Federal Reserve's Open Market Committee has repeatedly signalled that a reduction in labor market "slack" (i.e., an increase in labor demand that likely translates into

5 Granger causality does not imply that a variable Y (e.g., market returns) changes because of changes to a different variable X (e.g., sell-side sentiment). Instead, Granger causality simply means that incorporating past values of X in a regression analysis improves the prediction of the current value of Y. The variable X can Granger cause changes to variable Y and, simultaneously, variable Y can Granger cause changes to X. In short, Granger causality defines a statistical test that quantifies the usefulness of information in one of the time series variables in predicting, but not literally causing, changes in value of the other time series variable (Granger, 1969). For more information, see Greene (2003).

6 Some might attribute the sharp decline in December 2008 to an outlier in the data. However, the data from the BLS for both wages and inflation represents today's best estimate (i.e., the BLS has had years to revise the number). Describing and discounting the results as an "outlier" ignores realized history. Furthermore, separate Granger causality tests based on VAR models fit on two disjointed periods that exclude the December 2008 observation suggest statically significant causality between wages and prices during the first period (Feb 1964-Jun 2008) but not during the second period (Feb 2009-Sep 2015).

higher wages) would provide the impetus to lift its targeted Fed Funds rates during 2015. Then what? Will the Fed continue to hike interest rates to ward off future inflation if the labor market tightens, or will inflation not respond to changes in labor market slack? The significance of this question extends beyond those trying to time Fed decisions. Since the long-term path of interest rates matters more for long-term economic growth and inflation than the date of the initial liftoff (see the August *Two Sigma Street View*), the answer to this question matters to anyone trying to forecast economic states.

The most recent data from the BLS (October 2015) indicates that wage growth has reached an annualized 2.4 percent while inflation has fallen to 0.1 percent. The market digested those numbers and increased the implied probability of a Fed Funds rate hike in December from less than 30 percent in early October to nearly 70 percent in early November.[7] One wonders what those wage and inflation numbers mean to the implied (but potentially unobservable) probability of various economic growth and monetary policy scenarios beyond December.

7 Bloomberg estimated for the probability of a rate hike based on Fed Fund futures.

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INTERESTING TECHNOLOGY-RELATED ARTICLES

Two Sigma is a technology company that applies a rigorous, scientific method-based approach to investment management. We draw upon a diverse set of fields to inspire our technology, including artificial intelligence and distributed computing. Occasionally, we read articles in the popular press that describe applications of technology that we find interesting, thought-provoking, and relevant for people thinking about improving the investment management process. Below is a subset of the articles we read this month. Please do not view the inclusion of these articles as an endorsement by Two Sigma of their viewpoints or the companies discussed therein. Two Sigma welcomes discussions (and contributions) about these and other such technology-related articles.

"McDonald's New Digital Menu Boards Suggest Meals According to the Weather" by Whitney Filloon, *Eater.com,* November 11, 2015 (http://www.eater.com/2015/11/11/9716058/mcdonalds-weather-menu-boards).

McDonald's "decided to install new digital menu boards that recommend meals based on the weather." Using simple temperature data and historical demand patterns, McDonald's digital signs will condition promotional pitches to hungry eaters by the weather. McDonald's US President Mike Andres noted that "customers ended up spending more on every transaction in restaurants where the new menu boards were tested in Canada." Expect these digital signs to hit the US market in 2016.

"Skype Founders Build a Robot for Suburban Streets" by John Markoff, *The New York Times,* November 2, 2015 (http://www.nytimes.com/2015/11/03/science/skype-founders-build-a-robot-for-suburban-streets.html).

Starship Technologies plan to "use reasonably straightforward autonomous navigation technologies to solve what is described as the 'last mile' problem — getting goods like groceries, drugstore items and most small packages to suburban homes." Unlike publicized approaches by Google and Amazon that utilize airborne drones, Starship Technologies hope to employ terrestrially grounded robots. Another advantage of this technology is that it would enable customers to "try on" their purchases and return them immediately at almost no incremental cost. After all, the robot return trip is already baked into the delivery cost.

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