# TRIANGLE MODEL VS. HYBRID NEW KEYNESIAN:

# COMPARING FORECAST RESULTS OF TWO PHILLIPS CURVES

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## SIGNATURE PAGE

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| **THESIS:** | TRIANGLE MODEL VS. HYBRID NEW KEYNESIAN: COMPARING U.S. INFLATION FORECASTS OF TWO PHILLIPS CURVES |
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## ABSTRACT

This paper compares the fit and forecasting power of two kinds of expectations-augmented Phillips curves. Gordon's triangle model expresses inflation as a function of three components, one of which is lagged inflation. In addition to this lagged term, the hybrid New Keynesian Phillips curve also contains a forward-looking term to represent the expected future rate of inflation. The role and type of inflation assumed by each model mark their difference from the other. Using United States data spanning 1999-2014, estimation of the two models showed that the triangle model is relevant in forecasting historical inflation in the full period and two sub-periods before and after 2006. In contrast, the HNKPC was weak over the entire data span, and relevant only after 2006 when it captures that 2007-08 Financial Crisis and the beginning of the Federal Reserve's forward guidance policies.

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## Introduction

The Phillips curve is an empirical model demonstrating the inverse relationship between inflation and unemployment. The absence of a theoretical foundation explains the imprecision of the tradeoff after the oil price shocks in the 1970s, and subsequent adaptations of the model sought to account for influences outside the control – and even expectations – of governments and central banks: the reactionary behavior of households and firms, the impact of food and energy prices, the complexities of interconnected global economies, and policy credibility.

This paper estimated two expectations-augmented Phillips curves models, Gordon's triangle model and the Hybrid New Keynesian model, spanning the period 1999-2014. The goal is to determine which model is more appropriate for describing historical data before and after the 2007-08 Financial Crisis. Is one model is superior over the other in forecasting, given that households and firms are using all available data – including cues from the Federal Reserve?

The United States entered the new millennium flush from the prosperous 1990s, inflating housing and credit bubbles. The country went to war, but there was zero-net job creation, "a lost decade for American workers. . . By the end, there were two [recessions], bookends to a debt-driven expansion that was neither robust nor sustainable." (Irwin, 2013)

The Fed's forward guidance policies to restore stability in the markets was unprecedented. Its purchases of U.S. treasuries and mortgage bonds expanded its balance sheet from the pre-crisis level of $954 billion to $4 trillion by the end of 2013. (Kearns, 2013) Monetary policy tools like bond-buying programs, paying interest on reserves, uantitative easing and public announcements of policies can be interpreted as signals designed to affect the public's expectations of the state of the economy in the short-term future. The assumption for the period of interest, 2006-2014, is that inflation expectations of households and firms are shaped by consequences of the financial crisis, as well as explicit policy announcements from the Fed. The backward- and forward-looking terms present in the models are relevant and topical. The structure of this paper is as follows: First, an overview of the evolution of the Phillips curve and the concepts underlying the triangle model and the HNKPC. Next, model estimation and forecast results for the two models. The last section discusses the consistency of the triangle model, and the relevance of the HNKPC only in periods of explicit central bank forward guidance.

## Evolution of the Phillips curve

The Phillips curve was originated by Phillips (1958), who observed the opposite movements of changes in money wage rates and unemployment in the United Kingdom between 1861 and 1957. He found that changes in wage rates were explained by the level of unemployment and the rate of change of unemployment in response to employer demand for labor services. When unemployment is low and demand for workers is increasing, employers and industries have a tendency to competitively bid up wages to attract labor from other firms. When labor demand is low and unemployment is rising, wage rates fall because workers are unlikely to accept jobs paying below prevailing rates. This pull and slackening in employer demand affect wage adjustments. In short, changes in the price of labor services are influenced by both the demand for workers and the level of unemployment in the economy.

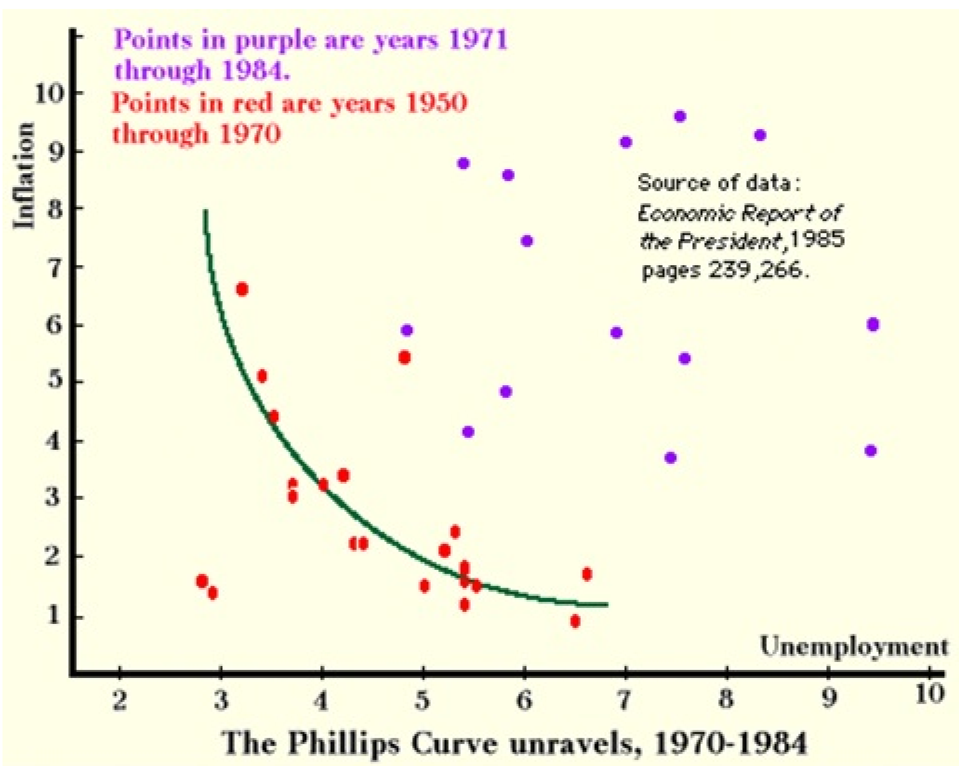



*Figure 1*. The Phillips curve before and after the 1970s

Phillips' findings were soon formalized by Samuelson and Solow (1960) using United States data. They were unable to reproduce the same outcomes as that of Phillips' U.K. data due to the idiosyncracies of the two countries' economies labor markets. The composition and the geographical "compactness" of the U.K. labor market differed from that of that of the United States. The geographical and industrial mobility of workers has a hand in determining the excess supply in labor. "It is clear the more fractionated and imperfect a labor market is, the higher the over-all excess supply of labor may have to be before the average wage rate becomes stable and the less tight the relation will be in any case." (Samuelson and Solow, 1960). Still, their conclusion didn't contradict the U.K. data. If unemployment is high when aggregate demand is low, then wages and prices experience downward pressure. Results from their analysis suggested to them policymaking possibilities. To stabilize the economy, government can trade higher unemployment for stabilizing price levels and vice-versa. Thepresumed fixedness of this tradeoff made the Phillips curve an attractive tool for policymakers.

The tradeoff between unemployment and inflation became less precise in the 1970s when OPEC increased oil prices. Figure 1 illustrates the breakdown. The period experienced both high unemployment and rising prices – stagflation. It signaled the limitations of monetary and fiscal policies, and that their intentions alone can't explain or influence price adjustments. One of the pitfalls of the original Phillips curve critiqued by Friedman (1968) was that it did not distinguish between nominal and real wages and assumed "a world in which everyone anticipated that price levels would be stable and in which that anticipation remained unshaken."

**NAIRU**

Friedman and Phelps (1967) argued that the inflation-unemployment tradeoff only exists in the short run. The long-run Phillips curve is flat and rests on the

NAIRU, the non-accelerating inflation rate of unemployment.

The NAIRU is the level of unemployment in a labor market that includes those without work seeking jobs as well as the frictionally unemployed. (Friedman, 1968). Friedman in the same paper advised against pursuing tradeoff policies when unemployment is below the NAIRU because those would actually result in inflation acceleration. The role of monetary policy is to "provide a stable background for the economy" so that consumers and producers can expect price levels to behave a certain way. Expected inflation is preferable to unexpected inflation. The economy works best when consumers and producers can confidently make decisions because they know what to anticipate. (Friedman, 1968)

## Expectations

Although Friedman and Phelps (1967) popularized the role of adaptive expectations for explaining the persistence of inflation and its quantitative place in the Phillips curve model, their discussion was already predated by Muth's paper regarding expectations as measurable "rational dynamic models." He hypothesized that information is not wasted on economic agents.

While adaptive expectations theory takes into account past recent events in shaping household and firm behavior, rational expectations theory also considers the impact of anticipated and unanticipated supply shock. Phillips himself seemed ironically dismissive of the impact of commodities shocks, believing their effects on money wage rates was solely through cost-of-living adjustments when retail prices increase. The only way they could affect wage rate changes is when "retail prices are forced up by a very rapid rise in import prices (or, on rare occasions in the United Kingdom, in the prices of home-produced agricultural products)." (Phillips, 1958)

## Triangle Model and the New Keynesian Phillips Curve

Gordon's triangle model (1988) and the family of New Keynesian Phillips curves have their foundation in rational expectations theory. The triangle model sees inflation as a function of three components: inertia, or inflation already built into the economy; demand-pull inflation, or aggregate demand as represented by the unemployment gap; and cost-push inflation, energy and food commodities price shocks that affect aggregate supply. The distinction between the triangle model and original Phillips curve is that the former measures changes in prices, not changes in wage rates (Gordon, 2009).

It's been argued that the triangle model is better at explaining historical data. Some models have included into the cost-push component the prices of medical care services and personal computers to describe the low inflation of the mid- and late 1990s. The "new" technology shock was the decline in the prices of computers and computer peripherals that had the effect of increasing profit margins was slow in catching up with accelerating productivity (Eller and Gordon, 2003). Unemployment held low and steady between 3.9% and 4.2% through December 2000, in spite of food and energy prices rising, and medical care inflation converging with aggregate inflation by 1998. Medical care inflation was expected to continue accelerating at the start of the following decade, which justifies their inclusion in this paper's estimation of the triangle model.

The Keynesian Phillips curve model (Gali and Gertler, 1999) features expectations as forward-looking, a deviation from the adaptive expectations-oriented lagged term used by the triangle model. NKPC relates inflation to the expected future rate of inflation and real marginal cost. The supply shock term is gone. That is instead absorbed into the error term that the model assumes affects firms' mark-up costs. The NKPC was concerned with the persistence of monetary shocks. The framework of the model sees the interaction between that kind of persistence combined with rational expectations.

An empirical study of the two models by Roeger and Herz (2004) found that in the triangle model monetary shocks tend to have short-run response with no resulting effect on cumulative output; on the other hand, the NKPC model showed a positive cumulative effect on output. This interpretation of the Phillips curve has been subject to much scrutiny for dismissing the explanatory power of lagged inflation. Rudd and Whelan (2005) said the "failure of the model" was its inability to assess inflationary pressures when it excludes the persistence of past inflation. NKPCs have another problem – improving the fit of a model usually means adding complexities to the model. (Antipin-Luoto, 2008)

### Hybrid New Keynesian Phillips curve

The HNKPC (Gali and Gertler, 1999) takes the middle road between the traditional triangle model and the extremity of the NKPC. The model includes two expectations terms: lagged inflation and the expected future rate of inflation, in addition to an unemployment or output gap that represent firms' marginal costs. Retaining a backward-looking term is logical, since it reconciles the economic realities of inflation stickiness. The persistence of inflation is adaptive expectations at work; people's outlooks are in part shaped by past events. But if expected future economic behavior can be imbued with a sense of certainty, the expectation becomes purely foward-looking. This has interesting implications for a central bank, implying that it can achieve low inflation without increasing unemployment by changing expectations just through announcements of future monetary policy.
(Rudd-Whelan, 2001).

Given current economic conditions, a comparison of the triangle model and the HNKPC is topical.

## Methodology

The two single-equation models used were based on Gordon's triangle model and the HNKPC model:

$$\pi_t = \pi_{t-1} + \beta(u_t - u_n) + v_t + \varepsilon_t \tag{1}$$

$$\pi_t = \pi_{t-1} + E(\pi_{t+1}) + \beta(u_t - u_n) + \varepsilon_t \tag{2}$$

The triangle model in Equation 1 shows inflation as a function of three components: inertia as the lagged inflation variable $infl_{t-1}$; demand-pull inflation represented by the unemployment gap; and the supply shock term$v_t$ for cost-push inflation. Traditional shock components are food and energy costs.

$$infl_t = infl_{t-1} + uegap + food_t + en_t + \varepsilon_t \tag{3}$$

Note that the HNKPC in Equation 2 drops the supply shock component in favor of the forward-looking term $E(\pi_{t+1})$, the expected value of future inflation.

For this paper, the triangle model is initially estimated as :

$$infl_t = infl_{t-1} + uegap + food_t + en_t + ms_t + com_t + \varepsilon_t \tag{4}$$

During the model-fitting stage for the triangle model, the variables for the inflation rates of medical care services and cost of computers in Equation 4 were added. This writer interprets them as softer supply shocks if health (medical services) and technology consumption (computers) were to be regarded as commodities.

The 2000s experienced 48% rise in inflation while the overall CPI rose 26% in the same period (Commins, 2010). The trend reversed somewhat in the 2010s due to consumers substituting retail clinics and mobile health options for traditional hospitals; generic medicines; major employers switching to larger healthcare systems to drive down their overall costs; federal penalties against hospital readmissions to eliminate inefficiences and waste; and high deductibles that encouraged consumers to make more cost-conscious choices (PricewaterhouseCoopers, 2013). Factors expected to further inflate medical care costs are the growing cost of newly developed medicines and increased prices in medical care caused by consolidations in the healthcare industry. PwC estimated that mergers among hospitals could see costs spike by 20.3%.

Later the model estimation estimation process, medical care services and computer costs were eventually dropped from the triangle model after showing their lack of statistical significance, leading the final triangle model to be estimated in the form of Equation 5:

$$infl_t = infl_{t-1} + uegap + food_t + en_t + \varepsilon_t \tag{5}$$

The HNKPC assumes central banks can influence inflation by changing expectations of households and firms by telling them what to expect through public announcements. In the case of the Fed, part of its recovery-phase forward guidance policies involve confirming its plans to keep inflation low as long as the unemployment is above the target rate of 6.5% (Federal Reserve, 2014). Equation 6 uses the federal funds rate ($ffr$) in Equation to stand in for $E(infl_{t+1})$.

$$infl_t = infl_{t-1} + ffr_t + uegap + \varepsilon_t \tag{6}$$

Each model will be run for the full period, 1998M12-2014M01 and two sub-periods, 1999M02-2006M12 and 2006M12-2014M01.

## Data

Data used for this research were obtained from the FRED database of the Federal Reserve Bank of St. Louis. Inflation, expected rate of inflation, food and energy prices, and medical care and computer prices are the Consumer Price indices: CPIAUCSL (CPI-All Items); CPI energy and food commodities (CPIENGSL and CPIUFDSL); and CPI medical care services, and personal computers and peripherals (CUSR0000SAM2 and CUUR0000SEEE01). The remaining series are in percentages: the effective Federal Funds Rate (FEDFUNDS); civilian unemployment (UNRATE); and the non-accelarating inflation rate of unemployment (NROU).

There is a problem. All but the NAIRU are monthly. In order to compute the unemployment gap (ue_gap), the NAIRU's quarterly frequency needs to converted to monthly to match the other data series. Values for months in between quarters were generated in Excel until the NAIRU series has 361 values corresponding to the data sets with monthly frequencies. Table 1 outlines this process.

Table 1
*NAIRU Frequency Conversion*

IMSUB =$B$2+(1/3)*($B$3-$E$2)

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | DATE | NAIRU | | DATE | NAIRU | |
| 2 | 1984-01-01 | 6.05 | | 1984-01-01 | 6.05 | |
| 3 | 1984-04-01 | 6.05 | | 1984-02-01 | 3-$E$2) | |
| 4 | 1984-07-01 | 6.04 | | 1984-03-01 | 6.05 | |
| 5 | 1984-10-01 | 6.03 | | 1984-04-01 | 6.05 | |
| 6 | 1985-01-01 | 6.03 | | 1984-05-01 | 6.046667 | |
| 7 | 1985-04-01 | 6.02 | | 1984-06-01 | 6.043333 | |
| 8 | 1985-07-01 | 6.02 | | 1984-07-01 | 6.04 | |
| 9 | 1985-10-01 | 6.01 | | 1984-08-01 | 6.036667 | |
| 10 | 1986-01-01 | 6.00 | | 1984-09-01 | 6.033333 | |

IMSUB =$B$2+(2/3)*($B$3-$E$2)

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | DATE | NAIRU | | DATE | NAIRU | |
| 2 | 1984-01-01 | 6.05 | | 1984-01-01 | 6.05 | |
| 3 | 1984-04-01 | 6.05 | | 1984-02-01 | 6.05 | |
| 4 | 1984-07-01 | 6.04 | | 1984-03-01 | 3-$E$2) | |
| 5 | 1984-10-01 | 6.03 | | 1984-04-01 | 6.05 | |
| 6 | 1985-01-01 | 6.03 | | 1984-05-01 | 6.046667 | |
| 7 | 1985-04-01 | 6.02 | | 1984-06-01 | 6.043333 | |
| 8 | 1985-07-01 | 6.02 | | 1984-07-01 | 6.04 | |
| 9 | 1985-10-01 | 6.01 | | 1984-08-01 | 6.036667 | |
| 10 | 1986-01-01 | 6.00 | | 1984-09-01 | 6.033333 | |

When plotted over time some of the indices display deterministic trend; others persistence, such as the energy index and the federal funds rate; and cyclicality is apparent in unemployment and the newly generated unemployment gap($uegap = unrate - nairu$). After deseasonalizing and transformation into inflation rates, all variables actually exhibit persistence. The graphs in Table 2 already hint at non-constant means and variances.

Time series data are prone to serial correlation (when a variable is correlated with lagged values of itself) and nonstationarity, when means and variances change over time. When unaddressed, both produce inconsistent Ordinary Least Square (OLS) beta coefficient estimates. First-differencing usually resolves both issues. The models in this paper were corrected using AR(autoregressive) processes in the first order, AR(1). Its inclusion accounts for the direct effect of the most recent past values of the errors on the current value being measured, which is inflation. (Enders, 2009)

Tests used in model-ftting were the Durbin-Watson for serial correlation, Breusch-Godfrey LM test for serial correlation on residuals, Augmented Dickey-Fuller tests for stationarity, and the Breusch-Pagan-Godfrey Heteroskedasticity Test for residuals. All were conducted on Eviews 7.

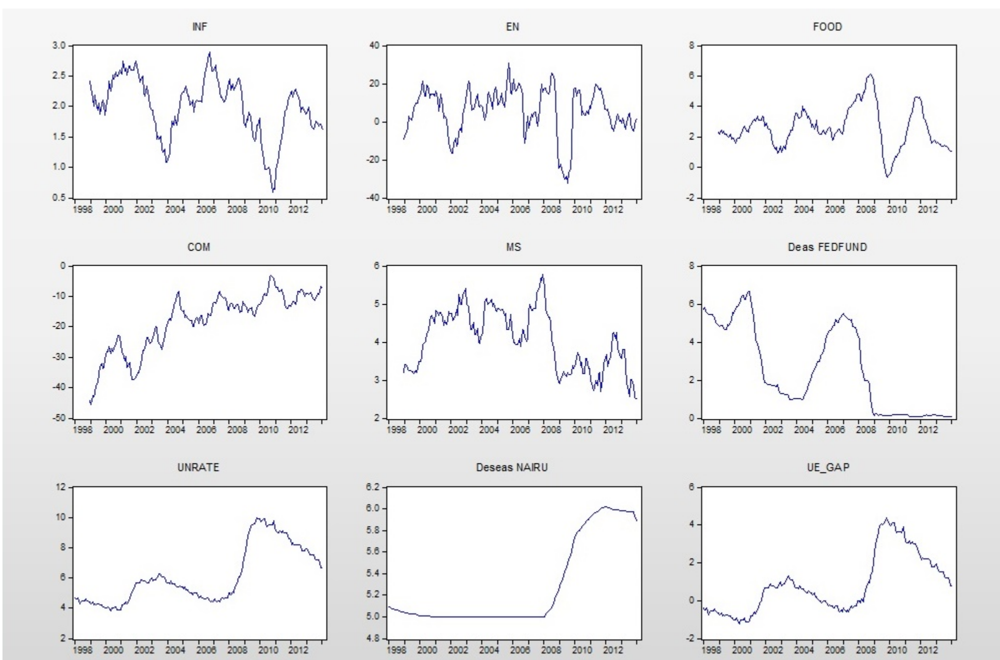



*Figure 2*. Nonstationarity of variables

Unit root tests for all converted variables signal nonstationarity. Each becomes stationary after taking the first-difference. In the case for the unemployment gap, ue_gap, the series becomes stationary only at the 10% test critical value after it's first-differenced; it becomes stationary at the 10%, 5% and 1% levels after second-differencing. Recognizing the nonstationarity of variables is particularly important in time series models. They can determine if the estimated models are stationary, cointegrated or spurious ("fake regression"). (Enders, 2009) If both dependent and independent variables are nonstationary at level but the error is stationary, it can be inferred that there is cointegration among variables. If at level all three are nonstationary, then the model is spurious and first-differencing should be the appropriate correction.

## Triangle Model

Table 2

*Equation 4, 1998-2014*

Dependent Variable: INFL
Method: Least Squares
Date: 05/10/14 Time: 10:12
Sample (adjusted): 1998M12 2014M01
Included observations: 182 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.562195 | 0.167268 | 3.361048 | 0.0010 |
| INF(-1) | 0.328039 | 0.036868 | 8.897627 | 0.0000 |
| UE_GAP | -0.041252 | 0.018115 | -2.277301 | 0.0240 |
| FOOD | 0.127456 | 0.020297 | 6.279647 | 0.0000 |
| EN | 0.060173 | 0.003148 | 19.11274 | 0.0000 |
| COM | -0.006288 | 0.002692 | -2.335436 | 0.0207 |
| MS | 0.070230 | 0.029894 | 2.349293 | 0.0199 |

| | | | |
|---|---|---|---|
| R-squared | 0.957350 | Mean dependent var | 2.371585 |
| Adjusted R-squared | 0.955888 | S.D. dependent var | 1.231871 |
| S.E. of regression | 0.258727 | Akaike info criterion | 0.171620 |
| Sum squared resid | 11.71448 | Schwarz criterion | 0.294851 |
| Log likelihood | -8.617378 | Hannan-Quinn criter. | 0.221576 |
| F-statistic | 654.7016 | Durbin-Watson stat | 0.582079 |
| Prob(F-statistic) | 0.000000 | | |

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 131.3360 | Prob. F(2,173) | 0.0000 |
| Obs*R-squared | 109.7300 | Prob. Chi-Square(2) | 0.0000 |

This paper tested two versions of the triangle model. Gordon's traditional model, Equation 3 was estimated along with the expanded form specified in Equation 4. Considering the effect new technology and high cost of health care, the new variables were expected to have some explanatory power in the estimated regression. Model adjustments proved in the end that the traditional model was more suitable.

### 1999-2014

A model containing four supply shock variables was estimated. All coefficients in the extended model are highly significant. The output of the model, shown in Table 2 , also suffers from serial correlation in its residuals, implying that this model is a spurious regression. The correlogram of the residuals hint that an AR(1) correction is needed.

An AR(1) correction takes care of serial correlation, confirmed by a

Table 3

*Equations 4 and 3with AR Correction*

Dependent Variable: INFL
Method: Least Squares
Date: 05/10/14 Time: 12:38
Sample (adjusted): 1999M02 2006M12
Included observations: 95 after adjustments
Convergence achieved after 17 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 1.513768 | 0.492306 | 3.074854 | 0.0028 |
| INFL(-1) | 0.021433 | 0.030900 | 0.693620 | 0.4898 |
| UE_GAP | 0.158855 | 0.103809 | 1.530271 | 0.1296 |
| FOOD | 0.087309 | 0.045207 | 1.931320 | 0.0567 |
| EN | 0.080363 | 0.002552 | 31.48717 | 0.0000 |
| COM | -0.000123 | 0.007158 | -0.017162 | 0.9863 |
| MS | 0.046439 | 0.067477 | 0.688224 | 0.4931 |
| AR(1) | 0.965147 | 0.028485 | 33.88319 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.981412 | Mean dependent var | 2.663839 |
| Adjusted R-squared | 0.979916 | S.D. dependent var | 0.804073 |
| S.E. of regression | 0.113951 | Akaike info criterion | -1.425650 |
| Sum squared resid | 1.129673 | Schwarz criterion | -1.210587 |
| Log likelihood | 75.71839 | Hannan-Quinn criter. | -1.338749 |
| F-statistic | 656.2030 | Durbin-Watson stat | 1.904325 |
| Prob(F-statistic) | 0.000000 | | |

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 0.576279 | Prob. F(2,85) | 0.5642 |
| Obs*R-squared | 1.270921 | Prob. Chi-Square(2) | 0.5297 |

Dependent Variable: INFL
Method: Least Squares
Date: 05/10/14 Time: 12:46
Sample (adjusted): 1999M02 2006M12
Included observations: 95 after adjustments
Convergence achieved after 14 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 1.726462 | 0.372440 | 4.635537 | 0.0000 |
| INFL(-1) | 0.022045 | 0.030173 | 0.730622 | 0.4669 |
| UE_GAP | 0.178847 | 0.098184 | 1.821545 | 0.0719 |
| FOOD | 0.087439 | 0.044795 | 1.951999 | 0.0541 |
| EN | 0.080340 | 0.002512 | 31.98614 | 0.0000 |
| AR(1) | 0.966669 | 0.027534 | 35.10871 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.981311 | Mean dependent var | 2.663839 |
| Adjusted R-squared | 0.980261 | S.D. dependent var | 0.804073 |
| S.E. of regression | 0.112969 | Akaike info criterion | -1.462332 |
| Sum squared resid | 1.135816 | Schwarz criterion | -1.301035 |
| Log likelihood | 75.46079 | Hannan-Quinn criter. | -1.397156 |
| F-statistic | 934.6243 | Durbin-Watson stat | 1.866781 |
| Prob(F-statistic) | 0.000000 | | |

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 0.907940 | Prob. F(2,87) | 0.4071 |
| Obs*R-squared | 1.942316 | Prob. Chi-Square(2) | 0.3786 |

Breusch-Godfrey LM test on the residuals and the Durbin-Watson test statistic. The higher $R^2$ values indicates the model fit is improved, and AIC and SIC statistics are smaller. Food and energy are still statistically significant after the correction. Medical care services is weakly significant and computers are insignificant – with a t-statistic of -0.017162. The coefficient sign for the unemployment gap is positive.

The last two supply shock variables are dropped, and the model reverts to Equation 3. The regression of this model finds the residuals serially correlated. After including an AR(1) correction, test statistics in Table 3 shows energy and food as highly significant. The unemployment gap is weakly significant; lagged inflation has the weakest explanatory power.

**1999-2006**

This particular period saw the United States at the end of an economic expansion, react to the September 11, 2001 attacks, and the build-up of housing and credit bubbles. Job creation was low during the 2000s when “the trillions of dollars that poured into housing investment and consumer spending in the first part of the decade distorted economic activity.” (Irwin, 2013).

Table 4
*Equation 3, 1999-2006*

Dependent Variable: INFL
Method: Least Squares
Date: 05/22/14 Time: 12:46
Sample (adjusted): 1999M02 2006M12
Included observations: 95 after adjustments
Convergence achieved after 14 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 1.726462 | 0.372440 | 4.635537 | 0.0000 |
| INFL(-1) | 0.022045 | 0.030173 | 0.730622 | 0.4669 |
| UE_GAP | 0.178847 | 0.098184 | 1.821545 | 0.0719 |
| FOOD | 0.087439 | 0.044795 | 1.951999 | 0.0541 |
| EN | 0.080340 | 0.002512 | 31.98614 | 0.0000 |
| AR(1) | 0.966669 | 0.027534 | 35.10871 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.981311 | Mean dependent var | 2.663839 |
| Adjusted R-squared | 0.980261 | S.D. dependent var | 0.804073 |
| S.E. of regression | 0.112969 | Akaike info criterion | -1.462332 |
| Sum squared resid | 1.135816 | Schwarz criterion | -1.301035 |
| Log likelihood | 75.46079 | Hannan-Quinn criter. | -1.397156 |
| F-statistic | 934.6243 | Durbin-Watson stat | 1.866781 |
| Prob(F-statistic) | 0.000000 | | |

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 0.907940 | Prob. F(2,87) | 0.4071 |
| Obs*R-squared | 1.942316 | Prob. Chi-Square(2) | 0.3786 |

It signalled a stagnation that would define the first decade of the 21st century. Job creation was net-zero the 2000s, and percent change in household net worths was -4%. (Irwin, 2013)

Again, at level the model estimated is spurious and requires an AR(1) correction. Table 4 shows that AR(1) eliminated the serial correlation issue. The coefficients for the two supply shock variables remain significant. The unemployment gap is weakly significant and has a positive sign.

**2006-2014**

This sub-period was marked by the 2008 Financial Crisis triggered by the sub-prime mortgage market meltdown. The Fed for the first intervened in the market to stabilize the broader economy (Plosser, 2014). Before doing corrections on its obvious serial correlation problem, all coefficients are highly significant. The coefficient sign for the unemployment gap is negative. Lagged inflation, and food and energy are consistency significant. However, an LM test confirms the presence of a unit root in the model's residuals.

Table 5

*Equation 3, 2006-2014*

Dependent Variable: INFL
Method: Least Squares
Date: 05/22/14 Time: 13:17
Sample: 2006M12 2014M01
Included observations: 86

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 1.296988 | 0.098775 | 13.13067 | 0.0000 |
| INFL(-1) | 0.142140 | 0.051806 | 2.743686 | 0.0075 |
| UE_GAP | -0.115649 | 0.018224 | -6.346098 | 0.0000 |
| FOOD | 0.184571 | 0.025208 | 7.321929 | 0.0000 |
| EN | 0.080262 | 0.004460 | 17.99528 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.976184 | Mean dependent var | 2.067551 |
| Adjusted R-squared | 0.975008 | S.D. dependent var | 1.521317 |
| S.E. of regression | 0.240502 | Akaike info criterion | 0.044201 |
| Sum squared resid | 4.685122 | Schwarz criterion | 0.186895 |
| Log likelihood | 3.099365 | Hannan-Quinn criter. | 0.101629 |
| F-statistic | 830.0310 | Durbin-Watson stat | 0.330804 |
| Prob(F-statistic) | 0.000000 | | |

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 152.5116 | Prob. F(2,79) | 0.0000 |
| Obs*R-squared | 68.30836 | Prob. Chi-Square(2) | 0.0000 |

Dependent Variable: INFL
Method: Least Squares
Date: 05/22/14 Time: 13:32
Sample: 2006M12 2014M01
Included observations: 86
Convergence achieved after 17 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 1.159157 | 0.258804 | 4.478908 | 0.0000 |
| INFL(-1) | 0.014134 | 0.024763 | 0.570780 | 0.5698 |
| UE_GAP | -0.021068 | 0.058874 | -0.357850 | 0.7214 |
| FOOD | 0.212473 | 0.039791 | 5.339749 | 0.0000 |
| EN | 0.094680 | 0.002559 | 37.00037 | 0.0000 |
| AR(1) | 1.265397 | 0.117286 | 10.78897 | 0.0000 |
| AR(2) | -0.347865 | 0.115673 | -3.007317 | 0.0035 |

| | | | |
|---|---|---|---|
| R-squared | 0.995987 | Mean dependent var | 2.067551 |
| Adjusted R-squared | 0.995682 | S.D. dependent var | 1.521317 |
| S.E. of regression | 0.099963 | Akaike info criterion | -1.690140 |
| Sum squared resid | 0.789417 | Schwarz criterion | -1.490367 |
| Log likelihood | 79.67600 | Hannan-Quinn criter. | -1.609740 |
| F-statistic | 3267.994 | Durbin-Watson stat | 1.994651 |
| Prob(F-statistic) | 0.000000 | | |

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 1.554061 | Prob. F(2,77) | 0.2179 |
| Obs*R-squared | 3.336722 | Prob. Chi-Square(2) | 0.1886 |

Before doing corrections on its obvious serial correlation problem, all coefficients are highly significant. However, an LM test confirms the presence of a unit root in the model's residuals. Table 5 shows that the model becomes stable after AR(1) and AR(2) corrections. Food and energy costs are the only statistically significant variables in the model.

**Forecast results**

In-sample results for the forecast period 2013M11 to 2014M01 are compared with inflation figures reported by inflationdata.com, an online publication specializing in inflation analysis. Those values are the INF_BLS columns in Table 6. The predicted inflation rates for 2013M11 through 2014M1 using models for sub-periods 1999M02-2006M12 and 2006M12-2014M01 were close to one another in values.

Table 6

*Triangle Model Inflation Forecasts*

Forecast results: 1998-2006

| | INFLFF | | INF_BLS |
|---|---|---|---|
| 2012M06 | 1.672278 | 2012M06 | 1.7 |
| 2012M07 | 1.497088 | 2012M07 | 1.4 |
| 2012M08 | 1.709721 | 2012M08 | 1.7 |
| 2012M09 | 1.837447 | 2012M09 | 2.0 |
| 2012M10 | 2.098441 | 2012M10 | 2.2 |
| 2012M11 | 1.858522 | 2012M11 | 1.8 |
| 2012M12 | 1.741663 | 2012M12 | 1.7 |
| 2013M01 | 1.587370 | 2013M01 | 1.6 |
| 2013M02 | 1.846744 | 2013M02 | 2.0 |
| 2013M03 | 1.612732 | 2013M03 | 1.5 |
| 2013M04 | 1.164555 | 2013M04 | 1.1 |
| 2013M05 | 1.335387 | 2013M05 | 1.4 |
| 2013M06 | 1.758769 | 2013M06 | 1.8 |
| 2013M07 | 1.890847 | 2013M07 | 2.0 |
| 2013M08 | 1.550108 | 2013M08 | 1.5 |
| 2013M09 | 1.183075 | 2013M09 | 1.2 |
| 2013M10 | 0.952218 | 2013M10 | 1.0 |
| 2013M11 | 1.126020 | 2013M11 | 1.2 |
| 2013M12 | 1.499895 | 2013M12 | 1.5 |
| 2014M01 | 1.648300 | 2014M01 | 1.6 |

Forecast results: 2006-2014

| | INFLF2 | | INF_BLS |
|---|---|---|---|
| 2012M06 | 1.722120 | 2012M06 | 1.7 |
| 2012M07 | 1.558816 | 2012M07 | 1.4 |
| 2012M08 | 1.740913 | 2012M08 | 1.7 |
| 2012M09 | 1.808211 | 2012M09 | 2.0 |
| 2012M10 | 2.108041 | 2012M10 | 2.2 |
| 2012M11 | 1.897962 | 2012M11 | 1.8 |
| 2012M12 | 1.817142 | 2012M12 | 1.7 |
| 2013M01 | 1.644315 | 2013M01 | 1.6 |
| 2013M02 | 1.794781 | 2013M02 | 2.0 |
| 2013M03 | 1.606690 | 2013M03 | 1.5 |
| 2013M04 | 1.271749 | 2013M04 | 1.1 |
| 2013M05 | 1.393873 | 2013M05 | 1.4 |
| 2013M06 | 1.741943 | 2013M06 | 1.8 |
| 2013M07 | 1.858930 | 2013M07 | 2.0 |
| 2013M08 | 1.547835 | 2013M08 | 1.5 |
| 2013M09 | 1.248412 | 2013M09 | 1.2 |
| 2013M10 | 1.013342 | 2013M10 | 1.0 |
| 2013M11 | 1.120559 | 2013M11 | 1.2 |
| 2013M12 | 1.429034 | 2013M12 | 1.5 |
| 2014M01 | 1.625300 | 2014M01 | 1.6 |

## HNKPC

Among the challenges of estimating the HNKPC is finding a suitable proxy for the forward-looking term (Gordon, 2009).

This paper uses the effective federal funds rate as a proxy. Under the rationale that it is the interest rate for banks to borrow federal funds to maintain their reserve ratio, then it can be used as a benchmark for short-term interest rates. A bank won't charge interest rates for borrowers at a rate lower than what they pay to borrow funds. Depository institutions are required to hold reserve assets equal to a proportion of each dollar of deposit liabilities, in order to provide adequate liquidity on hand to meet customers' withdrawal requests. Currently, the Fed pays 0.25% interest on required reserve balances, and 0.25% interest on excess reserves. (Federal Reserve, 2014)

The Fed's three waves of Quantitative Easing, in which they purchased financial assets from banks, resulted in excess reserves. Circulation of this easy money sparked fears of higher price levels and inflation. By paying interest on excess reserves – funds available for lending – the Fed is compensating depositories for the opportunity cost of investing those excess funds for a higher interest return. The Fed was already expected to begin paying interest on reserves after Congress

Table 7

*Augmented Dickey Fuller Tests*

**Augmented Dickey-Fuller Unit Root Test on INFL**

Null Hypothesis: INFL has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -3.092516 | 0.0308 |
| Test critical values: | 1% level | -3.508326 | |
| | 5% level | -2.895512 | |
| | 10% level | -2.584952 | |

**Augmented Dickey-Fuller Unit Root Test on FFR**

Null Hypothesis: FFR has a unit root
Exogenous: Constant
Lag Length: 8 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -3.487745 | 0.0106 |
| Test critical values: | 1% level | -3.508326 | |
| | 5% level | -2.895512 | |
| | 10% level | -2.584952 | |

**Augmented Dickey-Fuller Unit Root Test on UE_GAP**

Null Hypothesis: UE_GAP has a unit root
Exogenous: Constant
Lag Length: 5 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -2.153039 | 0.2250 |
| Test critical values: | 1% level | -3.508326 | |
| | 5% level | -2.895512 | |
| | 10% level | -2.584952 | |

**Augmented Dickey-Fuller Unit Root Test on D(INFL)**

Null Hypothesis: D(INFL) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -5.259832 | 0.0002 |
| Test critical values: | 1% level | -4.068290 | |
| | 5% level | -3.462912 | |
| | 10% level | -3.157836 | |

**Augmented Dickey-Fuller Unit Root Test on D(FFR)**

Null Hypothesis: D(FFR) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -5.129547 | 0.0003 |
| Test critical values: | 1% level | -4.068290 | |
| | 5% level | -3.462912 | |
| | 10% level | -3.157836 | |

**Augmented Dickey-Fuller Unit Root Test on D(UE_GAP)**

Null Hypothesis: D(UE_GAP) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=11)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -4.141716 | 0.0081 |
| Test critical values: | 1% level | -4.068290 | |
| | 5% level | -3.462912 | |
| | 10% level | -3.157836 | |

approved the Financial Services Regulatory Relief Act in 2006. It authorized the Fed to pay interest on required reserve balances and excess reserves held by depositories starting October 2012. At the time, the idea of paying interest on required reserves was envisioned as a way to increase the flow of credit to borrowers by eliminating the opportunity cost depositories face in holding funds that can't earn interest. The FSRRA's implementation date moved up to October 2008 by the Emergency Economic Stabilization Act to October 2008, in response to the subprime mortgage crisis. It allowed the U.S. Treasury to spend up to $700 billion to purchase illiquid assets like mortgage-backed securities and supply liquidity to banks. "By affecting the public's expectations about the future path of policy, this forward guidance can impact the current economy." (Plosser, 2014)

In this paper, the HNKPC takes the form specified by Equation 6. It's important to remember the nonstationarity of the dependent and independent variables.

Based on shapes of the graphs in Figure 2 and Augmented Dickey-Fuller test results in Table 7 for $infl$, $uegap$ and the expected future rate of inflation $ffr$, the dependent and independent variables are not stationary at level. $Infl$ and $ffr$ are only stationary at the 10% and 5% critical level, but not at the 1% level. The variables become stationary after taking the first difference. The error is also nonstationary, indicating that the regression is spurious at level.

**1999-2014**

Table 8

*Equation 5, 1998-2014*

Dependent Variable: INFL
Method: Least Squares
Date: 05/10/14 Time: 09:48
Sample (adjusted): 1998M12 2014M01
Included observations: 182 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.091307 | 0.142487 | 0.640809 | 0.5225 |
| INF(-1) | 0.880025 | 0.031148 | 28.25270 | 0.0000 |
| UE_GAP | 0.034469 | 0.038236 | 0.901472 | 0.3686 |
| FFR | 0.055561 | 0.030279 | 1.834967 | 0.0682 |

| | | | |
|---|---|---|---|
| R-squared | 0.861496 | Mean dependent var | 2.371585 |
| Adjusted R-squared | 0.859162 | S.D. dependent var | 1.231871 |
| S.E. of regression | 0.462302 | Akaike info criterion | 1.316536 |
| Sum squared resid | 38.04270 | Schwarz criterion | 1.386953 |
| Log likelihood | -115.8047 | Hannan-Quinn criter. | 1.345082 |
| F-statistic | 369.0537 | Durbin-Watson stat | 1.151778 |
| Prob(F-statistic) | 0.000000 | | |

Dependent Variable: INFL
Method: Least Squares
Date: 05/10/14 Time: 09:45
Sample (adjusted): 1999M01 2014M01
Included observations: 181 after adjustments
Convergence achieved after 13 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.666932 | 0.531522 | 1.254758 | 0.2112 |
| INF(-1) | 0.626194 | 0.230325 | 2.718745 | 0.0072 |
| UE_GAP | -0.016976 | 0.089558 | -0.189558 | 0.8499 |
| FFR | 0.098035 | 0.090150 | 1.087472 | 0.2783 |
| AR(1) | 0.655113 | 0.234427 | 2.794527 | 0.0058 |

| | | | |
|---|---|---|---|
| R-squared | 0.891334 | Mean dependent var | 2.375880 |
| Adjusted R-squared | 0.888864 | S.D. dependent var | 1.233920 |
| S.E. of regression | 0.411352 | Akaike info criterion | 1.088502 |
| Sum squared resid | 29.78108 | Schwarz criterion | 1.176858 |
| Log likelihood | -93.50942 | Hannan-Quinn criter. | 1.124323 |
| F-statistic | 360.9105 | Durbin-Watson stat | 1.843325 |
| Prob(F-statistic) | 0.000000 | | |

The HNKPC model is weak when used for the entire span of selected data. Table 8 shows the coefficient for $ffr$ lacks explanatory power both before and after the model is corrected for serial correlation, after the error becomes stationary after applying AR(1). The unemployment gap is weakly significant, and lagged inflation is statistically insignificant.

This makes intuitive sense. The theory behind the model relies on the power of central bank policy, which is most influential when authorities explicitly confirm short-term stabilization plans to the public.

**Model weakness before 2006**

The results are the same when a sample size of the model is adjusted for 1999-2006. The $ffr$ coefficient is not significant, and the residuals are serially correlated. After adding the AR(1) for correction, the model still fails to show that $ffr$ is significant. It can be concluded that the hybrid New Keynesian model for inflation is weak in a period absent of explicit forward guidance.

Table 9

*Equation 6, 1998-2014*

Dependent Variable: INFL
Method: Least Squares
Date: 05/22/14 Time: 09:55
Sample (adjusted): 1998M12 2006M11
Included observations: 96 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.503878 | 0.283575 | 1.776881 | 0.0789 |
| INF(-1) | 0.816776 | 0.054219 | 15.06443 | 0.0000 |
| UE_GAP | -0.106808 | 0.208486 | -0.512302 | 0.6097 |
| FFR | -0.014247 | 0.083144 | -0.171351 | 0.8643 |

| | | | |
|---|---|---|---|
| R-squared | 0.773530 | Mean dependent var | 2.643949 |
| Adjusted R-squared | 0.766146 | S.D. dependent var | 0.813524 |
| S.E. of regression | 0.393408 | Akaike info criterion | 1.012834 |
| Sum squared resid | 14.23882 | Schwarz criterion | 1.119682 |
| Log likelihood | -44.61603 | Hannan-Quinn criter. | 1.056024 |
| F-statistic | 104.7452 | Durbin-Watson stat | 1.490087 |
| Prob(F-statistic) | 0.000000 | | |

Dependent Variable: INFL
Method: Least Squares
Date: 05/22/14 Time: 09:59
Sample (adjusted): 1999M01 2006M11
Included observations: 95 after adjustments
Convergence achieved after 13 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.734148 | 0.767149 | 0.956982 | 0.3411 |
| INF(-1) | 0.440030 | 0.282403 | 1.558163 | 0.1227 |
| UE_GAP | 0.296554 | 0.323829 | 0.915773 | 0.3622 |
| FFR | 0.218451 | 0.135602 | 1.610970 | 0.1107 |
| AR(1) | 0.635713 | 0.252258 | 2.520094 | 0.0135 |

| | | | |
|---|---|---|---|
| R-squared | 0.795242 | Mean dependent var | 2.654999 |
| Adjusted R-squared | 0.786141 | S.D. dependent var | 0.810564 |
| S.E. of regression | 0.374844 | Akaike info criterion | 0.926584 |
| Sum squared resid | 12.64574 | Schwarz criterion | 1.060998 |
| Log likelihood | -39.01272 | Hannan-Quinn criter. | 0.980897 |
| F-statistic | 87.38559 | Durbin-Watson stat | 1.732313 |
| Prob(F-statistic) | 0.000000 | | |

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 12.00287 | Prob. F(2,90) | 0.0000 |
| Obs*R-squared | 20.21434 | Prob. Chi-Square(2) | 0.0000 |

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 0.514600 | Prob. F(2,89) | 0.5995 |
| Obs*R-squared | 1.097282 | Prob. Chi-Square(2) | 0.5777 |

"Even if policymakers choose not to be so explicit, the actions a central bank takes over time can enhance the public's understanding of how the institution is likely to set policy. This helps make the central bank's policy choices at least somewhat predictable." (Plosser, 2014) If reputation through action is the best signal for the broader economy, then there is a risk the public may not completely comprehend the signal a central bank is trying to send. In a way, Plosser saw this as the Fed's "communication problem."

**2006-2014**

The story changes in the sub-period 2006-2014, when the U.S. economy dealt with the consequences of the housing and credit bubbles and coped through the post-Financial Crisis recovery period.

Testing the model in this time frame allowed it to capture both the endogeneity of inflation persistence and forward-looking expectations. These particular features have been credited by Antipin and Luoto (2008) for good forecasting performance in their own studies of univariate and multivariate VAR

Table 10

*Equation 6, 1999-2006*

Dependent Variable: INFL
Method: Least Squares
Date: 05/22/14 Time: 09:55
Sample (adjusted): 1998M12 2006M11
Included observations: 96 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.503878 | 0.283575 | 1.776881 | 0.0789 |
| INF(-1) | 0.816776 | 0.054219 | 15.06443 | 0.0000 |
| UE_GAP | -0.106808 | 0.208486 | -0.512302 | 0.6097 |
| FFR | -0.014247 | 0.083144 | -0.171351 | 0.8643 |

| | | | |
|---|---|---|---|
| R-squared | 0.773530 | Mean dependent var | 2.643949 |
| Adjusted R-squared | 0.766146 | S.D. dependent var | 0.813524 |
| S.E. of regression | 0.393408 | Akaike info criterion | 1.012834 |
| Sum squared resid | 14.23882 | Schwarz criterion | 1.119682 |
| Log likelihood | -44.61603 | Hannan-Quinn criter. | 1.056024 |
| F-statistic | 104.7452 | Durbin-Watson stat | 1.490087 |
| Prob(F-statistic) | 0.000000 | | |

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 12.00287 | Prob. F(2,90) | 0.0000 |
| Obs*R-squared | 20.21434 | Prob. Chi-Square(2) | 0.0000 |

Dependent Variable: INFL
Method: Least Squares
Date: 05/22/14 Time: 09:59
Sample (adjusted): 1999M01 2006M11
Included observations: 95 after adjustments
Convergence achieved after 13 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.734148 | 0.767149 | 0.956982 | 0.3411 |
| INF(-1) | 0.440030 | 0.282403 | 1.558163 | 0.1227 |
| UE_GAP | 0.296554 | 0.323829 | 0.915773 | 0.3622 |
| FFR | 0.218451 | 0.135602 | 1.610970 | 0.1107 |
| AR(1) | 0.635713 | 0.252258 | 2.520094 | 0.0135 |

| | | | |
|---|---|---|---|
| R-squared | 0.795242 | Mean dependent var | 2.654999 |
| Adjusted R-squared | 0.786141 | S.D. dependent var | 0.810564 |
| S.E. of regression | 0.374844 | Akaike info criterion | 0.926584 |
| Sum squared resid | 12.64574 | Schwarz criterion | 1.060998 |
| Log likelihood | -39.01272 | Hannan-Quinn criter. | 0.980897 |
| F-statistic | 87.38559 | Durbin-Watson stat | 1.732313 |
| Prob(F-statistic) | 0.000000 | | |

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 0.514600 | Prob. F(2,89) | 0.5995 |
| Obs*R-squared | 1.097282 | Prob. Chi-Square(2) | 0.5777 |

forecasting models.

Restoring and preserving stability in the markets has been the primary goal of the Fed. By clearly communicating its policies and the time frame in which it is expected to operate has been crucial to recovery efforts. It's an attempt to moderate the uncertainties inhererent in speculation. Muth's (1961) paper contemplated the quantitative properties of well-informed expectations of price: the reduction of price variances when its effect as a market disturbance is spread out over several time periods, "thereby allowing shocks partially to cancel one another out. Speculation is profitable, although no speculative opportunities remain. These propositions might appear obvious."

Table 11 coefficients for lagged inflation and federal funds rate are statistically significant. In the case of the latter, this is notable since it lacked explanatory power when the same model is used for the entire span of the data series. Lagged inflation and ffr are highly significant while the unemployment gap is not. However, the model's Durbin Watson statistic of 0.999934 indicates that there is positive serial correlation.

Table 11

*Equation 6, 2006-2014*

Dependent Variable: INFL
Method: Least Squares
Date: 05/10/14 Time: 17:18
Sample: 2006M12 2014M01
Included observations: 86

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.185599 | 0.256046 | -0.724867 | 0.4706 |
| INFL(-1) | 0.929841 | 0.043937 | 21.16282 | 0.0000 |
| UE_GAP | 0.079524 | 0.062708 | 1.268162 | 0.2083 |
| FFR | 0.118269 | 0.056328 | 2.099638 | 0.0388 |

| | | | |
|---|---|---|---|
| R-squared | 0.879582 | Mean dependent var | 2.067551 |
| Adjusted R-squared | 0.875176 | S.D. dependent var | 1.521317 |
| S.E. of regression | 0.537488 | Akaike info criterion | 1.641574 |
| Sum squared resid | 23.68925 | Schwarz criterion | 1.755730 |
| Log likelihood | -66.58770 | Hannan-Quinn criter. | 1.687517 |
| F-statistic | 199.6530 | Durbin-Watson stat | 0.999934 |
| Prob(F-statistic) | 0.000000 | | |

To correct this, the AR(1) term is added. The new D-W statistic of 1.797173 places it within the acceptable range of "no serial correlation." An ADF test on the residuals also rejects the null that there is a unit root.

In this revised output, lagged inflation and the federal funds rate are highly significant, while the unemployment gap is not. This model seems to support the argument underlying hybrid NKPC literature that future expectations of inflation can be influenced by a central bank authority.

It should be noted that the Fed's forward guidance policy is built around explicit announcements to the public that inflation will remain low as it continues to extend its stabilizing policies. Chief among these policies is the decision to keep the federal funds rate at 0.25%.

Within the context of this model, the federal funds rate is meant to represent future expectations because of how it influences short-term rates. A good time series model will display no serial correlation, no heteroskedacity and normal distribution of its residuals. The ADF test above points to the absence of a unit root.

Table 12 also shows an LM test confirming the absence of serial correlation in the residuals. The Obs $R^2$ of 4.60 and its p-value of 0.09 – more than the 0.05

Table 12

*Equation 6 with AR, 2006-2014*

Dependent Variable: INFL
Method: Least Squares
Date: 05/10/14 Time: 17:30
Sample: 2006M12 2014M01
Included observations: 86
Convergence achieved after 21 iterations

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 1.334653 | 1.119389 | 1.192306 | 0.2366 |
| INFL(-1) | 0.441876 | 0.101109 | 4.370297 | 0.0000 |
| UE_GAP | -0.184649 | 0.247129 | -0.747177 | 0.4571 |
| FFR | 0.750175 | 0.323417 | 2.319531 | 0.0229 |
| AR(1) | 0.929288 | 0.036892 | 25.18963 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.916273 | Mean dependent var | 2.067551 |
| Adjusted R-squared | 0.912139 | S.D. dependent var | 1.521317 |
| S.E. of regression | 0.450940 | Akaike info criterion | 1.301416 |
| Sum squared resid | 16.47110 | Schwarz criterion | 1.444111 |
| Log likelihood | -50.96091 | Hannan-Quinn criter. | 1.358844 |
| F-statistic | 221.6081 | Durbin-Watson stat | 1.797173 |
| Prob(F-statistic) | 0.000000 | | |

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 2.236283 | Prob. F(2,79) | 0.1136 |
| Obs*R-squared | 4.607988 | Prob. Chi-Square(2) | 0.0999 |

Heteroskedasticity Test: Breusch-Pagan-Godfrey

| | | | |
|---|---|---|---|
| F-statistic | 0.752702 | Prob. F(3,82) | 0.5239 |
| Obs*R-squared | 2.304790 | Prob. Chi-Square(3) | 0.5116 |
| Scaled explained SS | 4.703787 | Prob. Chi-Square(3) | 0.1948 |

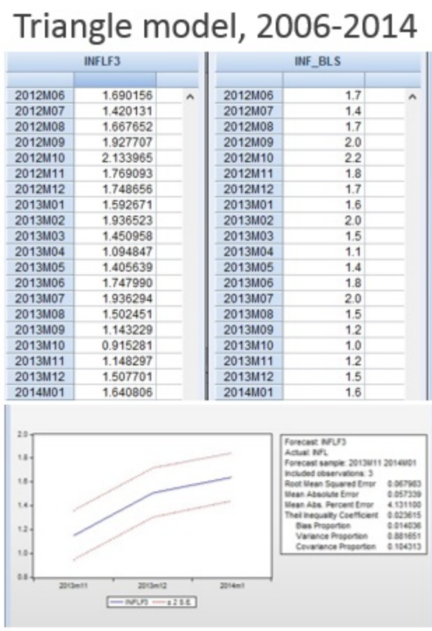
p-value needed to reject the null – also confirms that there is no serial correlation. Residuals are also homoskedasctic. The Breusch-Pagan-Godfrey test statistic of 2.30 and p-value of 0.5116 cannot reject the null hypothesis that residuals are heteroskedastic. The results of this model are also consistent with the findings of Gali et al (2001) that the forward-looking term in HNKPC models are typically large and highly signficant.

**Forecast results**

Forecast results for the HNKPC are close to those of the triangle model in the same sub-period 2006-2014. Neither model are deviate far from the inflation figures derived by http://inflationdata.com from BLS data.

Table 13

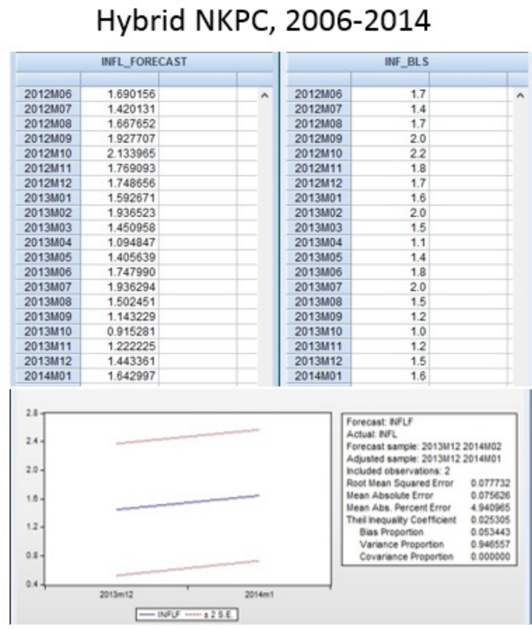
*Forecast Results: Triangle Model vs. Hybrid NKPC*



Triangle model, 2006-2014

| | INFLF3 | INF_BLS |
|---|---|---|
| 2012M06 | 1.690156 | 1.7 |
| 2012M07 | 1.420131 | 1.4 |
| 2012M08 | 1.667652 | 1.7 |
| 2012M09 | 1.927707 | 2.0 |
| 2012M10 | 2.133965 | 2.2 |
| 2012M11 | 1.769093 | 1.8 |
| 2012M12 | 1.748656 | 1.7 |
| 2013M01 | 1.592671 | 1.6 |
| 2013M02 | 1.936523 | 2.0 |
| 2013M03 | 1.450958 | 1.5 |
| 2013M04 | 1.094847 | 1.1 |
| 2013M05 | 1.405639 | 1.4 |
| 2013M06 | 1.747990 | 1.8 |
| 2013M07 | 1.936294 | 2.0 |
| 2013M08 | 1.502451 | 1.5 |
| 2013M09 | 1.143229 | 1.2 |
| 2013M10 | 0.915281 | 1.0 |
| 2013M11 | 1.148297 | 1.2 |
| 2013M12 | 1.507701 | 1.5 |
| 2014M01 | 1.640806 | 1.6 |





Hybrid NKPC, 2006-2014

| | INFL_FORECAST | INF_BLS |
|---|---|---|
| 2012M06 | 1.690156 | 1.7 |
| 2012M07 | 1.420131 | 1.4 |
| 2012M08 | 1.667652 | 1.7 |
| 2012M09 | 1.927707 | 2.0 |
| 2012M10 | 2.133965 | 2.2 |
| 2012M11 | 1.769093 | 1.8 |
| 2012M12 | 1.748656 | 1.7 |
| 2013M01 | 1.592671 | 1.6 |
| 2013M02 | 1.936523 | 2.0 |
| 2013M03 | 1.450958 | 1.5 |
| 2013M04 | 1.094847 | 1.1 |
| 2013M05 | 1.405639 | 1.4 |
| 2013M06 | 1.747990 | 1.8 |
| 2013M07 | 1.936294 | 2.0 |
| 2013M08 | 1.502451 | 1.5 |
| 2013M09 | 1.143229 | 1.2 |
| 2013M10 | 0.915281 | 1.0 |
| 2013M11 | 1.222225 | 1.2 |
| 2013M12 | 1.443361 | 1.5 |
| 2014M01 | 1.642997 | 1.6 |



## Conclusion

The outcome of the regression models estimated confirm two things: the triangle model isn't passe, and the HNKPC holds as long as the period under which it is tested is nested in an economic environment of forward guidance.

In the 3-period in-sample forecast, the HNKPC performed better for 2013M11. Its 2014M1 forecast is quite close to the triangle model forecast; forecasts by the two models were nearly on point. The HNKPC is more applicable in times of explicit forward guidance by central banks reflects Gali and Gertler's (1999) assertion that a household and firm's outlook on marginal costs is an important determinant of inflation. That outlook is influenced by lagged term, but the greater explanatory power lies with the forward-looking term. It comes with the caveat that the policy designed to shape future expectations must be as credible as the authorities implementing it. The HNKPC's weakness before 2006 shouldn't be interpreted as a period lacking Fed credibility, but rather the absence of a signal that specifically informs the market of future inflationary behavior. The Fed at the time was not as deeply immersed in stabilizing the markets as it is today.

The triangle model was robust in all periods. This won't come as a suprise for Gordon (2009), stating that the persistence of inflation has been a feature of post-World War II economy in the United States and is therefore hard to ignore. Although the proxy variable for the forward-looking term showed the credibility of a central bank can influence expectations, the literature on HNKPC isn't united in how to best represent future expectations. That may be part of the reason why the model is prone to over-complication.

The "two approaches need to pay more attention to each other and to engage in a dialogue about which models apply to which episodes, and what factors would motivate a shift in relevance between the alternative models." (Gordon, 2009) The triangle model still appears to be relevant. The superiority of one model over the other is difficult to prove. The approach to estimating either form of the Phillips curve seems contingent on the context of the period under examination.

## References

Antipin, J., & Louto, J. (2008, June). “Forecasting performance of the small-scale hybrid New Keynesian model.” Working papers, Helsinki School of Economics; 451.

Commins, J. (2010, October). “Healthcare costs soar above overall inflation.” Health Leaders Media Council. http://www.healthleadersmedia.com/page-1/FIN-258088/Healthcare-Costs-Soar-Above-Overall-Inflation

Eller, J.W. and Gordon, R.J. (2003, May) “Nesting the New Keynesian Phillips Curve within the Mainstream Model of U. S. Inflation Dynamics.” CEPR Conference: The Phillips Curve Revisited, Berlin, Germany, June 5-6,2003.

Enders, W. (2009). Applied Econometric Time Series, 3rd ed. Danvers, Massachusetts. Wiley& Sons, Inc.

Federal Reserve (2014). “How does forward guidance about the Federal Reserve's target for the federal funds rate support the economic recovery?” Board of Governors of the Federal Reserve. http://www.federalreserve.gov/faqs/money_19277.htm

Friedman, M. (1968, March) “The Role of Monetary Policy.” The American Economic Review 58(1), 1-17.

Galí, J.and Gertler, M (1999, October) “Inflation Dynamics: A Structural Econometric Approach.” Journal of Monetary Economics, 44(2),195-222.

Galí, J. , Gertler, M., Lopez-Salido, J.D. (2001, June) “Notes on Estimating the Closed Form of the Hybrid New Phillips Curve.” New York University. http://www.nyu.edu/econ/user/gertlerm/ggrw1.pdf

Gordon, R.J. (1988), Macroeconomics: Theory and Policy, 2nd ed., Chap. 22.4, “Modern theories of inflation.” Boston, Massachusetts. McGraw-Hill.

Gordon, R. J. (2009, March). “The History of the Phillips Curve: Consensus and Bifurcation.” NBER Working Paper. http://faculty-web.at.northwestern.edu/economics/gordon/Pre-NBER_forComments_Combined_090307.pdf

Irwin, N. (2010, January 2). “Aughts were a lost decade for U.S. economy, workers.” Washington Post. http://www.washingtonpost.com/wp-dyn/content/article/2010/01/01/AR2010010101196.html

Lucas Jr., R. E. (1976, January). “Econometric policy evaluation: a critique.” Georgetown University. http://faculty.georgetown.edu/mh5/class/econ489/Lucas-Critique.pdf

Phelps, E. S. (1967, August). “Phillips Curves, Expectations of Inflation and Optimal Unemployment over Time.” Economica, 34(135), 254-281.

Phillips, A. W. (1958, November). “The Relation Between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861–1957.” Economica, 25(100), 283-299.

PricewaterhouseCoopers (2013). "Factors affecting 2014 medical cost trend." PwC. http://www.pwc.com/us/en/health-industries/behind-the-numbers/

Muth, J. F. (1961, July). "Rational Expectations and the Theory of Price Movements." Econometrica, 29(3), 315-335.

Plosser, C. I. (2014, February 12). Forward Guidance. In Board of Governors of the Federal Reserve. http://www.philadelphiafed.org/publications/speeches/plosser/2013/02-12-13_siepr.pdf

Roeger, W., & Herz, B. (2004, October). "Traditional versus New Keynesian Phillips Curves: Evidence from Output Effects." International Journal of Central Banking. http://www.ijcb.org/journal/ijcb12q2a3.htm

Rudd, J., & Whelan, K. (2001, June 26). "New Tests of the New-Keynesian Phillips Curve." Board of Governors of the Federal Reserve. http://www.federalreserve.gov/pubs/feds/2001/200130/200130pap.pdf

Rudd, J., & Whelan, K. (2005, December 19). "Modelling Inflation Dynamics: A Critical Review of Recent Research." Board of Governors of the Federal Reserve. http://www.federalreserve.gov/pubs/feds/2005/200566/200566pap.pdf

Samuelson, P. A., & Solow, R. M. (1960, May). "Analytical Aspects of Anti-Inflation Policy. In International Journal of Central Banking." http://web.econ.unito.it/bagliano/macro3/samsol_aer60.pdf