DO GAP MODELS STILL HAVE A ROLE TO PLAY IN FORECASTING INFLATION?

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ABSTRACT

Since the end of Great Recession, researchers have turned their attention to studies on economic recovery, and the speed of correction in the United States. While the economy is recovering, researchers have begun to expect the possibility of inflation in the future. A recent article from the Federal Reserve Bank of Cleveland found that simple models of inflation tend to forecast inflation better than large statistical models. This paper re-visits the price gap model where the central idea is that the price level is determined by the money stock, output and velocity. A horse race is then run whereby a price gap model is tested against atheoretic models based simply on past information, and a structural output gap model. The overall results indicate that the price gap model does in fact display the lowest forecast error over the shorter term forecast horizons, and thus has the most usefulness for inflation forecasting. Robustness checks are then run – the models are re-estimated with a different measure of inflation (CPI less food and energy prices), and the forecasting horizon is extended to 12 quarters. The price gap model is sensitive to the measurement of inflation and loses some of its forecasting power when core CPI (CPI less food and energy prices) is used. Naïve forecasts tend to perform better when forecasting inflation series that are less volatile. However, from the policymaker's standpoint, it would be more appropriate to have better forecasting power over a more volatile series and so the price gap model would be the ideal choice out of the four models tested here. When the forecasting horizon is extended, the price gap model continues to have the lowest forecast errors.

JEL: E30, E31, E37

KEYWORDS: Inflation, Inflation Forecasting, Price Gap Model, Output Gap Model

INTRODUCTION

The primary task that policy makers are charged with is the elucidation of, and prediction of, key macroeconomic variables for the purposes of designing and sequencing policy measures. Economic studies have thus spent a fair amount of time understanding the forces behind changes in the macro-economy, and forecasting macroeconomic variables such as output, employment and inflation. A very large literature focuses on the behavior of and predicting of inflation. Accurate forecasting is important when it comes to inflation targeting. It has been suggested that since inflation responds to monetary policy with a lag of about one-two years (Bernanke and Woodford, 1997), monetary authorities would be better off targeting forecasts of inflation rather than the inflation rate itself. If this is an important strategy, then it is all the more important to accurately forecast inflation.

A recent Federal Reserve Bank of Cleveland study by Meyer and Pasaogullari (2010) found that naïve models performed rather well when compared to simple statistical models. Following this approach, this paper looks at theoretical versus naïve models for forecasting inflation. The remainder of the paper is organized as follows: the literature review section discusses past studies that are relevant to this study while the model development section presents the theoretical development of the price gap model. The data and methodology section discusses the data sources and the four overall models tested in this paper – these are benchmark AR and ARMA processes, a price gap model, and a simple Phillips-curve model. The results from the statistical analyses are explained in the results and discussion section, and the paper ends with concluding remarks regarding the forecasting power of the price gap model and the significance of the results for monetary authorities and other policy makers.

LITERATURE REVIEW

Forecasting inflation with as low an error as possible is vital for accurate macroeconomic policy formulation. Policymakers strive to control inflation for a variety of reasons. These include the following: high and volatile inflation rates do not allow for a stable investment and business climate, inflation lowers the standard of living (Billi, 2011), domestic inflation adversely affects exports and lead to high allocative and welfare costs within the economy. The policymaker's job is further complicated by the fact that the target inflation rate is not necessarily zero, but is a positive percentage. A justification for a positive inflation rate lies in the short-run trade-off between inflation and unemployment. Furthermore, if there is actual deflation, this could lead to loss of value of collateralized assets (this did in fact occur during the Great Recession of 2007-2009) and declining asset values for investors and creditors alike (Billi, 2011). Thus, inflation forecasting is an important area of economic study and has important policy implications.

Past papers have emphasized the role of Phillips-curve type models in predicting inflation, and have assessed the validity of the models in terms of their forecasting power (see for example Atkeson and Ohanian (2001), Camba-Mendez and Rodriguez-Palenzuela (2003) and Stock and Watson (2008). In general, Phillips curve type models provide a relationship between an aggregate measure of economic activity such as output or unemployment and some specification of the inflation rate (Atkeson and Ohanian, 2001). Modern Phillips curve models specifically employ an output gap approach and argue that inflation can be explained by lags of inflation and information contained in the output gap (the difference between the current level of output in the economy and the long run potential GDP). When the output gap is positive, inflation accelerates and the central monetary authority's usual response is to increase the interest rate (Razzak, 2002). Higher interest rates serve to slow the economy down, and output returns to the full employment level, thus eliminating the output gap and reducing inflation.

Output gap models hinge on estimating the output gap correctly as the measure of full employment is always subject to discussion. There is always concern that incorrectly estimating the output gap would lead to unnecessary tightening and loosening of monetary policy (Razzak, 2002). This viewpoint is also shared by Orphanides (1998), who observes that "if policy-makers mistakenly adopt policies that are optimal under the presumption that their understanding of the state of the economy is accurate when, in fact, such accuracy is lacking, they inadvertently induce instability in both inflation and economic activity". The Federal Open Market Committee (FOMC) has often debated the usefulness of the Phillips Curve model in explaining inflation in the United States (Liu and Rudebusch, 2010).

The classic price gap model was developed by Hallman, Porter and Small (1991), henceforth referred to in this paper as HPS. This model is known as the P* model. The model arose out of an attempt to find the link between the M2 measure of money stock and prices in the long run and also to solve the problem of which monetary aggregate to target to design effective monetary policy. The unique quality of this model is its emphasis on deviations of money velocity from "equilibrium" values as important in the determination of the level of prices.

This approach is derived from the quantity theory of money. The basic idea is that there is an optimal price level (P*) that is derived from the equilibrium values of velocity (V*) and output (Y*) in the economy. The P* model assumes that output in the economy follows a smooth deterministic trend. The measure of equilibrium output, Y*, is assumed not to be affected by monetary policy. Money is therefore neutral in the long run. The original P* model also assumes that V* is constant. To this end V* is taken to be the mean or average value of velocity over a sample while the equilibrium measure of output growth in the economy is the potential GDP measure. Based on V* and Y*, and actual money growth an equilibrium price level P* is developed (as explained in the Model Development section). V* and Y* are expected to return to their equilibrium values over time and this in turn drives P back to P*. Ultimately the main difference between the P*-type models and other inflation models such as the output gap models is the introduction of some form of a velocity gap that reflects the actions of monetary policy on inflation.

Policy recommendations then depend on the relationship of P* to the actual price level. Needless to say the direction and magnitude of the difference between P and P* is very important for policy formulation. The usefulness of the P* model is only highlighted if it provides information that is not provided by other inflation models (Christiano, 1989).

The question arises as to whether models based on empirical relationships (such as the price gap or Phillips Curve type models) provide forecasts that are superior to forecasts generated by simpler models based on past information alone. The literature is rather divided on this aspect. Atkeson and Ohanian (2001) use data from 1984 to 1999 (a period of significant inflation stability following the tumultuous period of the 1970s) to compare a Phillips Curve type model to a simple model where inflation is the expected to be the percentage change between inflation four quarters previous and the current inflation rate. The results indicate that the Phillips Curve type models do not beat the naïve forecasts. This result is also seen in a recent paper by Dotsey, Fujita and Stark (2011) which shows that the Phillips curve models provide statistically significant inferior forecasts when compared to models based on past information. However, they do find that when forecast horizons are extended and the economy is weak, the Phillips Curve models' performances improve. Stock and Watson (2007) have discussed the decreasing ability of structural models to beat models based on past information, especially since the "Great Moderation" (this is the reduction in the volatility of real business cycles over the last three decades and the term was coined by Stock and Watson in their 2003 paper).

Ang et al. (2007) compare four different inflation forecasting methods over two different out-of-sample periods: post-1985 and post-1995. The models they use are of four varieties – those based on past information, Phillips curve based models, yield curve based models, and models based on surveys of agents such as consumers or professionals (such as the Livingston or Michigan surveys). The survey forecasting method turns out to be superior for consumer price index based measures of inflation when compared to the models based on past information and the structural models. Possible explanations that are proposed include the fact that surveys are based on a significantly larger amount of information than the other models. This finding lies in contrast to an earlier finding by Fama and Gibbons (1984) who showed that the Livingston surveys under-estimated inflation over the medium to longer term forecast periods.

Stock and Watson (1999) carry out a detailed study of the Phillips Curve models' forecasting abilities over the 12 month forecasting horizon. Their in-sample period was 1959 to 1969, and the out of sample forecast period was 1970-1996. The authors begin their analysis with an unemployment based Phillips Curve model, but then extend their analysis to a more modern Phillips Curve type approach based on different aggregate economic activity such as industrial production, housing starts, manufacturing capacity utilization and others. Their results indicate that for the short term horizons, the Phillips Curve models perform reasonably well and the Phillips Curve approach holds water. For the period 1977-2000, Fisher et. Al (2002) find that the direction of change of expected inflation that the Phillips Curve models forecast is correct about two thirds of the time when the forecast horizon is short. These forecasts actually improve as the forecast horizon is extended.

Forecasting a series using past information (among other explanatory variables) continues to be a standard approach in the literature (see for example Liu and Rudebusch, 2010, Clausen and Clausen, 2010, and Aron and Muellbauer, 2012). Clausen and Clausen (2010) use the AR(1) approach as a simple benchmark tool against which to measure the performance of other models. Following this approach models based on past information are also the benchmarks in this paper.

Model Development

As mentioned, the basis of the P* model lies in the quantity theory of money and the equation of exchange. The equation of exchange forms the root of the model:

$$MV = PY \tag{1}$$

Where M = M2 (broad money stock); V = Velocity; P = GDP deflator, and Y = output in the economy at constant prices. The second step involves solving for the price level in the aggregate economy:

$$P = M(V/Y) \tag{2}$$

Thereafter two key assumptions are made. Velocity and output are assumed to be mean reverting over time (that is they display cyclical behavior). Output is assumed to revert to a measure of potential output over time. Potential output theoretically refers to the full employment level of national real output. The equilibrium values for velocity (for velocity this is taken to be the sample-mean) and output are entered into the equation of exchange and the equilibrium price level is solved for, resulting in equation (3).

Assumptions: V and Y will return to the equilibrium values V*, and Y* over time.

$$P^* = M(V^*/Y^*) \tag{3}$$

P* is the level of prices that is proportional to the money stock per unit of potential output. The next step involves taking natural logs of equations (2) and (3) – this gives us equations 2' and 3' below.

$$\ln P = \ln M + \ln V - \ln Y \tag{2'}$$

$$\ln P^* = \ln M + \ln V^* - \ln Y^* \tag{3'}$$

Equation 4 below then solves explicitly for the price gap (done by subtracting equation 3' from 2').

$$(\ln P - \ln P^*) = (\ln V - \ln V^*) + (\ln Y^* - \ln Y) \tag{4}$$

To conserve on notation, equation (4) above is reduced to the form below:

$$(p - p^*) = (v - v^*) + (y^* - y) \tag{4'}$$

HPS incorporate all forward-looking information into p* itself, and include only backward looking information. They propose a simple ad hoc formulation that uses the previous period's inflation measure as the best estimation of lagged information over their sample period (1955-1988). HPS then present their versions of equations 5 and 6 above in the form of equation 5' below.

$$\pi_t = \alpha[p_{t-1} - p^*_{t-1}] + \pi_{t-1} \;;\alpha > 0 \tag{5}$$

$$\Delta\pi_t = \alpha[p_{t-1} - p^*_{t-1}] \;;\alpha > 0 \tag{6}$$

Equation 6 simply has the last lag of inflation moved to the left hand side of equation 5', and thus shows that accelerations of inflation are also related to the price gap. HPS include the possibility that further lags of inflation can be included – they extend the model to include four lags of the accelerations in inflation. In generalized form then, HPS then present the P* model as a function of a price gap and the sum of lagged changes in inflation:

$$\Delta\pi_t = \alpha\,(\text{p-p*})_{t-1} + \beta_1 \Delta\pi_{t-1} + \beta_2 \Delta\pi_{t-2} + \beta_3 \Delta\pi_{t-3} + \beta_4 \Delta\pi_{t-4} \qquad (7)$$

Overall, it is vital to note that the validity of the money-supply driven models of the price level depend on two key assumptions: that there is an identifiable trend in the velocity of money and that money is in fact, neutral in the long run. Potential output is therefore not affected by money supply changes.

The P* approach is based on a long-run view of the equation of exchange. HPS have shown that the model has proven explanatory power over the 2-3 year forecasting horizon. However, it received a fair amount of criticism over the years. The basic model assumes that velocity is mean reverting, and thus returns to its equilibrium value over time. Pecchenino and Rasche (1990) have discussed the idea that neither velocity nor output is in fact, mean reverting. This criticism loses its significance, however, when one considers that velocity and output do not enter the P* model directly – they do so in terms of gaps. Hoeller and Poret (1991) have shown that if a linear combination of two non-stationary gaps is stationary, then the non-stationary gaps can enter a regression as right hand side variables. For econometric stability then it need only be necessary for the price gaps to be stationary and not the individual component deviations of velocity and output from equilibrium values.

The basic P* model forecasts inflation in accelerations of the inflation rate. Ebrill and Fries (1991) suggested it is more appropriate to predict inflation in levels rather than differences. They find that the equation specified in levels has a better fit. The original P* model regresses changes in the inflation rate on current inflation – in effect a change in the inflation rate is a difference of a difference and can lead to serial correlation. This paper cannot confirm this finding. When a model in differences is run against a model in levels, there is no evidence of serial correlation (as evidenced by the Durbin-Watson statistic).

Tatom (1990) cites a flaw with the P* model – the lack of an MA process in any autoregressive specification of current inflation. Tatom also suggests that the P* model may have a better fit with the M1 money stock measure – however, since M1 velocity would be more susceptible to monetary policy and changes in interest rates, M2 velocity is preferable as a money measure. Recent studies assess the importance of the P* model using international data. Two examples are papers by Habibullah and Smith (1995) and Ozdemir and Saygili (2008). Habibullah and Smith (1998) find that the P* model is appropriate for explaining inflation in Philippines over the time period 1981 to 1994. Ozdemir and Saygili (2008) test the P* approach on Turkish data and finds that it holds explanatory power for Turkish inflation, and is superior to the Phillips Curve approach.

DATA AND METHODOLOGY

The period of analysis for this paper is 1959:1 to 2012:4, and the data is sourced from the Federal Reserve Bank of St. Louis's FRED database. The data frequency is quarterly observations. This period of data is long enough to cover several key events in US macroeconomic history, such as the OPEC oil crisis and the recent Great Recession. Moreover, real business cycles have largely moderated over this period, leading to the term the "Great Moderation" (Stock and Watson, 2003). The use of such a long time series of data will also allow for the fine tuning of the predictive power of the various models used in this paper. The key variables used are the consumer price index (for all urban consumers), the M2 money stock, M2 velocity, real gross domestic product and the real potential gross domestic product. The sample is split into an in-sample period from 1959:1- 2007:1 and then an out-of-sample period (for forecasting purposes) from 2007:2 2012:4. From the data, the velocity gap, the output gap and the price gap are calculated based on the methodology in the previous section. Table 1 provides descriptive statistics on the mean and standard deviation for each of the base data series that are used in the paper.

Table 1: Descriptive Statistics for the Base Series (before Data Transformations)

	MEAN	STD. DEV
M2 MONEY STOCK	3083.94	2651.40
M2 VELOCITY	1.79	0.15
REAL GDP	7573.84	3423.58
REAL POTENTIAL GDP	7672.21	3543.82
QUARTERLY INFLATION RATE (%)	1.0	0.77

All variables are quarterly data from 1959:1 to 2012:4, sourced from the Federal Reserve's FRED database.
M2 money stock, real gross domestic product and real potential gross domestic product are in constant US dollars. For the econometric analyses of this paper, the data are transformed as per the price gap methodology.

HPS have differenced inflation rates – the acceleration of past inflation – as RHS variables to deal with stationarity issues. A drawback of differencing the data as HPS have done is that there is a loss of long-run information - "differencing eliminates all info on the long run properties of the model". This issue is discussed by Maddala (1992). One solution is to run the model in a levels form (as was done by Ebrill and Fries, 1991), while another solution is to run a vector error correction model. This paper runs the models in levels of inflation.

$$\pi_t = \delta + \beta_1 (p\text{-}p^*)_{t-1} + \beta_2 \pi_{t-1} + \beta_3 \pi_{t-2} + \beta_4 \pi_{t-3} + \beta_5 \pi_{t-4} + \mu_t \tag{8}$$

where $(p\text{-}p^*)_{t-1} = (v\text{-}v^*)_{t-1} + (y^*\text{-}y)_{t-1}$

<u>Models Based on Past Information</u>

Studies have compared the P* type models with AR-type models. Hoeller and Poret (1991) compare the P* approach with a standard second order autoregressive model. In this paper, the benchmark models are two-fold – an AR(4) approach and a simple ARMA (4,4) approach – adopting the MA terms is necessary to remove serial correlation. The ARMA (4,4) approach is chosen based on both the minimum AIC and SBC criteria. By modeling inflation using an ARMA process, Tatom's (1990) concern about the lack of MA terms is addressed. Using this approach, the current inflation rate is explained using four lags of inflation and four MA terms. Equations 9 and 10 below presents the models based on past lags of accelerations of inflation.

$$\pi_t = \delta + \beta_1 \pi_{t-1} + \beta_2 \pi_{t-2} + \beta_3 \pi_{t-3} + \beta_4 \pi_{t-4} + \mu_t \tag{9}$$

$$\pi_t = \delta + \beta_1 \pi_{t-1} + \beta_2 \pi_{t-2} + \beta_3 \pi_{t-3} + \beta_4 \pi_{t-4} + \gamma_1 \varepsilon_{t-1} + \gamma_2 \varepsilon_{t-2} + \gamma_3 \varepsilon_{t-3} + \gamma_4 \varepsilon_{t-4} + \mu_t \tag{10}$$

Based on this discussion, the following four models are run:
1. A benchmark AR(4) model;
2. The benchmark ARMA (4,4) model;
3. The price-gap model;
4. A standard Phillips-curve type model with an output gap.

A standard Phillips-curve type model based on Lucas is used in this paper. This is the modern form of the Phillips curve type model, where the output gap is measured as a deviation of output from the potential output level. When the output gap is positive, inflation accelerates, and monetary authorities respond by increasing the interest rate if they wish to reduce inflation. A higher interest rate reduces demand for investment and consumption and thus reduces inflation.

Stock and Watson (1999) employ the use of the simulated out of sample methodology. Similar methodology is used in several other papers that compare inflation forecasting models (see for example Le Bihan and Sedillot (2000), Forni, et al (2003), and Stella and Stock (2012)). In this paper, the four models are run over the in-sample period and then a rolling forecast method is adopted over the out-of-sample period 2007:2 to 2012:4, whereby the in-sample data set is initially increased by a quarter each time. The forecasts are thus performed for the k=1 horizon. The analysis is then continued for the k=4 horizons (and this horizon is later extended as a robustness check). The initial approach of forecasting single quarter inflation rates is in keeping with recent studies such as Faust and Wright (2011) as such forecasts allow for easier assessment of the various models' performance as the time horizons change.

EMPIRICAL RESULTS AND DISCUSSION

Table 1 presents in-sample results from the model based on past information, the price gap model, and the simple Phillips-Curve type model. The dependent and independent inflation variables are all specified in terms of levels. The results indicate that the price gap model tested is significant in explaining inflation. The AR and ARMA approaches are appealing in their simplicity and their econometric sense, and they also have very comparable adjusted R-squared values (Table 2).

Table 2: In-Sample Results for the Four Models (Inflation Calculated from Changes in the Consumer Price Index for all Urban Consumers)

Model	AR(4)	ARMA(4,4)	Price Gap Model	Output Gap Model
δ	0.11 (2.17)**	0.29 (1.75)	0.19 (3.63)***	0.09 (1.89)
$(p\text{-}p^*)_{t-1}$			17.45 (4.91)***	
$(y^*\text{-}y)_{t-1}$				-3.86 (-3.18)***
π_{t-1}	0.60 (8.18)***	-0.20 (-0.83)	0.45 (6.00)***	0.53 (7.09)***
π_{t-2}	0.02 (0.27)	-0.21 (2.17)**	0.05 (0.67)	0.03 (0.31)
π_{t-3}	0.45 (5.34)***	0.58 (4.84)***	0.41 (5.17)***	0.46 (5.61)***
π_{t-4}	-0.18 (-2.36)**	0.55 (2.63)	-0.10 (-1.44)	-0.09 (-1.20)
ε_{t-1}		0.83 (3.31)***		
ε_{t-2}		0.83 (5.69)***		
ε_{t-3}		0.36 (1.56)		
ε_{t-4}		-0.23 (-2.54)**		
Adjusted R-squared	0.73	0.74	0.76	0.74

****t-statistics significant at 1% level or less, **t-statistics significant at 5% level or less, *t-statistics significant at 10% level or less.*
Table 1 shows the regressions results for the in-sample period from 1959:1 to 2007:1 , using quarterly data sourced from the Federal Reserve. The dependent variable is the rate of inflation. (p-p) is the price gap, where p is the current price level in the economy, and p* is the level of prices that is proportional to the money stock per unit of potential output. (y*-y) is the output gap, where y* is the current level of real potential GDP, and y is the current level of real GDP. π represents inflation calculated as the annualized percentage change in the quarterly consumer price index.*

It is interesting to note that the output gap in the Phillips-curve type model has a lower explanatory power than the HPS price gap, indicating that the HPS price gap is capturing much more information than a simple output gap. This suggests that the HPS gap is providing additional information that would allow for a more refined inflation forecast.

To evaluate the best forecast in any horizon, previous studies such as those by Christiano (1989), HPS (1991), Fisher and Fleissig (1995), Atkeson and Ohanian (2001) and the Congressional Budget Office (CBO, 2013) are followed in using the root mean square error (RMSE) measure. The different models are initially tested in terms of forecasting ability over the one-quarter-ahead horizon, and then the forecasts are tested over the one-year-ahead (four-quarter-ahead) horizon.

Table 4 presents the RMSE values for all four models over the two different forecast horizons. To reiterate, the forecasts are generated using a rolling-regression forecast method where the in-sample regression period is extended one forecast period at a time. The findings are very similar to those echoed by the literature as far as naïve models are concerned. These models provide forecasts that are very comparable to the theoretical or statistical models such as the output gap model. However, by far the lowest-error predictions of forecasts are generated by the price gap model; this finding holds over both the shorter-term horizons.

Table 3: RMSE for Forecasts 1-Quarter Ahead and 4-Quarters Ahead (Inflation Measures Based on the Consumer Price Index for all Urban Consumers)

	k=1	k=4
AR(4) APPROACH	0.86	1.01
ARMA(4,4) APPROACH	0.92	1.06
PRICE GAP MODEL	0.71	0.77
PHILLIPS CURVE APPROACH	1.06	1.08

This table shows RMS for one and 4 quarters ahead.

Robustness Checks

Two key robustness checks are run to test the stability of the results. First, all the models are re-estimated with a different measure of inflation calculated from the consumer price index less food and energy prices (core CPI). The results from this analysis are presented in Table 4. The use of core CPI is useful for policy formation as this measure removes the impact of energy price shocks and is sometimes referred to by policymakers (Clark and McCracken, 2006).

The significance of the price gap model in explaining inflation remains robust to the use of core CPI. However, the question arises as to whether the model maintains its forecasting power. Table 5 presents the RMSE values for the k=1 and k=4 forecasting horizons when inflation is measured using core CPI (CPI less food and energy prices). The results show that the forecasting power of all four models improves – this is expected as core CPI has much less volatility than CPI for all urban consumers due to the absence of energy price and food price shocks. However, the results do indicate that naïve AR(4) model now provides superior forecasts. This finding reflects the results of Meyer and Pasaogullari (2010) who show that naïve models perform rather well compared to the more sophisticated structural models.

The second robustness check involves extending the horizon for the forecasts in order to check the various models predictive power over longer term horizons. The forecasting horizon is now 12 quarters ahead. This allows for the assessment of the various models' forecasting power over the medium to longer term horizon. For this analysis, the inflation rate is again calculated from the Consumer Price Index for all urban consumers. The RMSE values for the forecasts are shown in Table 6 below.

Table 4: In-Sample Results for the Four Models (Inflation Calculated from Changes in the Consumer Price Index less Food and Energy – Core Inflation)

Model	AR(4)	Arma(4,4)	Price Gap Model	Output Gap Model
δ	0.10 (2.17)***	0.23 (1.78)*	0.15 (3.37)***	0.07 (1.50)
$(p-p^*)_{t-1}$			15.69 (5.35)***	
$(y^*-y)_{t-1}$				-3.09 (-2.90)***
π_{t-1}	0.67 (9.15)***	-0.01 (-0.04)	0.50 (6.62)***	0.62 (8.31)***
π_{t-2}	0.09 (1.02)	-0.05 (-0.61)	0.12 (1.46)	0.09 (1.03)
π_{t-3}	0.26 (2.97)***	0.27 (3.34)***	0.27 (3.34)***	0.29 (3.37)***
π_{t-4}	-0.11 (-1.52)	0.56 (5.73)***	-0.04 (-0.55)	-0.05 (0.64)
ε_{t-1}		0.69 (4.85)***		
ε_{t-2}		0.71 (5.56)***		
ε_{t-3}		0.50 (3.68)***		
ε_{t-4}		-0.31 (-3.14)***		
Adjusted R-squared	0.76	0.78	0.79	0.77

****t-statistics significant at 1% level or less, **t-statistics significant at 5% level or less, *t-statistics significant at 10% level or less. Table 1 shows the regressions results for the in-sample period from 1959:1 to 2007:1, using quarterly data sourced from the Federal Reserve. The dependent variable is the rate of inflation. (p-p*) is the price gap, where p is the current price level in the economy, and p* is the level of prices that is proportional to the money stock per unit of potential output. (y*-y) is the output gap, where y* is the current level of real potential GDP, and y is the current level of real GDP. π represents inflation calculated as the annualized percentage change in the consumer price index and is represented up to 4 lags.*

Table 5: RMSE for Forecasts 1-Quarter Ahead and 4-Quarters Ahead (Inflation Measures Based on CPI Less Food and Energy Prices)

	k=1	k=4
AR(4) APPROACH	0.28	0.29
ARMA(4,4) APPROACH	0.44	0.47
PRICE GAP MODEL	0.43	0.46
PHILLIPS CURVE APPROACH	0.63	0.68

This table shows RMSE forecasts for 1 and 4 quarters ahead

The price gap model maintains the lowest RMSE even when the forecasting horizon is extended, thus reflecting its usability for policy formulation. As monetary authorities forecast forward to later phases in the real business cycles, the ability to harness a good forecasting model is important. Price gap models are marginally superior to naïve forecasts even over a medium term horizon.

CONCLUSION

Economic literature is rich in studies on forecasting inflation. The literature has suggested that the Fed should target inflation forecasts rather than the actual inflation rate itself, because of the lag between monetary policy and the effect on inflation. The classic price gap approach was hailed by many as an innovative approach to forecasting inflation and the model gained fame because of its forecasting capability over the longer horizons between two and three years.

Table 6: RMSE for the 12-Quarter Ahead Forecast Horizon (Inflation Measures Based on CPI for Urban Consumers)

	k=12
AR(4) APPROACH	0.55
ARMA(4,4) APPROACH	0.51
PRICE GAP MODEL	0.47
PHILLIPS CURVE APPROACH	0.71

This table shows the RMSE for the 12 quarter ahead forecast horizon.

This paper uses US data to assess the performance of the price gap model in forecasting inflation using recent data. Quarterly data is used to increase observations and the data is sourced from the Federal Reserve's FRED database. The data period is 1959:1 to 2012:4; the in-sample period is 1959:1 2007:1 and the out-of-sample forecasting period is 2007:2 to 2012:4. In order to fully assess the predictive role of the price gap model over other inflation forecasting models, three other competitive models are tested - an AR(4) model and an ARMA (4,4) model, and a Phillips Curve approach.

While recent studies have found that atheoretic models perform at par with or better than more sophisticated models, this study shows that the price gap model displays the lowest forecast errors over the 1-quarter ahead and 4-quarter ahead forecast horizons, and this result is robust to a longer horizon of 12-quarters ahead. However, the price gap model is sensitive to the measure of inflation and does not perform as well as a naïve autoregressive process when core CPI (CPI less energy and food prices) is used to calculate inflation. However, appropriate policy formulation should rely on a model that is able to perform well in spite of energy and price shocks and so the price gap model is the best inflation forecasting tool out of the four models tested in this paper. This result has important monetary policy implications, because of the monetary policy response to the correct identification of the size of the gap. Given that the size of the price gap is of vital importance, further research is needed on the optimal way to measure the velocity and output gaps.

The direction of the gap is also important - if the gap between P* and P is positive, this indicates that inflation will accelerate in the future to meet P*. If the Fed wishes to control inflation, they would then need to increase the interest rate. One the other hand, if the gap is negative, inflation will decelerate and monetary loosening may be in order. At the current time, the Federal Reserve is indeed contemplating a monetary contraction which indicates that the price level is below the long run equilibrium price level.

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