Rethinking the Phillips Curve: A Study of Recent Inflation Dynamics in the G-7

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Mark Cloutier

April 2012
Preface

As an introduction to my thesis, I would like to acknowledge my advisor – Robert Murphy – for his outstanding contribution to this work. This absolutely would not have been possible without his support, guidance, confidence in and commitment to me. Further, I would like to thank my family and friends for keeping things in perspective throughout my authorship of this work in the way that only they can.
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Introduction

This paper sets out to explain recent inflation dynamics in the G-7\(^1\), focusing specifically on fluctuations that have occurred since the beginning of the Great Recession in 2008. Over the past fifty years, the Phillips curve has been used to predict the short run trade-off between unemployment and inflation. And, generally, the Phillips curve has served quite well as a framework for explaining inflation. Recently, however, economists encountered a problem when using Phillips curves estimated through 2007 to create dynamic forecasts of inflation for the United States over 2008-2011; they predicted a significant deflation, which did not occur. Several explanations have been posited for this failure of the model as it applies to the United States’ economy, including a change in the way that expectations about inflation are formed and a change in the sensitivity of inflation to economic slack. Additionally, some suggestions made before the crisis have been noted for their particular relevance, including Bryan and Cecchetti (1994), who proposed using a weighted median of price changes across industries to more accurately measure core inflation. To date, the empirical work on the failure of the Phillips curve to predict recent inflation has been largely restricted to the United States’ economy. Ball and Mazumder (2011) consider several modifications to the standard Phillips curve to improve the accuracy of inflation predictions in the United States over the period 1960 to 2010. In this paper, we aim to generalize those

\(^1\) An economic and political group composed of seven industrialized nations: France, Germany, Italy, Japan, Canada, United Kingdom, and United States.
results throughout the G-7. We will create dynamic forecasts of inflation for each country in the G-7 using a standard Phillips curve and compare those results to forecasts created using the modified curve suggested by Ball and Mazumder.

We have selected the G-7 because it offers a set of modern economies which have accessible data on necessary indicators and on the presence and reliability of central banks. Further, there is significant variability in the current state of these economies and the level at which each was affected by the economic downturn from 2008-2011. This study will help provide more certainty as to the general applicability and accuracy of the changes to the Phillips curve proposed in this paper.

This research is important because deflation is a significant threat to the world economy and a better understanding of the link between unemployment and inflation will allow for more accurate forecasting of future inflation. By generalizing the theories of Ball and Mazumder, we are able to lend support to their theories of time-varying slope and level-anchoring on a more general level. This being said, Ball and Mazumder warned that a continuation of the current recovery rate in the United States might eventually lead to deflation as expectations continue to adjust. This implies that many of the countries for which our analysis was performed face that same risk. Creating an accurate forecasting method, therefore, is an essential tool in combating future deflation and downturn.

I. The Phillips Curve

We first introduce a standard Phillips curve and explain its components. Since the work of Milton Friedman in the 1970’s, the Phillips curve has measured the inflation-unemployment tradeoff with respect to three main determinants: expected inflation, the deviation of unemployment from its natural rate, and supply shocks. We can express this relationship as follows:

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2 Please note that we have elected to follow the notation and structure proposed by Ball and Mazumder (2011) as closely as possible in order to make our results easily comparable.
\[ \pi_t = \pi^e_t + \alpha(u - u^*)_t + \epsilon_t \]  

(1)

Where \( \pi \) is annualized inflation, \( \pi^e \) is expected inflation, \( \alpha \) is the unemployment coefficient, \( u - u^* \) is the gap between unemployment and its natural rate, and \( \epsilon \) is an error term. It is important to note that in this case, the error term reflects the effects of relative price changes, including supply shocks. However, in this paper we will be using measurements of core inflation, which strip away the effects of supply shocks. In this case, we assume relative price changes are removed imperfectly and the error term reflects those effects which are not removed; this will be treated in more detail later in the paper. Additionally, a common variant of this equation, which we will use in this paper simply because of the consistency and availability of the data, substitutes the output gap, \([GDP - Potential GDP]/Potential GDP\), for the unemployment gap, \( u - u^* \). The inverse relationship between the output gap and the unemployment gap is specified by Okun’s Law.

To measure expected inflation in our basic Phillips curve, this work will follow the example of Ball and Mazumder (2011), which utilizes a special case of the curve estimated by Gordon and Stock-Watson. In this case, the curve is based entirely on backward-looking expectations and assumes that expected inflation is the average of inflation over the previous four quarters:

\[ \pi_t = \frac{1}{4} (\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) + \alpha(gap)_t + \epsilon_t \]  

(2)

where we have substituted the output gap for the unemployment gap in equation (1).

In addition to implying purely backward-looking expectations, this model implies a specific relationship between the output gap and inflation. A one percentage point increase in the gap,

\( \frac{1}{4} \) This is the slope of the Phillips curve, which is theoretically determined by the level and variance of inflation
\( \frac{1}{4} \) See footnote 7 for an explanation
\( \frac{1}{4} \) Okun’s law is the empirically observable relationship between unemployment rate and output gap. For every percentage point that unemployment increases above its natural rate, output gap increases by two percentage points; this means that they have a trade-off coefficient of \( \frac{1}{2} \).
sustained over one quarter, will have a total impact on inflation of 0.4 times the gap coefficient $\alpha$. If that gap persists over one year, the long-term impact will be 1.6 times $\alpha$. (See appendix 1 for an explanation of this result).

We use equation (2) to make our initial dynamic forecasts for the G-7. First, we check the accuracy of the curve from 1960-2007 throughout the G-7; table 1 demonstrates the RMSE, MAE, and MAPE for each\(^6\). This exercise turns back fairly consistent results with no extreme outliers; however, this case does not hold when we run forecasts for 2008-2011 (also depicted in table 1). From 2008-2011, the standard Phillips curve predicts a large drop in inflation for the US, Canada, Japan, France, Italy, and the UK. These results are not perfectly synonymous – for example, models for the US, Canada, and Japan predict inflation will become negative (or in Japan’s case will become further negative) while models for France, the UK, and Italy predict that inflation will fall but stay positive – however, each predicts inflation will fall more significantly than it does. This result suggests that the theories presented by Ball and Mazumder with regard to the United States may be generally applicable at least throughout the G-7. This being said, Germany presents us with a unique case over the forecasting period. For Germany, the Phillips curve is relatively accurate, but in fact suggests inflation will remain slightly higher than the actual data reveals. In the next sections we will show that it is possible to create more accurate forecasts for each country in the G-7 – including Germany – with the theories suggested by Ball and Mazumder (2011). We will begin by discussing sticky price theory to explain how understanding the theory behind the Phillips curve can motivate improvements in the model.

II. Sticky Price Theory

\(^6\) Briefly: Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Mean Absolute Percentage Error (MAPE) are all measures of accuracy. The RMSE can be thought of as the standard error – the average distance of a data point from a fitted line. The MAE measures the average magnitude of errors in a forecast. Used together, the RMSE will always be larger than the MAE, however the greater the difference, the greater the variance in the individual errors in the sample. The MAPE is simply a measure of average percentage error.
Sticky price theory is the most common economic model used to explain the upward-sloping short-run aggregate supply curve. It posits that firms do not respond immediately to changes in demand, but rather because of long-term contracts, sticky wages, and menu costs – each affecting firms at a different level – firms differ in their ability to react quickly to demand changes in the market. In the model, some firm’s prices are assumed to be sticky, while others are assumed to be flexible, giving rise to the standard short-run aggregate supply curve \( Y = Y_{bar} + \beta(P-EP) \). A simple manipulation of this equation gives rise to the standard Phillips curve, which we use in this paper (the derivation is shown in appendix 2). Sticky price theory has become increasingly important because it motivates two important modifications we make to the model: the use of core inflation and the use of a time-varying slope. Sticky price theory suggests that when shocks occur, skewness will arise in the distribution of price changes, causing movements in aggregate inflation.

Measurements of core inflation, as previously explained, are meant to filter out these effects. Further, sticky price theory suggests that the slope of the Phillips curve will vary with the level and variance of inflation – specifically, as inflation and/or variance increases, nominal price stickiness will fall and lead to a steeper slope. Both these ideas will be treated in more detail in the next section.

III. Literature Review

3.1 Bryan and Cecchetti (1994)

In *Measuring Core Inflation* (1994), Bryan and Cecchetti discuss the best measure of core inflation.\(^7\) In their paper, the pair defined core inflation as “the component of price changes that is expected to

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\(^7\) Core inflation is a valuable measure as many economists believe that supply shocks have had little bearing on future inflation in the United States since the 1980’s; Ball and Mazumder (2011) cite papers such as Sommer (2004) and Hooker (2002) to justify this assertion.
persist over the medium-run horizons of several years.” This means that core inflation isolates two of the three components of Gordon’s “triangle model” - namely economic activity and expected inflation - while stripping away supply shocks. By using core inflation, we are able to see what portion of inflation is “money-induced.” Bryan and Cecchetti created a simple model driven by sticky-price theory in which they suppose at period one, the economy is stable and all firms are adjusted to any previous shocks. In period two, they introduce a supply shock. When they do this, they assume only some firms adjust their prices because menu costs create a minimum threshold at which firms deem it prudent. Further, the model assumes the shock has an arbitrary distribution. If the shock is symmetrical then no inconsistency occurs, however, if the shock is skewed and the distribution of price changes is unequal, then an average of the cross-sectional distribution of price changes will give an inaccurate measure of core inflation. This leads us to limited-influence estimates of core inflation where the outlying portions of the cross-sectional data are trimmed. Bryan and Cecchetti experiment with CPI less food and energy (XFE inflation), a 15-percent trimmed mean, and a weighted median. They conclude that the median has the “strongest relationship with past money growth and provides the most accurate forecast of future inflation.” However, they do not conclude that weighted median is significantly different from other measures of core inflation, therefore, due to the difficulty involved in generating a weighted median for the entire G-7 (and in the interest of keeping this research applicable to all countries and all extensions of this work for which a weighted median is not readily available) we will not go beyond acknowledging the weighted median for informational purposes. Instead, we will proceed with traditional core inflation, understanding that it is preferable to total inflation as it at least partially filters out the effects of supply shocks which, as explained, should not have a significant effect on inflation for countries with stability-conscious central banks.

3.2 Ball, Mankiw, and Romer (1988) & Ball and Mazumder (2011)
Ball, Mankiw, and Romer proposed that changes in the level and variance of inflation motivate a time-varying slope for the Phillips curve. Sticky price theory suggests that when nominal price adjustment is costly, firms will choose to make their adjustments when the level and variance of inflation is high. That is, with high inflation levels and/or variance, firms will adjust more frequently, increasing the sensitivity of price to changes in demand. This sensitivity is reflected in a steeper slope of the Phillips curve and implies that the coefficient ($\alpha$) increases in absolute value with the level and variance of inflation. This result is somewhat intuitive as high variable inflation means that large swings in price level are occurring, making it more costly to hold prices constant. On the other hand, in times of low levels and/or variance of inflation, firms are less likely to adjust, the curve becomes relatively flat, and fluctuations in nominal aggregate demand have large effects on output. (Ball and Mazumder suggest that this relatively flat slope is especially pertinent to the US model because it holds, more or less, from the late 1980’s through 2011; further, we will show that this is also the case for many of the other countries in our sample, especially in the 2000’s).

We will now deviate from the specific text of Ball, Mankiw, and Romer (1988) in order to retain consistency in the form and notation we have used thus far in our paper. We will refer to the section on time-varying slope written in Ball and Mazumder (2011), which reflects the findings of Ball, Mankiw, and Romer (1988). Ball and Mazumder introduce a standard regression equation with a time-varying coefficient by generalizing the backward looking Phillips curve, equation (2), as such:

\[ \pi_t = \frac{1}{4} (\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) + \alpha_t (\text{gap})_t + \xi_t \]  

(3)

Where $\alpha_t = \alpha_{t-1} + \eta_t$

In this equation $\eta_t$ and $\xi_t$ are white noise errors which imply that the coefficient ($\alpha$) follows a random walk as it varies over time. While more than one method can be used to estimate the path of $\alpha$ as specified in DeVeirman (2007), Harvey (1989), Wright (2010), and Ball and Mazumder (2011), they reach
a general consensus on the overall trend. That is, regardless of the method used, the movements of $\alpha$ are remarkably consistent with the path prescribed by sticky price theory; as shown by Ball and Mazumder, the level and variance of inflation trend together and their movements are closely tracked by the coefficient $\alpha$. As one might assume, this means the United States experienced a relatively flat Phillips curve before 1973 and after the Volcker disinflation of the mid 1980’s, with a steep curve in the interim period of high, variable inflation from 1973-1985. Ball and Mazumder conclude by saying, “In the period since the mid-1980’s – the second half of the sample – the estimated $\alpha$ is quite stable. Given the standard errors, there is no evidence against a constant $\alpha$ over 1985-2010.” This result is of course for the United States. We apply a similar framework to the one suggested by the authors cited above in order to show that, given a relatively stable or constant $\alpha$, significant improvements can be made to the Phillips curve model and our dynamic forecasts throughout the G-7.

3.3 Ball and Mazumder (2011)

Ball and Mazumder expand on the work of Mishkin (2007), Bernanke (2010), and Kohn (2011), to argue that expectations have become “anchored” in the United States with the continued commitment of the Federal Reserve to low, stable inflation. This model is important because it argues that the standard model assumption (expected inflation equals past inflation) is no longer valid. Further, it validates the need for an accurate measure of core inflation, as it implies that shocks no longer feed significantly into expectations of future inflation. Ball and Mazumder present two kinds of anchoring – shock anchoring and level anchoring – and argue that expectations have become fully shock anchored since the early 1980’s and level anchoring, while incomplete, has gradually increased.

Ball and Mazumder note, as many have before, that before Paul Volcker, the Fed accommodated supply shocks, allowing inflation to rise, increasing expected inflation, and looping forward into future expectations. However, in the late 1970’s, Volcker began to systematically oppose this process and in
doing so, was able to form a credible commitment to stable inflation. That is, people came to believe that the Fed would not allow supply shocks to greatly affect inflation. As a result, supply shocks no longer have a significant effect on expectations or future inflation and “shock anchoring” has become a “stable feature of the post-Volcker monetary regime” (Ball and Mazumder pp. 20).

Level anchoring refers to a public belief that the Fed is committed to an inflation target – namely 2% PCE inflation (which corresponds roughly to 2.5% core inflation). While shock anchoring has been a steady fixture since the 1980’s, level anchoring is a more recent phenomenon – Ball and Mazumder cite Taylor (1993) in placing it around the early 1990’s for the US. In light of this belief, Ball and Mazumder introduce another alteration to our standard Phillips equation which integrates the public’s belief in the inflation target and balances it against lagged inflation as such:

\[ \pi_t = \delta_t 2.5 + (1 - \delta_t) \frac{3}{4} (\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) + \alpha \text{gap}_t + \epsilon_t \]  

(4)

Where \( \delta_t \) follows a random walk and expected inflation is an average of lagged inflation and 2.5% with time varying weights. When \( \delta = 0 \), expectations are purely backward looking and when \( \delta = 1 \), expectations are fully anchored at 2.5%. We use 2.5% here as opposed to 2% because we are using core CPI inflation, not core PCE inflation in our equation. Using actual inflation data, Ball and Mazumder reach estimates for \( \delta \) of 0.47 for unemployment gap and 0.30 for output gap in 2010Q4. Our own data provides us with a similar estimate of .29 (obtained from output gap) which we utilize in our model.

Ball and Mazumder note that anchoring in the equation has relatively little effect over the period from 2007-2010 as inflation remains relatively close to 2.5%. However, assuming \( \delta \) remains at its 2010Q4 level, when forecasting inflation over 2011-2013 they find the weight to be essential in correcting errors in the model. A significant deflation is predicted by the standard model over the next two years, but with anchoring, inflation bottoms out at 0.5% and then rises to 1% by the end of 2013 (Ball and Mazumder pp. 23). They note however, that the degree of anchoring which they use is highly
uncertain. They inquire as to whether expectations will remain at 2.5% while actual inflation is predicted to remain at or below 1% for several years. In one view, they hold people’s beliefs that the Fed will eventually return the inflation rate to 2.5% will be sufficient to hold up expectations. They concede however, that most theories, like sticky price and sticky information theory, say that prices depend on “expected inflation over the period when the prices are likely to be in effect” (Ball and Mazumder pp. 23). This view is also substantiated by the empirical work of (Fuhrer 2011). If this is the case, Ball and Mazumder suggest that it is unlikely sufficient anchoring will occur to maintain positive inflation in the United States from 2011-2013.

IV. Expanding on Existing Theory

4.1 Central Banks

The credibility of the Fed and its commitment to predictable and stable inflation is a key component of Ball and Mazumder’s argument for anchoring in the United States. Since this work seeks to generalize their results to the G-7, it is important to look at the policies and targets purveyed by central banks throughout the G-7.

One of the most interesting cases in the G-7 is the European Central Bank and the euro. Germany, Italy, and France are all tied to the euro and share a single monetary policy imposed by the ECB, namely, an inflation target of close to but less than 2% (European Central Bank). However, due to the differences among their economies, each country exerts a considerably different force on their individual levels of inflation. This will be discussed in greater depth later in the paper, but it is important to our analysis that Germany has experienced relatively low levels of unemployment throughout the recession as compared to other countries within and without the EU. Germany’s relative prosperity (despite a brief downturn) is largely responsible for its unique forecasting results.
Japan presents an interesting case because while it has a central bank, it lacked an inflation target until February of 2012. While Japan has now instituted a surprisingly low target of just 1%, it is not especially relevant to our analysis as the new target has no bearing on expectations in Japan during the forecasting period we examine (Tabuchi). As we will show later, however, our model assumes that expectations in Japan were anchored just above 0% during the recession as inflation has oscillated around zero since the early 2000’s. Japan is important because it presents an extreme case upon which to test Sticky price theory. If Sticky price theory holds, then Japan should have an exceptionally low coefficient (alpha) for output gap because inflation has been so low and has had such low variability.

The Bank of England sets a modest inflation target for the UK of 2.5% (Vickers). Although our series varies quarter-to-quarter, it is fairly stable year to year so we again expect a relatively low coefficient (alpha) on output gap and a mild commitment to anchored expectations. The UK is our only European country which is not tied to the ECB inflation target and policy. This is important because it reveals some important questions about the relative deflation in Europe against the rest of the G-7, which we discuss in the final section of this work.

Canada is perhaps the most stable of the countries we examine outside of the United States, with an inflation target set by the Central Bank of Canada from 1% to 3%, Canada experienced a brief deflation during 2009 but has otherwise remained relatively close to its targeted rate throughout the Great Recession (Bank of Canada). Bearing these facts in mind, we assume that the model for Canada will behave most like that of the US and correspondingly, that it will react most similarly to the United States as we apply changes to the curve as discussed above.

The model for the United States has been well discussed and documented in this paper and others, but briefly, the US has a strong central bank, which pursues an inflation target of 2.5% (Ball and Mazumder 2011).
Understanding the monetary policy, central bank reliability, and recent history of inflation for each of these countries allows us to better understand which corrections should be applied to forecast curves for each country and further in determining the degree to which each correction applies. For some countries, we expect that anchoring will be the more dominant weight while others should be primarily affected by time-variation or a combination of both.

V. Results

5.1 Introduction

In this section, we will present our findings on the applicability of time-varying slope and anchored expectations throughout the G-7. While we acknowledge the work done by Ball and Mazumder with respect to measuring inflation with a weighted median, we feel it is non-essential to correcting the basic flaws in Phillips curve forecasts with respect to times such as the Great Recession wherein there is a large and sustained change to inflation and unemployment.

Figure 1 and Figure 2 are designed to give the reader an idea of the magnitude (to capture exactly how widespread the effect is) of the Great Recession. Figure 1 shows the output gap for all countries in our sample. The recession is immediately obvious as it causes every country in our sample to sustain a pronounced and sustained “drop” - where a greater negative gap means that output is further below its potential than before - in output gap. This graph accurately captures the degree to which each country was hit and the speed at which it recovered. These will be helpful reference points when we discuss forecasting for each country. Figure 2 shows a comparison of all “standard” – 4 quarter lagged inflation curves from equation (2) – Phillips curve forecasts over 2008q1-2011q4. Please note that this graph is useless for determining how accurate each curve is individually; figure 2 is meant only as a reference to show the relative magnitude of each drop predicted by the traditional Phillips curve. It is interesting to
note that the four European countries are predicted to remain relatively higher than the three non-European countries, which we will discuss later in this section.

We will proceed in the following sub-sections by walking the reader through our methodology for formulating our “corrected” forecasts, providing detail on how and why we select the parameters we use during estimation, and then providing a discussion of the results. Please note that the sub-sections will decrease in their “comprehensiveness;” in the interest of negating redundancy, we will thoroughly explain each step in the first sub-section below and become progressively more concise in the latter sections in which certain details and explanations will have become repetitive provided the earlier sections have already been read.

5.2 United States

We begin with our results for the United States because it allows us to compare (or run an accuracy test) against the research done by Ball and Mazumder. With similar results, we will be able to proceed with confidence in discussing the Ball and Mazumder theories as they apply to other countries.

We begin with the basic backward looking Phillip’s curve, equation (2):

\[ \pi_t = \lambda (\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) + \alpha(gap)_t + \varepsilon_t \]

The equation imposes a weight of .25 on each of the previous four quarters of lagged inflation. We run a regression on this equation to produce our initial dynamic forecast of inflation for the US over the estimation period 2008q1 – 2011q4. As papers before have shown, this estimation fairs poorly as inflation is predicted to fall just below -3% in 2011q4 while actual core inflation stood at almost 2%. In order to account for this drastic under-prediction we reintroduce the concepts of anchoring and time-varying slope.
Recall equation (2) from above, which states that inflation is a function of expected inflation and the unemployment gap:

\[ \pi_t = \pi^e_t + \alpha(gap)_t + \epsilon_t. \]  (6)

We now introduce an equation for expected inflation with anchoring as follows:

\[ \pi^e_t = \delta(2.5 + (1- \delta)(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) \]  (7)

As was previously discussed, this equation allows for any value of delta between zero and one which allows for inflation to vary from being entirely determined by lagged inflation to being entirely tied to 2.5% respectively. This equation can be inserted back into equation (6) in place of expected inflation to create equation (4) which is discussed in section 3.3

\[ \pi_t = \delta(2.5 + (1- \delta)(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) + \alpha(gap)_t + \epsilon_t \]  (8)

We deviate from the example of Ball and Mazumder here. Instead of estimating for the entire path of delta (which they conclude is relatively stable beginning in the early 1990’s) we isolate delta in equation (8) as follows:

\[ \pi_t - 0.25(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) = \delta(2.5 - (0.25 (\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4})) + \alpha(gap)_t + \epsilon_t \]  (9)

This allows us to regress the left hand side of the equation on the right hand side and the output gap, which returns a value for delta over a given estimation period. Ball and Mazumder find (using a fixed ratio of variance and a Kalman smoother) that delta is negligible until the late 1980’s before rising and becoming relatively stable in the early 1990’s. They find a value of .26 using output gap in the Phillips equation for 2007q4, which they assume to persist over the estimation period. In order to check against Ball and Mazumder we ran the regression suggested above for the period 1965q2-1985q4 which returned a delta which was slightly negative, but statistically 0. Next we estimated from 1986q1-2007q4
which returned a relatively small delta of .05. However, estimating from 1992q1-2007q4 and from 1997q1-2007q4 yielded deltas of .29 and .28 respectively. We concluded, as did Ball and Mazumder, that a relatively similar delta persists for the estimation period 2008q1-2011q4.

As discussed above, we assume that the US is fully shock-anchored; (we will assume this for all of the countries in the G-7). We do this because the effect is small and it is a relatively safe assumption – Ball and Mazumder show that this assumption holds true for the United States. Additionally, we select .29 as our degree of level-anchoring over the estimation period in accordance with our regressions from above. For the US, inflation is relatively close to 2.5% leading up to the forecast and the level of anchoring is relatively small; further, as Ball and Mazumder also point out, the degree of anchoring is fairly uncertain with a 95% confidence interval which spans from .08 - .50. In their paper, Ball and Mazumder run forecasts using predicted unemployment figures over 2011-2013 to extend their data set; in this situation where inflation leading up to the forecast was far below the target, anchoring became very significant and was needed to hold forecasts above 0. We will not specifically expound upon this for the United States because other countries within the G-7 will offer similar situations and will be discussed later in the paper. In our case with the Great Recession, while anchoring is important, it is not sufficient in and of itself to explain the degree of forecasting error.

This being said, we find the most interesting result for the US regression to be the coefficient on the output gap, alpha – which corresponds to the slope of the Phillips Curve. We run several regressions with the anchoring parameter of .29 in place for delta as follows:

$$\pi_t = (.29)2.5 + (1-.29)\frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) + \alpha(gap)_t + \epsilon_t$$

(10)

We run the first over the entire data set from 1965q2-2011q4, the second from 1985q1-2011q4, the third from 1992q1-2011q4, and the fourth from 1997q1-2011q – from which we are able to create forecast series. We did this because depending upon the length of time included, STATA calculates a
unique coefficient for the output gap (alpha) which moves with the level and variance of inflation. Recall that the coefficient, alpha, corresponds to the slope of the Phillips curve and that sticky price theory suggests higher and more variable inflation will lead to a steeper curve. The regression over 1965q2-2011q4 produced an alpha of .19 (a steeper curve resulting from the high and variable inflation of the mid 1970s and early 1980s) and the forecast series over 2008q1-2011q4 produced using the constant alpha of .19 and constant delta of .29 only removed about half the error from the original Phillips Curve forecast; despite including the level anchoring at 2.5%, it predicted an inflation rate of 0.3% for 2011q4. This, however, is good news in disguise; after the early-1980s, a period of low, stable inflation set in and it is therefore unlikely that an alpha of .19 is a realistic parameter to hold over the estimation period. Narrowing the scope of our regression to include more recent data, we ran regressions over 1985q1 -2011q4, 1992q1-2011q4, and 1997q1-2011q4 which returned values for alpha of .07, .03, and .05 respectively. As inflation level and variability fell in the early 1990s – just as sticky price theory suggests – so did the propensity of businesses to adjust their prices. This created a flattening of the Phillips curve. Forecasts over 2008q1-2011q4 using alphas of .07, .03, and .05 made stark corrections in the curve (See figure 3) producing forecasts of 1.7%, 2.1%, and 1.9% for 2011q4 respectively compared to an actual core inflation rate of 1.9%.

This result leads us to conclude that perhaps the largest factor in the errors we have encountered is that the original model does not allow for a time varying slope. Thus, in times such as the great recession from 2008-2011, where inflation is generally low and stable at the outset, a sudden or extreme increase in unemployment and/or output gap will be overemphasized by the traditional Phillips curve. We will now examine how this result translates to the other countries in the G-7.

5.3 The United Kingdom
Although the Phillips equation does not suggest the UK will experience sub-zero inflation, the UK falls victim to the same under-prediction problems as the United States. A standard Phillips curve for the UK predicts inflation will be 2% throughout 2011; while this is not far from the 2.5% actual core inflation for 2011q4, it is a far cry from 6% inflation in 2011q2 and the yearly average of just above 4% for 2011.

As mentioned in section 4, the central bank of England utilizes an inflation target of 2.5%. We begin by running a standard Phillips curve regression using our lagged model with no anchoring parameter over the entire data set. Our resulting forecast for 2008q1-2011q4 is a relatively stable line near 2%. While this seems counterintuitive at first as inflation in the UK bounds continuously between 0% and 5% from quarter to quarter in the mid-2000s, keeping in mind that the model takes a lagged average of the last 4 quarters, a relatively flat prediction around 2% makes sense as year-to-year inflation is actually quite stable around this level.

In the UK, it is level-anchoring which makes the largest contribution towards correcting our forecasting errors. Again using the manipulation from equation (9), we can isolate an estimation for delta (the anchoring coefficient) with respect to the inflation target of 2.5%. When we do this using the full sample from 1997q2-2007q4 we get a relatively modest coefficient of 0.1, however, the confidence interval spans from just below -.37 to .57. This being said, although the quarter to quarter inflation rate is rarely near the target, looking at inflation on a truly annual basis, the English central bank is remarkably close to its target year to year. In figure 4, the graph shows forecasts with a delta for level anchoring of 0.1 and constant alphas, which are all actually slightly negative but not statistically different from 0; these fair only slightly better than the standard Phillips curve prediction and are not significantly different from each other. However, if the predictions are done again with a similarly reasonable level of anchoring such as 0.3 (one similar to the case of the US,) the graph becomes much
more accurate. The assumption that the UK has developed a fair degree of level anchoring is a relatively safe one. The UK has now had an inflation target for 20 years (since 1992) and has a fairly strong and independent central bank. The year-to-year consistency of inflation average coupled with these facts makes our assumption of anchoring a very reasonable one. Thus, with regard to the UK where there has not been significant time variation within the curve, much of the forecasting error in the original Phillips curve prediction can be attributed to the equation’s lack of an anchoring parameter.

We proceed from anchoring to check the effect of our time varying slope parameter. The results are somewhat surprising, but again, it is important to keep in mind the form of lagged regression we utilize and the consistency with which inflation varies in the UK. While inflation bottoms out below -2% in 2000q1 and peaks at 6% during 2010q2, it oscillates steadily just above 1% into the mid-2000s before beginning to climb in a similar fashion up above 2%. Thanks largely to this steady cyclical nature, our regressions for the UK over both 1997q2-2007q4 (the full sample) and 2002q1-2007q4 return alphas which are not statistically different from 0 for both an anchor of .1 and of .3. This occurs because inflation is never continuously high or low and the quarter to quarter variation is washed out when averaged together over longer periods.

5.4 Japan

Like the US and the UK, forecasts for Japan over the Great Recession using a standard Phillips curve produce significant under-predictions. While inflation in Japan did stand below zero at -1.2% in 2011q4, forecasts made using equation (2) produce -4.5% for the same quarter. Japan is perhaps the most unique within the group of countries which exhibit under-predictions. As noted before, Japan is different in that it has frequently experienced deflation since the 1980s and has no acting inflation target during the period which we are examining. Further, with near-zero inflation for almost 20 years coupled with low variability since the early-1980s, we can assume Japan will not be exceptionally
affected by a time-varying slope. This leaves us in an interesting predicament; based upon the excess deflation predicted by the traditional Phillips curve, it seems likely that there is some form of active level-anchoring despite Japan’s lack of an explicit inflation target. This topic should be explored further on its own as the 1% inflation target instituted by Japan’s central bank in 2012 has been intensely debated and criticized – a simple internet query for Japan’s inflation target will return a host of conflicting opinions on the subject. By looking at the average inflation rate over the past 15 years, we conclude that any level-anchoring which occurs is probably at 0%. Thus, we proceed with our analysis as we’ve done for previous countries, simply using 0% in our equation relating to level-anchoring.

For Japan, we again use equation (9) to isolate a value for our level-anchoring coefficient, delta. We use regressions in STATA as before, running regressions over the entire set from 1971q2-2007q4 and for smaller intervals beginning in 1985q1, 1992q1, and 1997q1. The full set gives a delta of only .06 and an alpha (time-varying slope coefficient) of .24; these numbers are unlikely to be in effect during our estimation period, however, as they take into account the long passed high, variable inflation of the mid-1970s. Instead, we look at the other three regressions which report a steadily increasing level of anchoring at .19, .39, and .54 respectively. We opt to use .39 because its 95% confidence interval overlaps with the interval produced in the other two regressions. This is a fairly high level of anchoring, however, given the relative proximity to zero-inflation which Japan has maintained over the last 15 years, this is unsurprising.

Holding delta fixed at .39 and assuming expectations are anchored at 0%, we use equation (10) to run regressions over 1971q2-2007q4, 1985q1-2007q4, 1992q1-2007q4, and 2002q1-2007q4. These regressions return values for alpha, which we will hold constant over our forecast period from 2008q1-2011q4. As mentioned above, the regression over the full set (1971q2-2007q4) returns a coefficient of .24 which diminishes significantly as we remove the 1970s from the set. The regressions beginning in
1985q1, 1992q1, and 2002q1 are not significantly different from one another returning values for alpha of .13, .11, and .09 respectively. This is the result of low inflation and low variability causing the curve to flatten significantly beginning in the late-1970s and continuing through our estimation period. We run dynamic forecasts using all three of the values generated by the truncated periods but find they are not significantly different from one another. Figure 5 shows only one of the forecasts from the three similar alphas above simply for clarity (the forecasts otherwise appear so close together it makes it difficult to see actual inflation). Our forecast is shown with the normal Phillips curve estimate and the forecast generated without adjusting for time-variation (an estimation which generates an alpha of .24).

In Japan’s case, it is clear that there is some implicit anchoring occurring. It appears that although the country lacks an explicit target, people have come to expect over the last two decades that inflation will hover somewhere near 0. Japan’s new inflation target, its effectiveness, and a justification of its level are outside the scope of this work but merit some further study with the understanding that even without an explicit target, it seems Japan’s businesses are steadily increasing their expectation that inflation is anchored around 0%.

Japan’s results again confirm the strategies discussed by Ball and Mazumder – adjusting for time-variation in the slope and allowing for anchoring. We think that these strategies again generated acceptable results in the case of Japan and add the caveat that we do not believe a country necessarily must have an explicit inflation target for level-anchoring to be an acting force.

5.5 Canada

Canada was one of the first countries to institute an inflation target along with the UK in 1991. However, it is unique in that it imposes a range of 1% to 3% as mentioned in section 4. While Canada experienced periods of high variable inflation from the early-1970s up until the early-1990s, a strong central bank commitment to controlling inflation is obvious in the inflation graph over the past two
decades. For this reason, it is obvious that time-variance will have some effect, but due to the relative stability of the last 20 years, anchoring should have a more pronounced effect. As was the case with the US and Japan, the standard Phillips curve predicts a significant drop in inflation over the forecast period 2008q1-2011q4; while actual core inflation in 2011q4 was 2.1% the standard Phillips curve from equation (2) produces -2.1%.

We proceed the same way as before, using equation (9) to test the level of anchoring over various periods. We find that there is no anchoring until the late 1980’s where the parameter begins to climb. Using data from 1986q1-2007q4 we produce a delta of .32, however, it is likely that more recent estimates will be more accurate. Using data from 1992q1-2007q4, delta spikes to .85 with a relatively small standard error of .24, however, in the later 1990s, the parameter sinks again. We opt to utilize the delta produced by the regression over 1997q1-2007q4 of .69 – still the highest such parameter in the G-7 produced for the Great Recession.

Holding delta fixed at .69, we compare time-varying slopes using the general regression in equation (10) as before. Because the Canadian central bank utilizes a target range from 1%-3% we elect to tie expectations to an average of 2% (we will discuss the consequences of this later in this subsection). As one might expect, the parameter falls significantly as variability fades in the late 1980s and inflation level falls to the lower end of its range in the early 2000s. We produce a graph in figure 6 which compares the standard Phillips curve equation to the forecasts produced by using the fixed delta of .69 and the fixed alphas of .28, .11, and .01 estimated over the periods 1985q1-2007q4, 1992q1-2007q4, and 2002q1-2007q4 respectively. It is clear from the graph that anchoring is the most important variable in correcting for forecasting error and is sufficient to keep our forecast positive and relatively accurate, however; time variation clearly helps “fine tune” the positioning of our actual correction.
Canada is a clear case in which a strong central bank with a clear and long-standing inflation target (which has been largely adhered to) influences the expectations of people and most importantly of businesses. Accounting for a widespread belief that inflation will remain between 1% and 3% removes much of the forecasting error from the standard Phillips curve. Further, recall that we chose to tie expectations to an average level target of 2% - if we choose to pick a slightly lower or higher inflation rate, the graph produced with the flatter slope (alpha of .01) or the steeper slope (.24) may move closer to the average. Thus, there is still some ambiguity as to the exact levels of alpha and delta, however, it is clear that they are present and acting together to buoy inflation above what the traditional Phillips curve suggests we should see during a time such as the Great Recession where unemployment and output gap are abnormally large.

5.6 France

We have withheld France, Italy, and Germany until the end because as was mentioned above, each economy fared quite differently during the Great Recession and because each is tied to the same inflation target imposed by the European Central Bank. The ECB sets an inflation target at near, but just below 2%; France varies between 0% and just above 4% but is largely contained between 1% and 3% during the span of our dataset which begins in the mid-1990s.

France is the most problematic of the countries we work with in this paper. We run core inflation through our regression equation (9) to isolate delta, but with such a short data set, any change in regression period yields a large change in delta. Further, the confidence intervals are enormous (as large as -.5 to 1.5, which is almost entirely non-sense with regard to our equation. Our results, despite having large standard errors, are .09 and .52 respectively using 1997q2-2007q4 and 2002q1-2007q4. Based upon the confidence intervals we opt to set delta = .33; we do this because it is a relatively even
split of the standard errors and predictions and because it is a reasonable prediction given the anchoring of other countries that have similar graphs of inflation following the ECB target.

We use equation (7) to generate alphas over the same time frames which are .05 and .03 respectively. This is what we would expect as the variance of inflation in France is lower without the effects of the late 1990s; however neither inflation nor variability is especially high during the sample. This change results in a modest correction in our graph shown in figure 7. The original prediction made with the standard Phillips curve is not exceptionally bad for France. While all the European countries experienced rather mild falls in inflation (as compared to Canada, the US, and Japan – see figure 2) France’s graph appears less in error as actual core inflation continues to fall somewhat significantly throughout the prediction period. This being said, correcting most prominently for a small degree of level-anchoring creates a much more accurate forecast, especially into 2011. From 2011q3 to 2011q4, France’s core inflation fluctuated from .5% to 2.6% (an average of about 1.5%); a standard Phillips curve predicts core inflation to be 1% in 2011q4 while our estimations using a delta of .33 and an alpha of .03 predicted inflation at 1.5% for the same quarter.

Our results for France are hindered by our smaller dataset but we are convinced through our study of other countries and the results we were able to obtain using logical assumptions for France that the Ball and Mazumder suggestions are at work in buoying France’s inflation rate slightly higher than a traditional Phillips curve would predict.

5.7 Italy

Italy, as mentioned above, is tied to the inflation target set by the ECB of just below 2%. As was the case with France, Italy does not suffer an excessively large deflation during the great recession moving largely between 1% and 3%. However, because of a significant rebound in the final quarters of 2011, the standard Phillips curve (again this refers to equation (2) with ¼ lagged inflation and no anchoring)
still falls victim to a fairly significant under-prediction as is the case with the previous five countries. In 2011q4, actual inflation in Italy was 1.7% while a standard Phillips curve predicts it should have been at .9%.

Italy is also handicapped by a shorter dataset; however, unlike France we get a fairly consistent anchoring parameter. Taken over the full set from 1997q2-2007q4, STATA returns a delta of .36 from the regression of equation (9). Based upon the relative stability of Italy’s core inflation between 1% and 3% throughout the dataset, this level of belief in the commitment to 2% inflation is reasonable.

Because inflation and variability are both low, our regression with equation (10) returns alphas of 0 and .05 for the periods 2002q1-2007q4 and 1997q2-2007q4 respectively. The graph in figure 8 shows our corrected forecasts with both constant alphas and a fixed delta of .36.

We again see a familiar flattening correction in the curve which stops it from the standard under-prediction. There is nothing remarkably different between Italy and France and this is what we expect as they are under the same monetary policy and have very similar levels of pre- and post-recession gaps in output.

5.8 Germany

We present Germany last because it is the sole outlier in the G-7 in that the Phillips curve actually over-predicts inflation during the Great Recession. Germany is a unique case because although it did experience a jump in output gap and unemployment rate at the outset of the Great Recession, it was by far the fastest country to emerge from the recession in the G-7 as can be seen by the comparative output gap graph in figure 1. By the end of our forecasting period in 2011q4, Germany had actually recovered so significantly that the standard Phillips curve was again predicting correctly. However, we aim to figure out if the same strategies we used to buoy inflation in predictions for the previous six
countries can be used to pull down the over-estimation that occurs in the forecast for Germany from 2008-2010.

We begin again by isolating delta in equation (9) and running regressions over the periods 1992q2-2007q4 (the full set), 1997q1-2007q4, 2002q1-2007q4, and 2005q1-2007q4. We find that anchoring is fairly low at the beginning of the set and steadily climbs into the early-2000s but begins to fall settling back in around .33 before the recession begins. Standard errors are around .20; however, the consistent basis upon which we find anchoring in the range of 30% lets us assume that the prediction is reasonable. Further, for other countries with similar degrees of variation and inflation in the 1990s, we see similar anchoring parameters.

Using a weight of .33 and the ECB imposed 2% inflation target, we regress equation (10) to find a reasonable estimation for alpha leading into the forecast period. We find that alpha begins fairly high around .18 taken over the entire estimation period but climbs steadily reaching .21 estimating from 1997q1-2007q4, .22 estimating from 2002q1-2011q4, and .33 estimating from 2005q1-2007q4. These can be explained as Germany experienced exceptionally high core inflation in the early 1990s reaching above 10% and experienced highly variable inflation in the later 2000s. Based upon our sticky price theory, we get a steeping of the Phillips curve when this occurs. We use fixed alphas of .18, .22, and .33 with a fixed delta of .33 tied to 2% inflation to generate our forecasts depicted in figure 9. Somewhat surprisingly, our use of anchoring and a time-varying slope acts differently than it has for the previous six countries; because alpha is larger than we generally see relative to delta, it acts significantly in pulling our forecasts down below the standard Philips curve estimation.

Germany is perhaps the most interesting country we discuss because it shows that accurate accounting for anchoring and time-varying slope is sufficient to correct for both the under-predictions which were the norm during the recession and the rare over-prediction which we saw in the case of
Germany. This works because although Germany is tied to 2% - far above the drop our forecasts produce during Germany’s downturn at the outset of 2008 – accounting for time-varying slope allows for our prediction to understand that in Germany’s case of once-high and still variable inflation, price-setters will move much more quickly in response to changes in economic output and inflation. The steep slope created when we allow for time variation, in other words, allows for the quick dip and for the fast recovery in our forecast, which does not occur in the standard Phillips curve.

Although these results are fairly compelling, there still exists a relatively high degree of uncertainty with respect to the exact levels of alpha and delta for our estimation periods. This leaves room for further study and more potential advances in forecasting accuracy. In this vein, our results leave room for new suggestions to permeate the debate about the cause of and solution to the sudden failure of the traditional Phillips curve.

VI. Topics for Further Research

6.1 Hysteresis

Hysteresis is a term used to describe a past influence or disturbance which affects the path of the economy. In the context of unemployment, hysteresis predicts that long spells of unemployment will lead to a higher natural rate of unemployment. This is a serious problem for many countries as high rates of unemployment have continued to persist from the outset of the Great Recession. Theory predicts that long spells of unemployment reduce the attractiveness of a worker to prospective employers. Time away from the job can reduce technical and social skills and further, it can erode incentives for the worker to continue looking for employment. This creates a cycle in which the workforce becomes depleted and the natural rate of unemployment increases.

The natural rate of unemployment is usually assumed to be determined by exogenous variables in the models we have examined thus far, but hysteresis suggests this may not be true. If hysteresis has
indeed come into play, a shift up in the natural rate of unemployment may explain many of the
problems with the Phillips curve. Incorporating this data into our model would significantly reduce the
extent to which a traditional curve would predict falling inflation rates. This topic needs further
research and some econometric analysis; however, it may greatly increase our understanding of recent
inflation dynamics and forecasting.

6.2 Relative degrees of forecasting error

We noted in our observations that all of the European countries in our sample had significantly
“flatter” dynamic forecasts when using the standard Phillips curve; it is easily observable in figure 2 that
predictions for European countries remained significantly higher than those for the US, Japan, and
Canada – this includes the UK which is not part of the monetary union under the Euro. Further, by
looking at figure 1, it is easy to see that the relative slope of the forecasts does not correspond to the
relative depth or speed of the recoveries depicted in figure 2, nor to their relative starting points. This
topic could use further research; however, we will comment that despite the UK’s absence from the
monetary union under the Euro, it is a member to the economic and political body of the European
Union. We believe that it may be thanks to the relative position of some of the countries within the
European Union (such as Germany) which were not hit as hard by the recession and acted as somewhat
of a buffer to the overall European economy that we see this muted forecasting error in Europe. This
being said, the topic could use further research and may bare entirely different results.

6.3 Anchoring in countries which lack explicit targets

Perhaps one of the most interesting accidental consequences of this research was our result with
regard to Japan. Despite Japan’s lack of an explicit target, our research makes it fairly clear that there is
a significant degree of anchoring around 0% inflation which has become the norm in the Japanese
economy.
In February of 2012, Japan instituted an inflation target of 1% in attempt to pull inflation up and spur the economy, which has been intensely debated with some saying it should be higher and others saying an inflation target doesn’t make sense at all for Japan. If anchoring is indeed occurring around 0%, this should be at the forefront of the debate over whether an explicit target should be established and if so what that target should be. Further, the Japanese central bank should consider what creating an explicit target will do to the current anchoring of expectations and to their own credibility if they are unable to move it from what has become its natural rate around 0%.

This topic is one for further research but its implications are important. We suggest a study which exclusively looks at countries which lack explicit targets (which is most of them for the time being) and studies the degree to which anchoring is occurring. This research could help central banks better understand the unintended consequences of instituting an explicit target, the appropriateness of various targets, and managing an economy while targets are still implicit.

VII. Conclusion

In this paper we have expanded on the work of Ball and Mazumder (2011). We have endeavored to generalize the methodology of Ball and Mazumder by incorporating a time-varying slope, anchored expectations, and the use of core inflation into a modified Phillips curve and estimated it for the set of G-7 countries. In doing so, we have created improved forecasts for every country in the G-7. This work shows that general improvements can be made to the standard Phillips curve and should be considered more widely when dealing with inflation forecasting.

Our study has found that time varying slope and level-anchoring work in concert to affect the general accuracy of dynamic forecasting. If one is able to properly identify the levels of
anchoring and time-varying slope in a given country for a given forecast period, he or she will be able to greatly increase certainty in a resulting forecast. Further, we have found that forecasting with anchoring and time-variation is not limited by explicit inflation targets and therefore necessarily by well-established central banks. Instead, anchoring can be implicitly held by price-setters within a country and be active regardless of the official policy of that country’s central bank.

We find that the utilization of core inflation, anchoring, and time-varying slope are applicable to correcting both problems with under-predictions and over-predictions which appear in traditional Phillips curve forecasts. Most prominently however, we note that the inclusion of these three modifications is successful in making improvements to dynamic forecasts for every country in the G-7. We base this claim upon table 1, which shows that our forecasts perform better than a standard Phillips curve when tested by various statistical measures of forecast error.

We hope these findings can be used as a pretext for the additional research we have suggested but also to improve the accuracy of future inflation forecasting. As noted in Ball and Mazumder (2011), it is unclear how long level-anchoring will tie expectations to a level above the one which we are observing, largely holding inflation positive throughout our study. This being said, we hope that improvements in our forecasting accuracy will help us better monitor deflation in the future both within the G-7 and elsewhere so that we may be better prepared to prevent or mitigate its effects.
VIII. References


DATA SOURCING:

I.N.S.E.E

OECD

EUROSTAT

National Institute of Statistics, Italy

Statistics Canada

Statistics Bureau, Japan

Office for National Statistics, UK

Deutsche Bundesbank

Federal Statistical Office, Germany

US Bureau of Labor Statistics (BLS)

Compilation and sourcing from Thomson Reuters
A. Tables

NOTE: For tables 1 and 2 vertically color coded numbers correspond to one another with table 2 showing the “improvements” made by our improved forecasts. The four red cells under MAPE denote invalid calculations (MAPE is not designed to handle sets which change from positive to negative). Also note CBI stands for Central Bank Independence and is borrowed from (Banaian). RMSE is root mean square error, MAE is mean absolute error, and MAPE is mean absolute percentage error (for a full description see footnote 6, page 6.) Also note that because we are using targeted constants for time-variation and anchoring, it does not make sense to include forecasts generated back to the beginning of the data set as we do in table 1.

Table 1: RMSE, MAE, and MAPE for standard Phillips Curve forecasts (before and after the Great Recession)

<table>
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<tr>
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<th>US</th>
<th>UK</th>
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<th>Italy</th>
<th>France</th>
<th>Japan</th>
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Table 2: RMSE, MAE, and MAPE for most accurate corrections utilizing anchoring and time-varying slope

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<th>US (delta=.29, alpha=.07)</th>
<th>UK (delta=.3, alpha=.1)</th>
<th>Germany (delta=.33, alpha=.18)</th>
<th>Italy (delta=.36, alpha=.05)</th>
<th>France (delta=.33, alpha=.03)</th>
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B. Figures

Figure 1

Output Gap Comparison

- US output gap
- UK output gap
- Germany output gap
- France output gap
- Canada output gap
- Japan output gap
- Italy output gap
Figure 3: Dynamic Forecasts for the US 2008q1-2011q4
Figure 4: Dynamic Forecasts for the UK 2008q1-2011q4
Figure 5: Dynamic Forecasts for Japan 2008q1-2011q4
Figure 6: Dynamic Forecasts for Canada 2008q1-2011q4

- Blue: Core inflation
- Red: Standard Phillips curve prediction
- Green: \( \delta = 0.69, \alpha = 0.28 \)
- Orange: \( \delta = 0.69, \alpha = 0.11 \)
- Gray: \( \delta = 0.69, \alpha = 0.01 \)
Figure 7: Dynamic Forecasts for France from 2008q1-2011q4

- Core inflation
- France Phillips Forecast
- \( \delta = 0.33 \), \( \alpha = 0.05 \)
- \( \delta = 0.33 \), \( \alpha = 0.03 \)
Figure 8: Dynamic Forecasts for Italy from 2008q1-2011q4
Figure 9: Dynamic Forecasts for Germany 2008q1-2011q4
C. Appendix

A.1 The Effect of Unemployment on Future Inflation

We explain this by feeding a one percentage point increase in unemployment, sustained over one quarter, through our equation.

\[ \pi_t = \frac{1}{4} (\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) + \alpha (u - u^*)_t + \epsilon_t \]

If we increase \( u \) by 1% at time \( t \), then it factors into expectations in the next quarter at time \( t - 1 \) and increases inflation by .25%. Even as inflation returns to its base level in the next quarter, the effect persists in the equation, represented by time \( t - 2 \), but is again diminished by the \( \frac{1}{4} \) multiplier. In the long term, the net effect will approach 0.4. Thus, if the 1 percentage point gap is sustained over one year, the net effect will be a 1.6 percentage point rise in inflation.

A.2 From the Sticky Price Theory of Aggregate Supply to the Phillips Curve

N. Gregory Mankiw explains the transition from the short-run aggregate supply curve to the Phillips curve as follows:

The aggregate supply curve can be represented by the equation:

\[ Y = Y_{bar} + \beta (P - EP) \]

Where: \( Y \) is output, \( Y_{bar} \) is the natural level of output, \( P \) is the overall price level, \( EP \) is the expected price level, and \( \beta \) is \( s/((1-s)/\alpha) \). In this case, \( s \) measures the number of firms with sticky prices, \( 1-s \) measures the number of firms with flexible prices, and \( \alpha \) measures how much the firm’s desired price responds to the level of aggregate output.

We begin by solving for price in the equation:
\[ P = EP + \frac{1}{\beta}(Y - Y_{bar}) \]

We then add a shock term \( \epsilon \) to the right side of the equation to represent exogenous events which affect price level and shift the curve:

\[ P = EP + \frac{1}{\beta}(Y - Y_{bar}) + \epsilon \]

In order to transform the equation from price level to inflation rates, we subtract last year’s price level given by \( P_{-1} \) from both sides of the equation:

\[ (P - P_{-1}) = (EP - P_{-1}) + \frac{1}{\beta}(Y - Y_{bar}) + \epsilon \]

This leaves us with inflation on the left hand side and expected inflation on the right hand side:

\[ \pi = E\pi + \frac{1}{\beta}(Y - Y_{bar}) + \epsilon \]

Finally, to go from output to unemployment gap, we use Okun’s Law, which states an inverse relationship exists between unemployment gap and output gap resulting in \(-\alpha(u - u^*) = \frac{1}{\beta}(Y - Y_{bar})\).

Thus: \[ \pi = E\pi - \alpha(u - u^*) + \epsilon \]