INFLATION EXPECTATIONS AND MISSING DISINFLATION: EMPIRICAL EVIDENCE FROM THE UK PHILLIPS CURVE

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Abstract

This paper uses data on professional and household inflation expectations surveyed by the Bank of England to explain missing disinflation during the Great Recession. Results from the United Kingdom suggest that changes in the slope of the typical Phillips curve and variation in marginal costs are unable to resolve the puzzle. I find that this missing disinflation is better explained by underlying shifts in firm expectations, providing they are well proxied for by professional forecasts in addition to household expectations.

I. INTRODUCTION

The decline in inflation after the Great Recession has been muted in advanced economies. This is in stark contrast to what occurred during major crises in the past like the Great Depression, in which deflation was sharp and ruinous, particularly within OECD nations. As a result, the evolution of prices in the presence of recent economic slack after the financial crisis of 2007/08 has invited substantial scepticism towards the Phillips curve, which is often used in contemporary macroeconomic analysis to predict the movement of prices using an inverse relationship between its rate of change and the aggregate level of economic activity. As a critical tool in monetary policy, it is necessary to determine if the relationship between inflation (wage growth) and unemployment remains a useful framework that ought to be internalised by the policymaker.

In defence of the famed relation, many have tried to shed light on this phenomenon, albeit to no real avail. For instance, one factor often invoked is the flattening of the Phillips curve, however empirical evidence for this does not seem to be predicated on structural changes that can account for shifts in the slope, which also fail to explain disinflation after the recession. More notable advances have used anchored expectations (Bernanke, 2010) or short-run unemployment (Stock, 2011; Gordon, 2013), albeit these approaches are also not without limitation. In this regard, the motivation of this paper is to investigate missing disinflation in a UK Phillips curve setting, thereby vindicating the relation from its inability to predict prices during the Great Recession and onwards.

This is achieved by replicating the approach of a more recent study on the United States for the United Kingdom (Coibion and Gorodnichenko, 2015), which contrasts itself from much of the existing literature. Specifically, this paper estimates an expectations-augmented Phillips curve using household and professional inflation expectations (as a proxy for those of firms) constructed by the Bank of England to capture missing disinflationary pressure post Great Recession. This particular approach is novel insofar as firm expectations are not readily available for most countries including the United States and the United Kingdom, yet their pricing decisions are invaluable to the Phillips curve. In proxying for these expectations, this paper accounts for what other studies have omitted at great expense to the relationship between inflation and real economic activity.

If successful, this paper would have contributed to the existing literature a robust defence of an integral concept in contemporary monetary theory whose interminable revision is unprecedented in macroeconomics. Since the stagflation of the 1970's the Phillips relation has been updated from primitive static models to far more complex dynamic variations that have been unable to explain the recent financial crisis, which has forced many to return to theory and more traditional models that are used in this paper such as the expectations-augmented Phillips curve. Regardless, the relationship between inflation and unemployment is so vital to modern economic analysis (Bernanke, 2007) that any empirical evidence supporting its persistence would have great implications for the policymaker and in particular, those institutions that depend heavily on it.

This study begins with Section II, which surveys existing literature to motivate the approach of this paper by outlining problems that undermine the power of relevant studies. It then proceeds with Section III, which tests for missing disinflation in the United Kingdom and its robustness to varying measures of inflation. After which, Section IV evaluates possible alternative explanations to the evolution of prices during the crisis. Section V investigates structural breaks in the slope of the Phillips curve and if this captures the missing disinflation puzzle. In Section VI, this paper examines the extent to which firm expectations are represented by household and professional forecasts before using them each as proxies in the Phillips curve to predict the evolution of inflation during the Great Recession. Penultimately, this paper discusses and summarises its main findings in Section VII before concluding on Section VIII.

II. LITERATURE REVIEW

Of the vast literature on the Phillips relation, studies concerning the missing disinflation puzzle are nascent and tend to focus more on the United States than the United Kingdom. Perhaps the most cited explanations to this puzzle are varying measures of inflation (Ball and Mazumder, 2011), anchored inflation expectations (Bernanke, 2010), flattening of the Phillips curve (IMF, 2013) and downward nominal wage rigidity (Krugman, 2012). However, each of these explanations are relatively weaker than what is proposed by Coibion and Gorodnichenko (2015) as underlying changes in firm inflation expectations due to an increase in input costs during the crisis.

As for those studies that use alternative measures of core inflation to account for the missing disinflation, the elimination of supply shocks that focus instead on expected inflation and economic activity (Ball and Mazumder, 2011) as opposed to inflation minus food and energy, are still unable to resolve this phenomenon in isolation. In fact, approaches in the literature often adjust the slope of the Phillips curve so it is non-constant and time variant to predict inflation more effectively. Despite this, alternative measures of core inflation even in conjunction with other adjustments to the Phillips curve still fail to comprehensively account for what eventuated in terms of the evolution of prices post Great Recession. It is therefore evident, that merely adjusting the manner in which one measures inflation is not sufficient to explain price dynamics during this period.

In contrast, the vast literature on anchored expectations as a potential explanation to missing disinflation is well documented and perhaps more successful. In particular, this approach suggests inflation expectations are less responsive (anchored) to past inflation due to greater public perception of the commitment to low and stable inflation post Great Recession (Mishkin, 2007; Kohn, 2010). However, this analysis, notably in Bernanke (2010), can only partially explain disinflation between 2009-2011, leaving the remaining quarters after the recession unaccounted for. More recent attempts to use anchored expectations in conjunction with short-term unemployment by Ball and Mazumder (2019) in the Phillips curve setting have been relatively successful, establishing the need for a more comprehensive approach. Regardless, questions concerning this approach remain, such as the extent to which expectations are anchored, the nature of this anchorage, or if such theory is able to explain missing disinflation during the recession at all (Ball and Mazumder, 2011).

As for literature on the slope of the Phillips curve, there is strong evidence to suggest that this has altered over time, particular before the crisis (Lansing, 2002; Lansing, 2006). However, the literature is inconclusive as to whether this is able to solve the missing disinflation. The slope of the Phillips curve determines the elasticity between inflation and unemployment, which in turn depends on how sticky prices and wages are. There is strong evidence to suggest that the US Phillips curve has flattened over time, thereby implying that during high unemployment, deflation would be muted just as inflation would at times of low unemployment (Simon, Matheson and Sandri, 2013; Blanchard, Cerutti and Summers, 2015). However, changes in the slope of the Phillips curve partially solve the missing disinflation puzzle and the reasons for it are not derived from structural changes within the economy. Further still, little analysis exists within the literature on the UK Phillips curve except that they have concluded a similar result (Cunliffe, 2017; Haldane, 2018).

Research suggesting the presence of downward wage rigidity across the advanced economies or for instance an increased elasticity between wage growth and long-term unemployment argue that this prevented wages from falling as much as they did in previous crises (Daly et al. 2012; Iwasaki, Muto and Shintani, 2018; Llaudes, 2005). However, data post recession does not seem to indicate a similar disinflation in wage growth (or at least on the same scale), meaning this framework may not be appropriate to the Phillips relation. This is particularly relevant to those studies that argue changes in marginal costs during the Great Recession can explain the lack of price disinflation and subsequent inflation overshooting, when in truth the behaviour of wages suggests otherwise.

Given the aforementioned, the methodology of Coibion and Gorodnichenko (2015) is able to explain inflation after the Great Recession far more effectively. In proxying for firm expectations with those of household forecasts, the underlying economic factors driving changes in inflation are used to explain the absence of strong disinflationary pressure. The justification for such proximation is that household expectations trace closely that of firms and even outperform professional and backward-looking forecasts. Thus, according to the authors, where others omit changes in household inflation expectations and by extension those of firms, they ultimately fail to account for what can explain the missing disinflation. Perhaps the greatest criticism of this paper however is the use of a restricted expectations-augmented Phillips curve framework that omits a number of potential variables whose heterogeneity may have contributed to the same phenomenon.

In addition, criticisms over the proximation of households with firm inflation expectations as being tenuous is not without some warrant, in addition to the pedestal it is given above professional forecasts by the authors, particularly as household expectations themselves internalise the forecasts of professionals (Peneva, Jorento and Massaro, 2015). However, what is abundantly clear within the literature on missing disinflation is that research on the United Kingdom is not as abundant than the United States. This may be primarily due to the fact that prices in the Eurozone did not react to the crisis in the same manner they did in the United States, and that missing disinflation was not present altogether within the region (Bobeica and Jarociński, 2017; Hubert and Le Moigne, 2018). This paper therefore seeks to first investigate missing disinflation within the United Kingdom during the Great Recession before using professional and household expectations as per Coibion and Gorodnichenko (2015) to determine if they better capture the evolution of inflation within the United Kingdom.

III. MISSING DISINFLATION

Contemporary macroeconomic theory assumes an empirical relationship between real and nominal variables. In contrast to the classical dichotomy, which opined the antithesis, this particular precept was epitomised by the theoretical Phillips curve originally proposed by Phillips (1958), in which the rate of money wage growth reflected the level of real economic activity. Later popularised in terms of inflation by Samuelson and Solow (1960) and then further extended in terms of expectations by Friedman (1968), the Phillips curve became an axiom to analyse and predict the evolution of prices in the short run. The expectations-augmented Phillips curve may be generalised as:

$$\pi_t - E_t\pi_{t+1} = c + \kappa x_t + v_t \tag{1}$$

where π_t represents inflation, $E_t\pi_{t+1}$ inflation expectations, c the constant, x the measure of economic activity and v_t cost-push shocks. This equation argues deviations in inflation from expected inflation are inversely related to real activity; captured by the coefficient β. New Keynesian variations are quick to incorporate microfoundations with nominal rigidities, in which for instance x would be proxied by marginal costs (Clarida, Galí and Gertler, 1999). However, despite its foundations in microeconomic theory, the New Keynesian Phillips Curve has hitherto failed to capture inflation dynamics during the Great Recession, which has only strengthened the need for more cardinal alternatives.

The variables of particular interest in the traditional Phillips curve are inflation expectations and economic activity. Unemployment is traditionally used to proxy for the latter due to simplicity and strength as an indicator (Phillips, 1958; Friedman, 1968), hence it will be a consistent feature of the Phillips curve throughout this paper. As for measures of inflation expectations, this has become an area of heavy research and debate, albeit suffice to say our baseline model shall be adaptive and in particular backward-looking. With quarterly data, it is also customary to approximate the expectations of future inflation by the average of the previous four quarters (Ball and Mazumder, 2011):

$$E_t\pi_{t+1} = \frac{1}{4}\sum_{i=1}^{4}\pi_{t-i} \tag{2}$$

where i is the lag of the corresponding quarter. Alternative measures of firm inflation expectations (such as those of professionals and households), and real activity (such as wages) are considered in subsequent sections of this paper. As for the measure of inflation, this paper uses the Consumer Price Index including Owner Occupiers' Housing costs (CPIH) adopted by the Office for National Statistics and rendered the most comprehensive measure of inflation (ONS, 2019). This serves as our baseline index, after which other measures (such as CPI, Core CPI and GDP Deflator) are used to investigate the sensitivity of our estimation to varying measures of inflation.

Disinflation in the United Kingdom

Figure I plots the Phillips curve for 1960Q1-2018Q4, shown graphically as the relationship between deviations in inflation from inflation expectations and unemployment rates for that quarter within the United Kingdom. Using CPIH as the index for inflation, there exists a negative relationship that is statistically significant at $\alpha = 1\,\%$ with an $R^2 = 0.075$. This implies that on average, higher levels of unemployment are associated with negative deviations in inflation from expectations. Observations during the crisis are distributed around the trend, albeit for points between 2010Q1-2011Q4 there is clustering towards the upper quadrant, indicating persistent quarters of positive deviations.

Figure I.

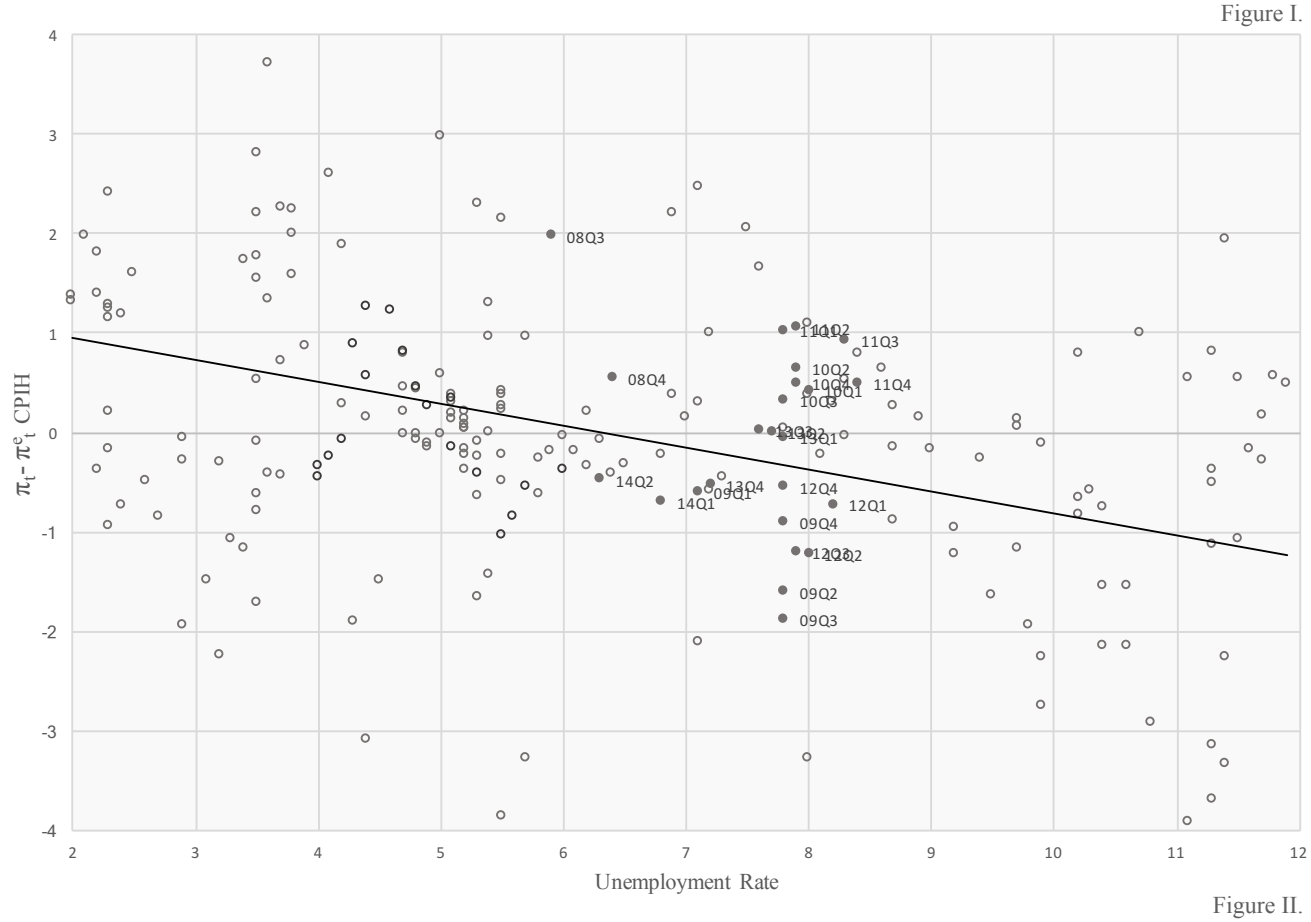
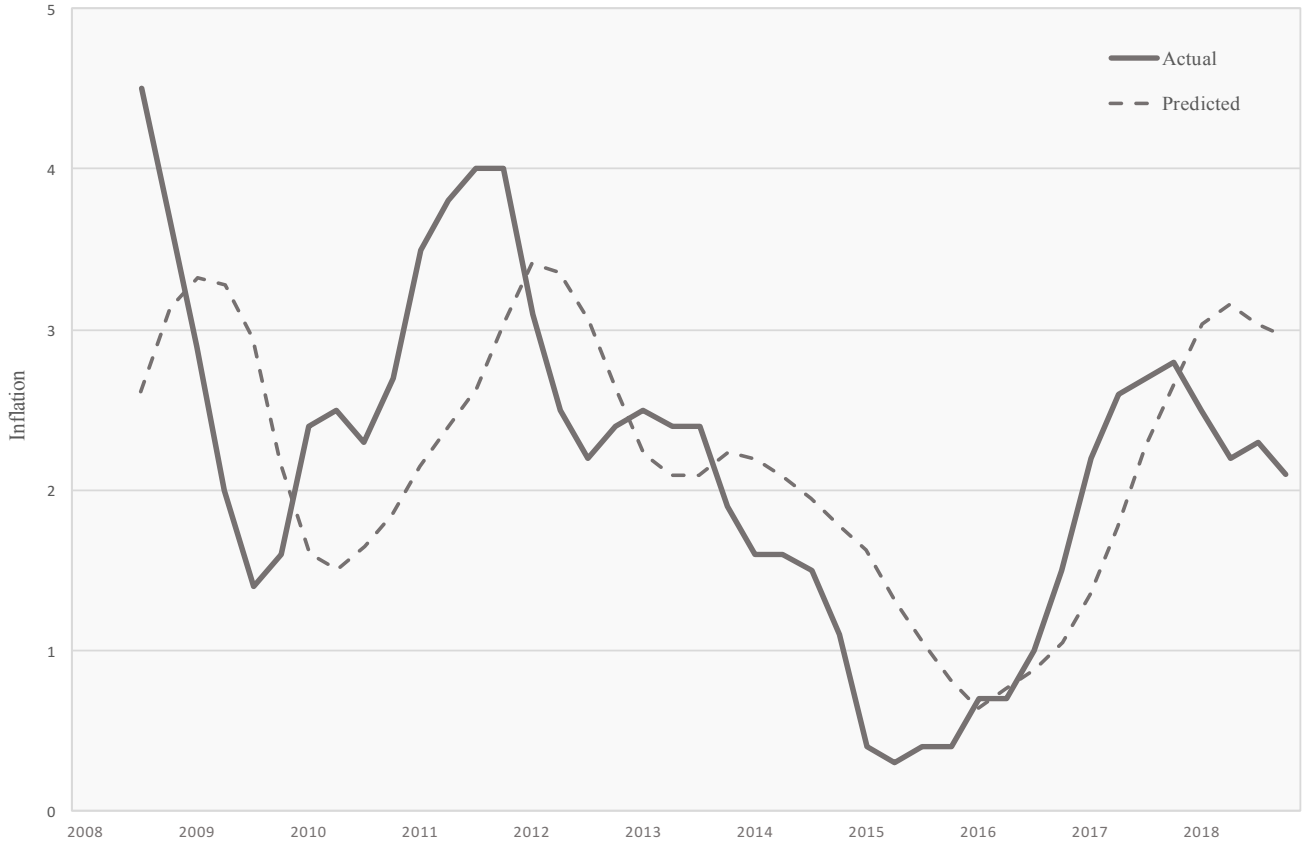


Figure II.



Note: Figure I plots a scatter graph for deviations in inflation from inflation expectations against unemployment from 1960Q1-2018Q4. Unfilled circles represent data for 1960Q1-2008Q2 and 2014Q3-2018Q4. Filled circles represent data for 2008Q3-2014Q2. The trend line captures estimated deviations in inflation as a function of unemployment in a linear regression, whose estimation output is detailed in the Appendix. Figure II plots the actual rate of inflation and the rate predicted by the Phillips curve in (1) using pre-crisis data for the post-crisis period to the present.

Figure II rearranges equation (1) to predict inflation using the Phillips curve estimated only on pre crisis data, namely 1960Q1-2008Q2. The results allow us to compare the actual evolution of inflation against inflation predicted by the Phillips curve. As the graph shows, UK inflation during the financial crisis for two primary years (2010Q1-2011Q4) was persistently higher than what was predicted by the Phillips curve. In particular, actual inflation averaged approximately 3.2% whereas expected inflation averaged merely 2.1%. However, there are two notable differences between the evolution of inflation within the United Kingdom and the United States. Firstly, the Bank of England pursues a known inflation target (of approximately 2%), meaning deflation is anathema to monetary policy, particularly evident during the crisis. This is in contrast to the Federal Reserve that oversaw deflationary pressure during the recession but due to an alternative monetary policy regime sought to control other fundamentals such as unemployment and growth. Secondly, missing disinflation is perhaps most apparent between the quarters 2010Q1-2010Q2, during which prices were expected to decline, albeit rose instead, after which actual rates were persistently higher than predicted until the last quarter of 2011Q4. In this regard and unlike the United States, the United Kingdom endured far more quarters of inflation overshooting as a result of the initial missing disinflation.

Robustness to Measures of Inflation

It may be argued that alternative measures of inflation reveal a different story of inflation during the Great Recession (Ball and Mazumder, 2011). This paper tests this claim with three known inflation indices. Firstly, the GDP Deflator accounts for the evolution of goods over time rather than fixing a basket and accounts for all goods and services rather than those just bought by consumers. In Figure III, the relationship between deviations in inflation from expectations and the rate of unemployment is expectedly negative and significant at $\alpha = 1\,\%$ with an $R^2 = 0.166$. Observations are more evenly distributed around the trend line and there are no persistent signs of missing disinflation. However, the Deflator is often regarded a measure to best capture real GDP than inflation, thus it may not be the most appropriate index to capture price dynamics (Altig, 2008).

Secondly, the CPI accounts for a weighted average of prices for a fixed basket of goods and services, albeit unlike the CPIH it excludes owner occupiers' housing costs (OOH). In Figure IV, we find a negative relationship, significant at $\alpha = 10\,\%$ with a lower $R^2 = 0.014$. Positive deviations in inflation from expectations are again qualitatively apparent during the crisis, with observations for 2010Q1-2011Q4 well above trend. Thirdly, Core CPI discounts food and energy to produce a more efficient measure of inflation (relative to headline rates) in the presence of price volatility. In Figure V, there is yet again a negative relationship, significant at $\alpha = 1\,\%$ with an $R^2 = 0.140$. Upon closer inspection, observations after the crisis seem to be clustered above the estimated trend line in even greater quantity. This is perhaps reasonable, given that during the recession food and energy prices were high and volatile due to exogenous shocks (Aminu, Meenagh and Minford, 2018).

It is clear from our estimation, that barring the GDP Deflator, missing disinflation during the crisis is robust to varying measures of inflation and that after the height of the recession, inflation between 2010Q1-2011Q4 was consistently higher than what we would have expected. Furthermore, this result was also present in unreported estimation using less popular measures of inflation such as personal consumption expenditure and core personal consumption expenditure. Thus, strictly in the framework of the adaptive expectations-augmented Phillips curve, there is evidence to suggest that the famed relation propagated so ardently by monetary policymakers has indeed malfunctioned in its ability to predict prices within the United Kingdom during the Great Recession. However, despite the signs of ill health, its pulse survives, insofar as the aforementioned findings do not detract from the statistically significant negative relationship between inflation and unemployment, which persisted even during the crisis and is also robust to varying measures of the former.

Figure III.

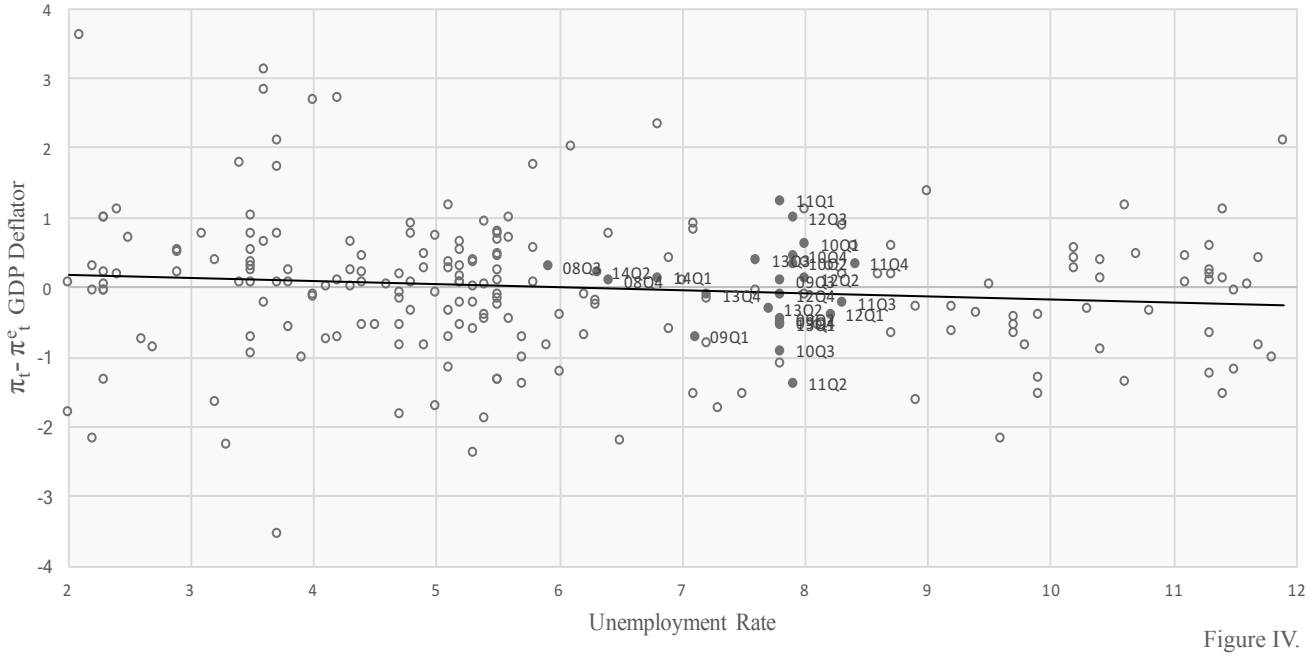


Figure IV.

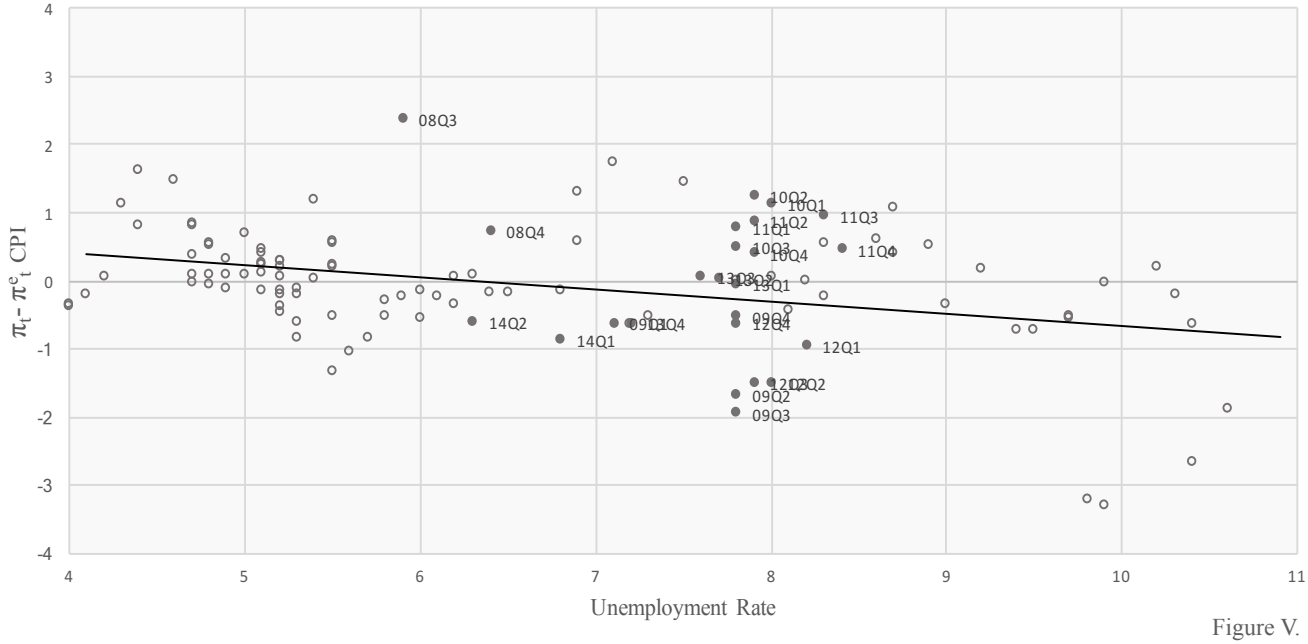
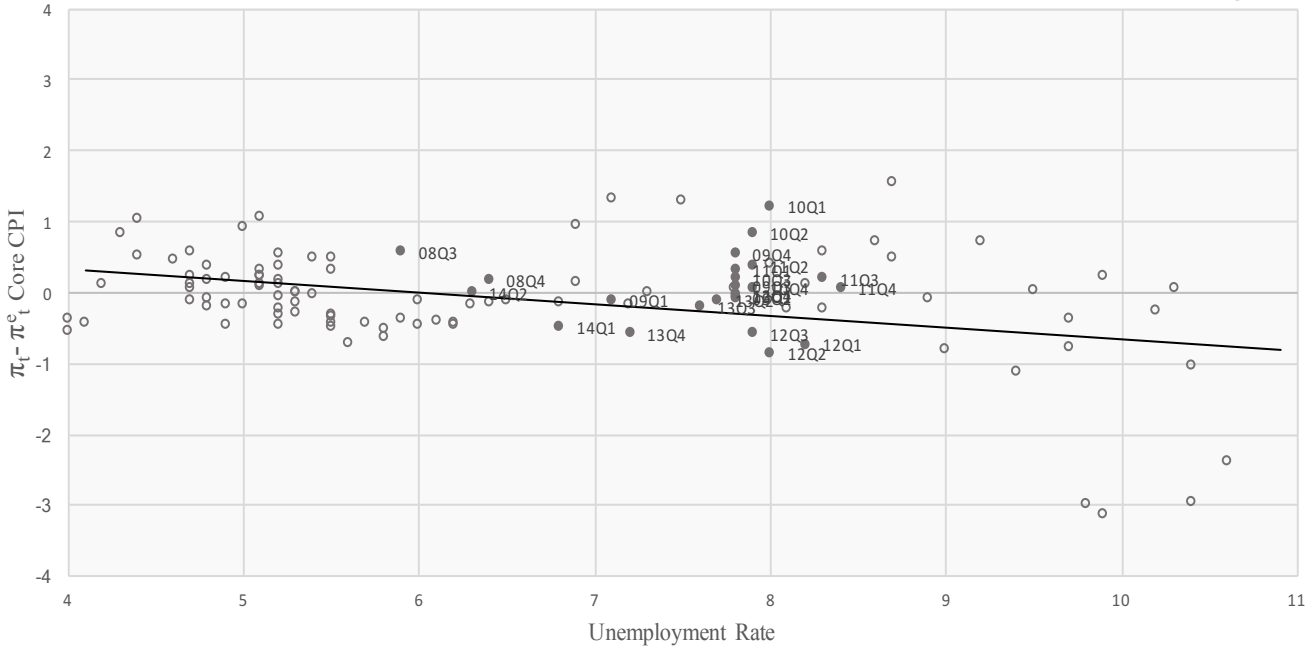


Figure V.



To determine if this is truly the case, this paper considers a number of possible explanations as per Coibion and Gorodnichenko (2015). Firstly, the unemployment rate may not be capturing real aspects within the economy that affect inflation. This is particularly true if the rate of unemployment had deviated from its natural rate (Friedman, 1968), which would lead to an inaccurate measurement of the relationship between our variables of interest. Secondly, it may also be the case as indicated by the literature, that the slope of the Phillips curve has changed due to structural changes in the UK economy. This would imply that the linear relationship between deviations in inflation from inflation expectations and the rate of unemployment, namely the speed of price adjustment, has changed over time. Thirdly, inflation may instead be related to marginal costs that capture real activity rather than unemployment, whose variation would undermine our estimates if left unaccounted for. Fourthly, it is plausible that inflation expectations of firms are not adaptive but of a different nature to what was initially assumed; proxied instead by household and professional expectations. This paper investigates each potential explanation to the missing disinflation puzzle so as to determine their veracity.

IV. POSSIBLE EXPLANATIONS

As noted, one of the core elements of the Phillips curve is how it captures variations in real economic activity. The rate of unemployment has long been used to achieve this, albeit as Friedman (1958) and Phelps (1968) have shown, this may not be the most accurate approach. Instead, deviations from the natural rate of unemployment may be the real forcing variable that is able to explain the evolution of inflation and is defined technically as the proportion of the labour force that are unemployed at full employment. However, the greatest drawback to this notion of unemployment is that it is entirely unobservable, hence there is a lack of evidence within the literature to prove it exists. In this regard, the natural rate of unemployment is an article of faith for which we must take a slight leap. It may be estimated and fed into the Phillips curve or derived from the Phillips curve itself. This paper shall consider both approaches as a possible explanation to the post crisis disinflation.

The Natural Rate of Unemployment

Omitting the natural rate of unemployment from the Phillips curve has a number of consequences on our results. In particular, our estimation of the slope of the Phillips curve would suffer from omitted bias due to unaccounted heterogeneity in the natural rate before the crisis. This would also taint our estimates for inflation, undermining our conclusions on the gravity of missing disinflation during the Great Recession. Furthermore, heterogeneity in the natural rate during the crisis would also bias our estimates in a similar manner, forcing us to conclude on what may have not been the case. To account for this particular bias, we incorporate estimates of the natural rate of unemployment constructed by the Organisation for Economic Development (OECD). However, as the natural rate is more popular in the Unites States, our sample for the United Kingdom is much smaller, with annual observations spanning only between 1970-2013. This data is used to regress the following Phillips curve:

$$\pi_t - E_t\pi_{t+1} = c + \kappa u_t^{gap} + v_t \tag{3}$$

where $u_t^{gap} = u_t - u_t^n$ is the yearly deviation of unemployment from the natural rate. The results are plotted in Figure VI. It is clear that the slope of the Phillips curve has become steeper at -0.94 and is statistically significant at the $\alpha = 1\,\%$ with a with an improved $R^2 = 0.1946$. This implies that shifts in the natural rate of unemployment before the crisis might explain the extent of missing disinflation, which seems to be even more apparent with observations from 2010-2011 positioned well away from the trend line towards the upper right quadrant. However, the overall amount of missing disinflation has remained relatively unchanged, certainly within the threshold of our previous findings.

Upon closer inspection, the actual natural rate of unemployment during the financial crisis is far lower on average than the rate predicted by the Phillips curve. Figure VII plots this estimated rate necessary to account for the missing disinflation with 95% confidence intervals alongside the actual natural rate of unemployment. Similar to what Coibion and Gorodnichenko (2015) have confirmed for that of the United States, the natural rate had to effectively trace actual unemployment during the crisis to capture missing disinflation, which indicates the structural nature of actual unemployment during this period. Despite the results, minimal changes in the natural rate of unemployment do not seem to entirely account for missing disinflation during the Great Recession and it is clear that other potential explanations ought to be investigated. Finally, evidence to suggest that the natural rate has changed at all and to what extent this explains inflation is negligible in the literature, notably for the United Kingdom. In this regard, this paper proceeds to use unemployment gaps as a forcing variable alongside unemployment, so as to comparatively examine other explanations to missing disinflation unaccompanied by the bias in omitting the natural rate of unemployment.

Figure VI.

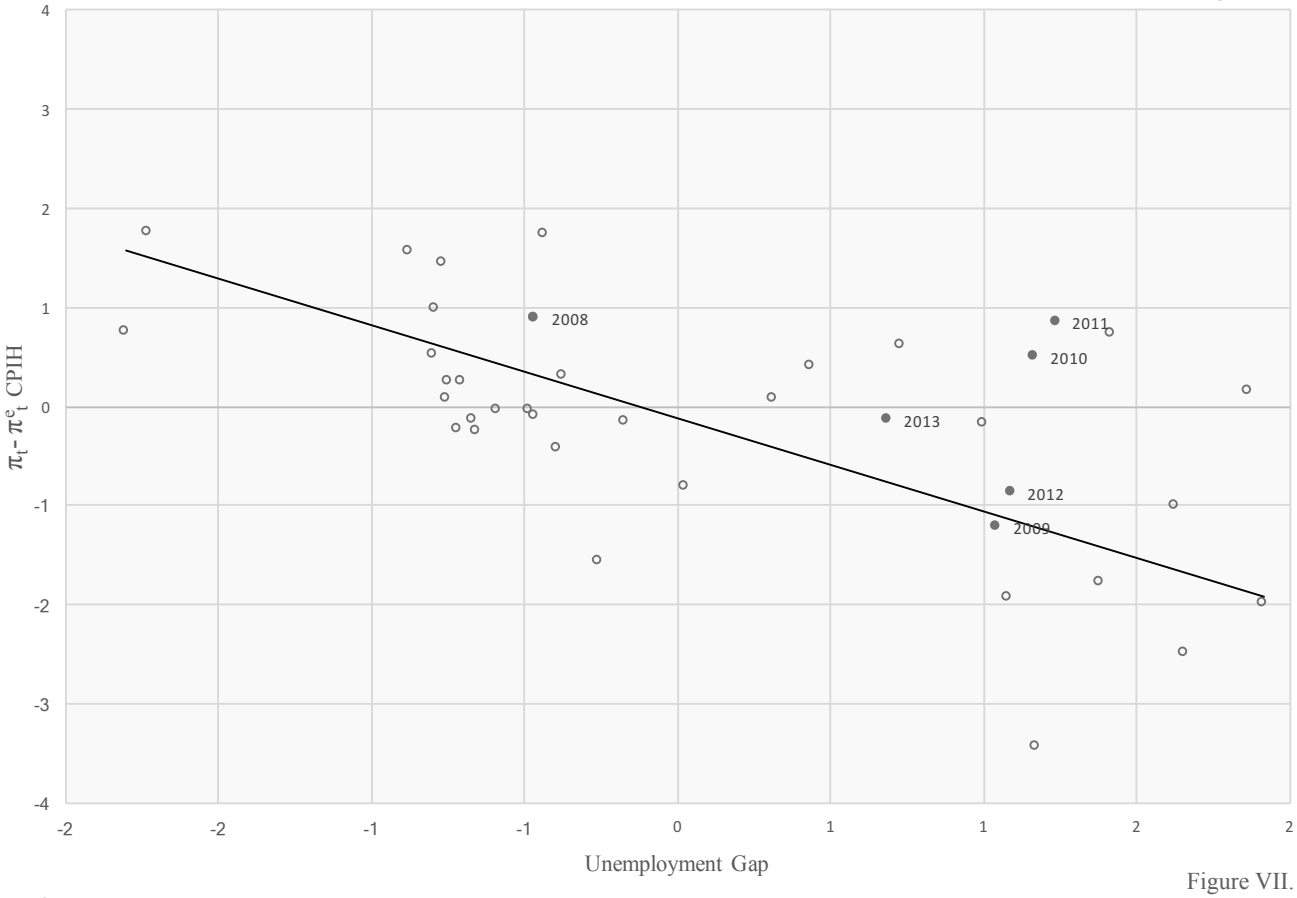
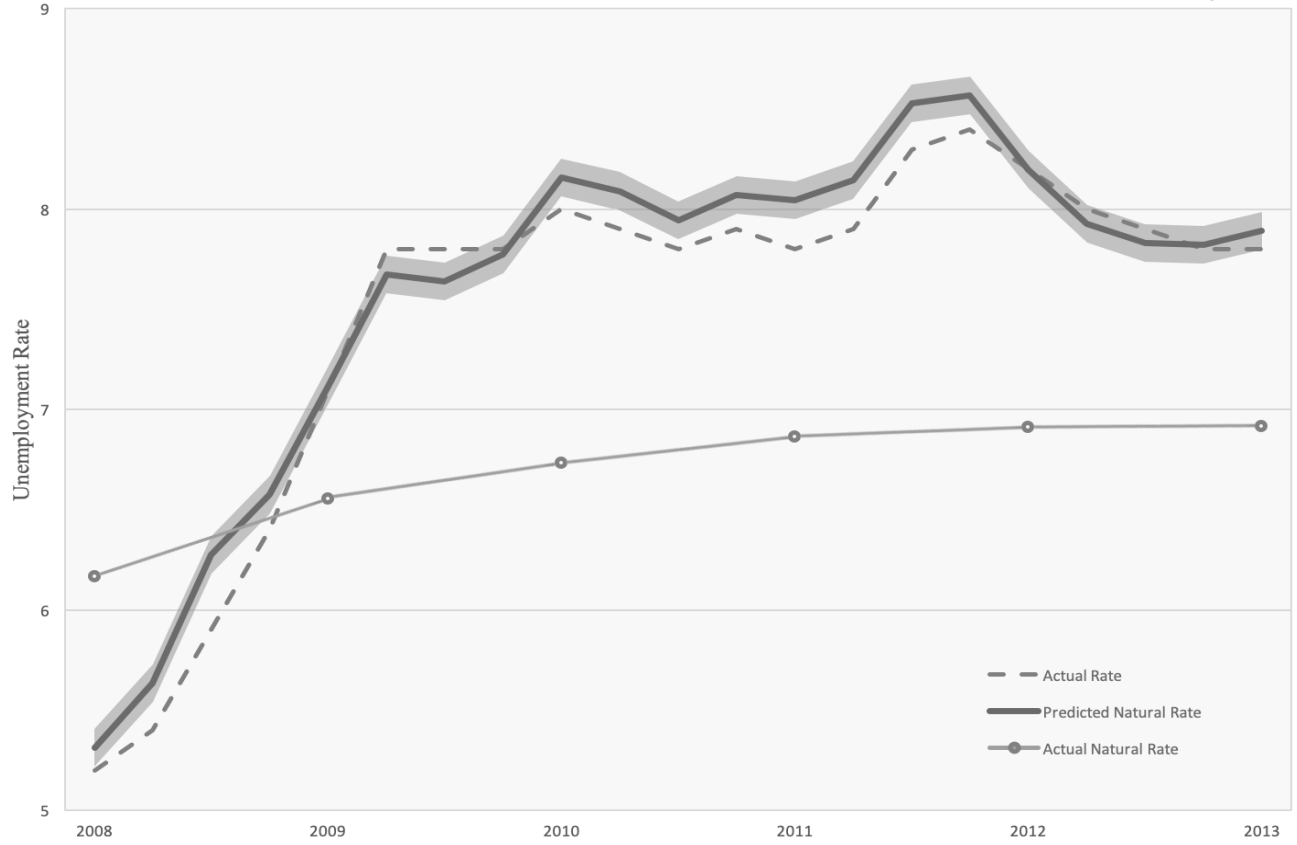


Figure VII.



Note: Figure VI plots annual deviations in inflation from expectations against deviations in the unemployment rate from the natural rate between 1970-2013. Unfilled circles represent observations for 1970-2007 and filled circles represent observations for 2008-2013. The trend line captures estimated deviations in inflation as a function of the unemployment gap in a linear regression. Figure VII plots the actual rate of unemployment, the actual natural rate and the predicted natural rate with 95% confidence intervals (whose derivation is detailed in the Appendix).

Contrary to traditional versions of the Phillips curve, New Keynesian variations use marginal costs as the regressor to explain the evolution of inflation. This forms part of the hypothesis that the missing disinflation was influenced by marginal costs that altered during the recession. However, the common use of labour shares to proxy for such marginal costs is not without its limitations (Clarida, Galí and Gertler, 1999; Galí, Gertler and Lopez-Salido, 2001; Woodford, 2003). As global labour shares have declined gradually over time (see Karabarbounis and Neiman, 2014), one would expect the missing disinflation during the Great Recession to have been more pronounced, implying an underestimation of the evolution of prices. Furthermore, the proximation of marginal costs by way of labour shares has been called into question by some due to the inability of the latter to capture cyclical variations in the former (Mazumder, 2010; King and Watson, 2012; Elsby, Hobjin and Sahin, 2013).

Furthermore, measurement error in marginal costs is a known issue that may bias estimates in the Phillips relation, which would also influence the extent of missing disinflation measured. In this regard, one may argue that marginal costs are not the most optimal measure of real activity. In order to resolve these problems, this paper replicates the approach of Coibion and Gorodnichenko (2015) by analysing wage growth during the crisis as a proxy for marginal costs, so as to determine if their evolution might account for the missing disinflation. This argument is advanced often by those who believe nominal wage rigidity (arising from pre-crisis declinations in inflation that placed downward pressure on average wages) engendered missing disinflation during the crisis (Krugman, 2012; Daly et al. 2012). In other words, the lack of disinflation in wage growth could explain a similar trend in prices, thereby explaining the missing disinflation as a consequence of nominal rigidity.

Wage growth is no stranger to the Phillips curve; it featured within the original specification proposed by Phillips (1958) himself before inflation was later introduced into the model. In light of this, one need only replace the deviations of inflation from expected inflation with the deviations of wage inflation from expected wage inflation, which yields the following Phillips curve:

$$\pi_t^w - E_t\pi_{t+1}^w = c + \delta u_t + \epsilon_t \tag{4}$$

where π_t^w is wage inflation and $E_t\pi_{t+1}^w$ is analogously adaptive and backward-looking (as the average of the previous four quarters). This paper uses time-series data from the Office for National Statistics (ONS) on quarterly wage inflation within the United Kingdom, assuming it is free from measurement error and accurately captures wage inflation within the labour market.

Figure VIII plots the original (wage) Phillips curve for 1960Q1-2016Q4. There exists a weak negative relationship, statistically insignificant at the $\alpha = 10\,\%$ with an $R^2 = 0.001$. Observations for the recession are evenly distributed around the trend line, albeit with high dispersion. This indicates that wage inflation was volatile during the crisis but on average in accordance with what the Phillips curve predicted. Figure IX plots the evolution of wage inflation post crisis. Whilst there are quarters in which actual wage inflation was well above or below the predicted rate, there is little persistence with the former averaging 0.41 and the latter 0.48 between 2008Q3-2014Q3.

Thus to conclude from this analysis, the use of wage inflation as a proxy for marginal costs yields little evidence to suggest that there was missing wage disinflation during the crisis. This also implies that appealing to nominal wage rigidity as a possible explanation for what occurred in terms of prices during the Great Recession is inaccurate as marginal costs did not display any unorthodox cyclicality within the data. In this regard, one may argue that explanations to the puzzle of missing disinflation must be derived from the pricing decision of firms; better captured by more orthodox specifications of the Phillips curve. Thus, it is necessary to continue searching for more appropriate explanations to the missing disinflation in terms of prices rather than wages.

Figure VIII.

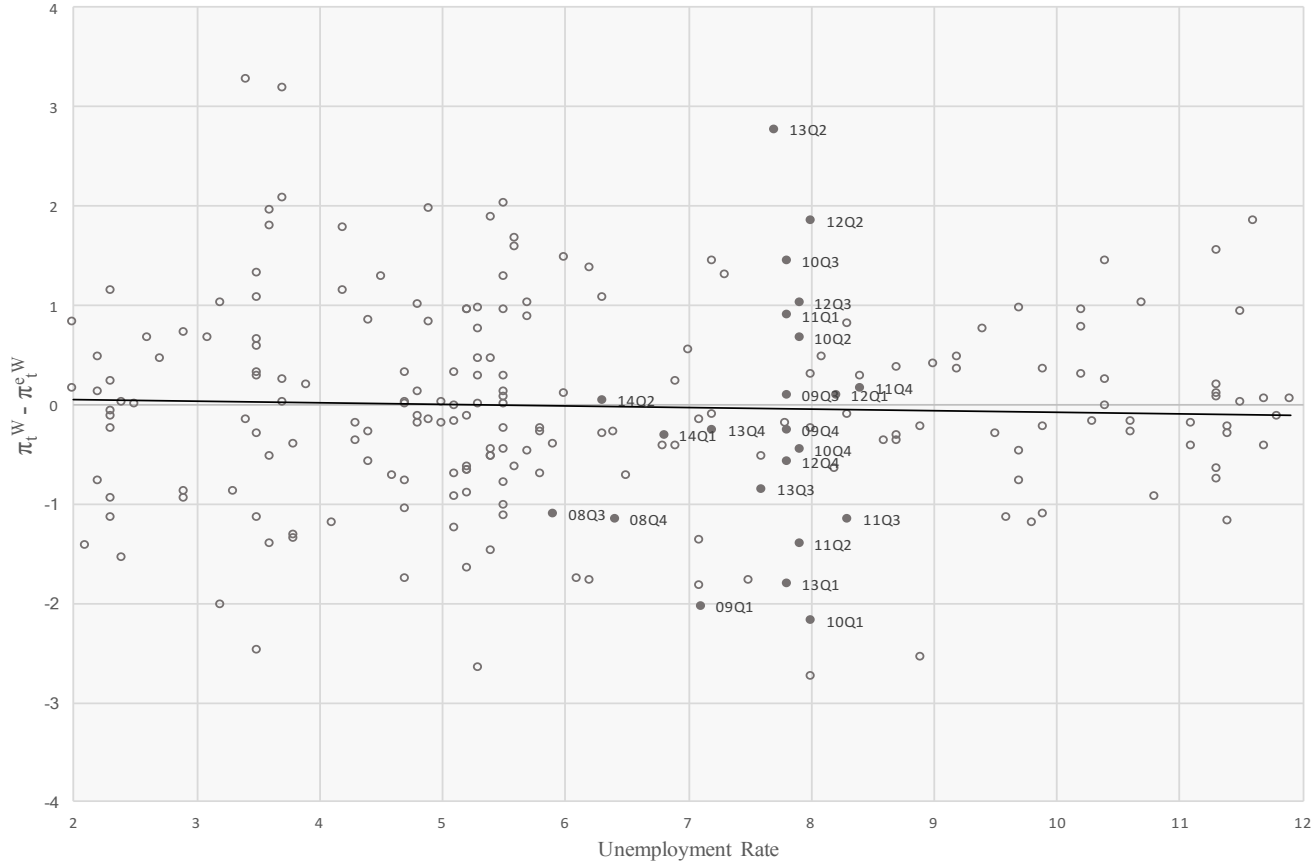
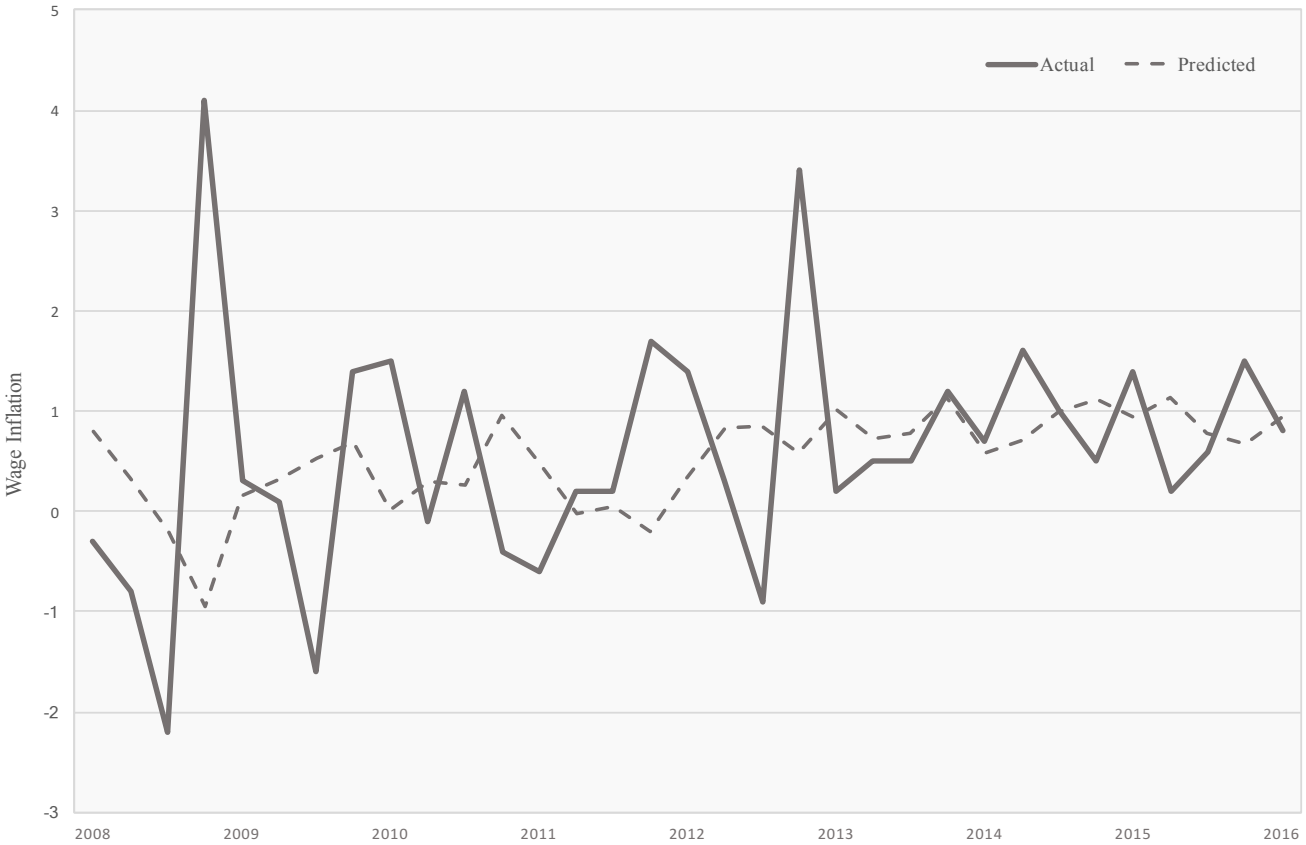


Figure IX.



Note: Figure VIII plots a scatter graph for deviations in wage inflation from expectations against the unemployment rate from 1960Q1-2016Q4. Unfilled circles represent data for 1960Q1-2008Q2 and 2014Q3-2016Q4. Filled circles represent data for 2008Q3-2014Q2. The trend line captures estimated deviations in wage inflation as a function of unemployment in a linear regression, whose estimation output is detailed in the Appendix. Figure IX is a time-series plot of the actual wage inflation rate against the wage rate predicted by the Phillips curve using pre-crisis data.

V. STRUCTURAL BREAKS

Another school of thought in the case of missing disinflation has focused on the slope of the Phillips curve and how this has flattened over time as an explanation; undermining the relation and its ability to predict the evolution of prices in the future, particularly during the crisis. In the following section this paper tests for changes in the slope of the Phillips curve over time and the extent to which this structural break might explain disinflation within the United Kingdom.

Changes in the Slope of the Phillips Curve

Figures X and XI both plot deviations of inflation from expectation against the unemployment rate and unemployment gap respectively. In the former we find a shift in the slope from -0.26 to -0.17, whereas in the latter we find a shift from -1.10 to -0.65, both of which are statistically significant at the $\alpha = 1\,\%$. These results consolidate the negative relationship across time and affirm a flattening of the Phillips curve between the two sub periods before the recession. Whilst informal, this evidence suggests that changes in the slope of the Phillips curve may explain the missing disinflation to some extent. However, it is necessary to formally derive such results empirically.

This paper constructs a new regression to investigate the statistical evidence by imposing a break in the slope of the Phillips curve. This will allow us to compare estimates between two periods so as to determine the extent of their variation through a time dummy variable that interacts with the forcing variable of interest, which is given by the following equation:

$$\pi_t - E_t\pi_{t+1} = c + \kappa u_t^{gap} + \gamma u_t^{gap} D_{\geq 90,t} + \theta D_{\geq 90,t} + v_t \tag{5}$$

where D is the time dummy variable equal to one for all periods between 1990-2008 and zero for all periods prior. The coefficient of particular interest in this regression is γ, as it is associated with the interaction of the unemployment gap with the dummy variable, which allows us to detect changes in the slope of the Phillips curve and thereby determine the veracity of our hypothesis.

Estimation results are reported in Tables I, II and III for the CPIH, CPI and GDP Deflator respectively between 1970-2008. In each variation, ordinary least squares output is presented in line with the value of the time dummy. The results show γ as positive, indicating a persistent flattening of the Phillips curve over time. However, this is significant at the $\alpha = 10\,\%$ with the GDP deflator and insignificant at all levels with both the CPIH and CPI. This provides mixed evidence for a change in the slope of the Phillips curve, albeit the great magnitude of these reductions are consistent across all regressions between 45%-65%. Given the evidence for changes in the slope of the UK Phillips curve is inconclusive, one must conclude it is a weak explanation to the missing disinflation.

Structural Breaks and Missing Disinflation

Literature on the flattening of the UK Phillips curve posits various explanations to this phenomenon of which some are structural (Saunders, 2017; Haldane, 2017); detected even by the New Keynesian Phillips Curve (IMF, 2013; Blanchard, Cerutti and Summers, 2015; BIS, 2017), whose slope, given certain assumptions by Galí (2008) cited in Coibion and Gorodnichenko (2015), may be written as:

$$\kappa = \frac{(1-\lambda)(1-\beta\lambda)}{\lambda} \cdot \frac{\alpha}{\alpha + (1-\alpha)\theta} \cdot (\sigma + \frac{\phi + 1 - \alpha}{\alpha}) \cdot \alpha \tag{6}$$

Figure X.

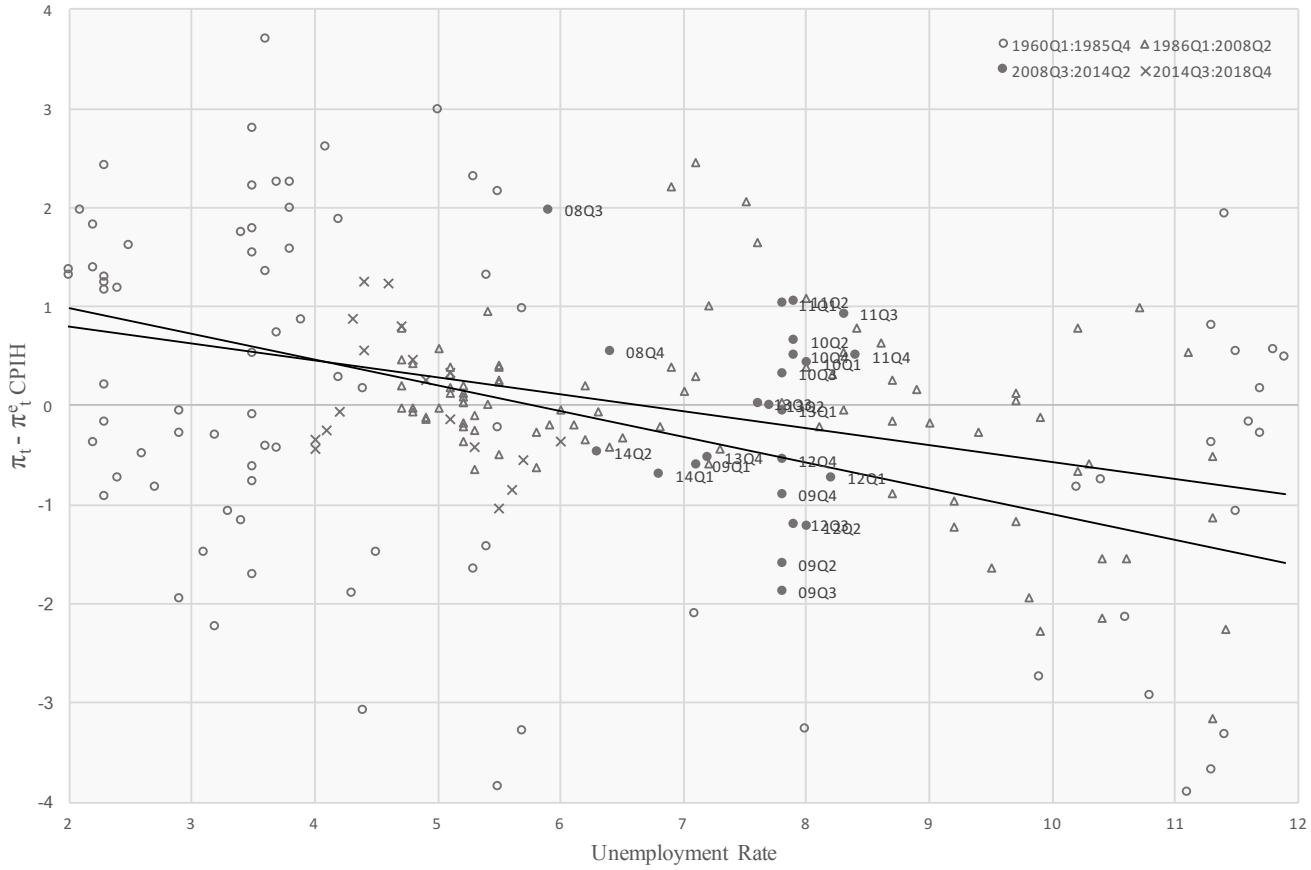
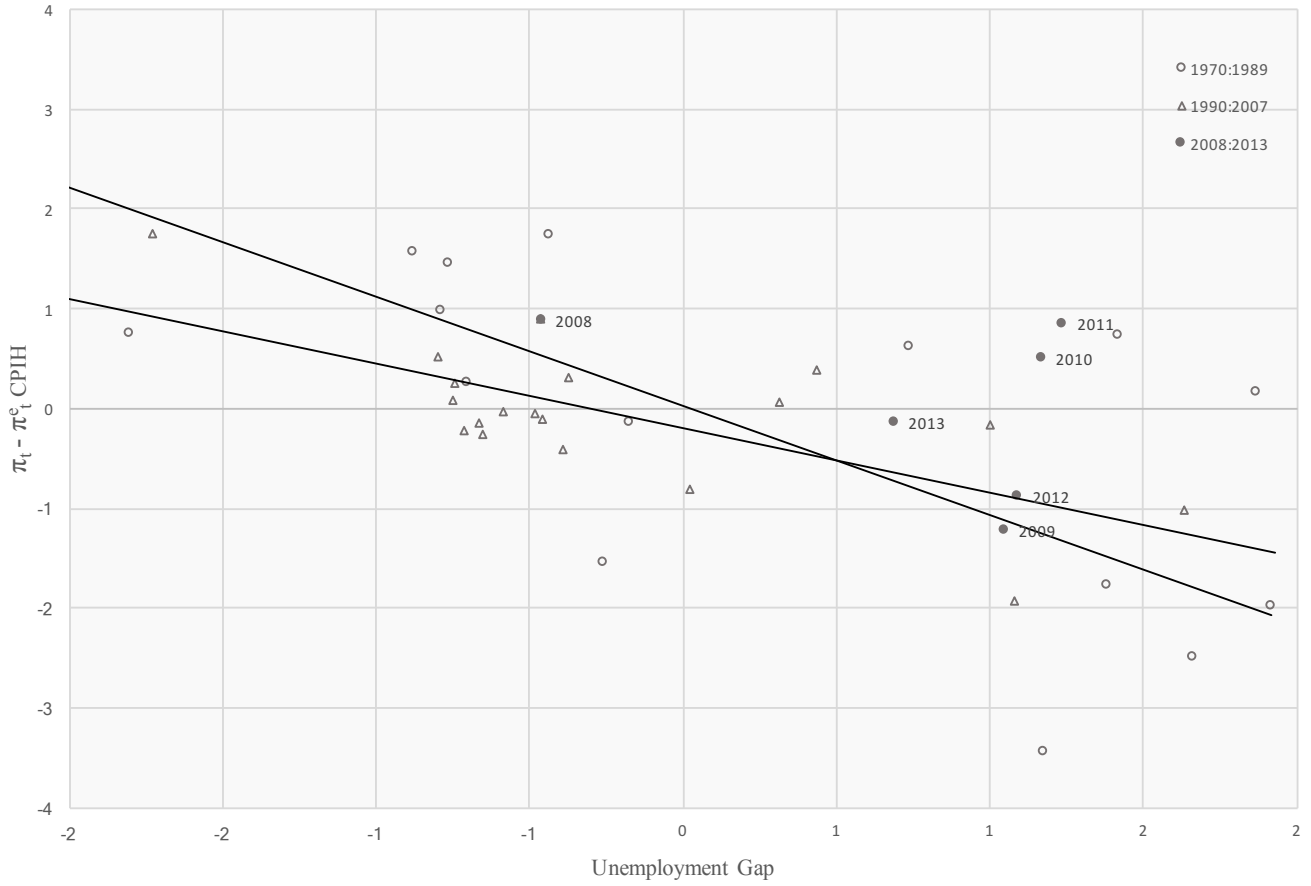


Figure XI.



Note: Figure X plots a scatter graph for deviations in inflation from expectations against the unemployment rate from 1960Q1-2016Q4. Pre-crisis data is subdivided between 1960Q1-1985Q4 and 1986Q1-2008Q2 to test for structural breaks. Figure XI uses a smaller sample of annual data for the unemployment gap between 1970-1989 and 1990-2007. In both graphs, the Phillips curve has flattened over time. The legend for each set of observations has been provided.

Table I. *Consumer Price Index Housing*

	OLS (1)	OLS (2)
$UE_t - UE_t^n, \kappa$	-1.447***	-1.698***
	(0.438)	(0.667)
$(UE_t - UE_t^n) \cdot D(year \geq 1990), \gamma$		0.711
		(0.737)
$D(year \geq 1990), \theta$		-0.398
		(0.905)
$\kappa + \gamma$		-0.987
R^2	0.203	0.220
N	39	39

Table II. *Consumer Price Index*

	OLS (1)	OLS (2)
$UE_t - UE_t^n, \kappa$	-1.443***	-1.751***
	(0.484)	(0.702)
$(UE_t - UE_t^n) \cdot D(year \geq 1990), \gamma$		0.885
		(0.841)
$D(year \geq 1990), \theta$		-0.415
		(0.990)
$\kappa + \gamma$		-0.866
R^2	0.189	0.210
N	39	39

Table III. *GDP Deflator*

	OLS (1)	OLS (2)
$UE_t - UE_t^n, \kappa$	-1.412***	-1.874***
	(0.487)	(0.701)
$(UE_t - UE_t^n) \cdot D(year \geq 1990), \gamma$		1.353*
		(0.774)
$D(year \geq 1990), \theta$		-0.500
		(0.982)
$\kappa + \gamma$		-0.521
R^2	0.167	0.209
N	39	39

Note: Each table reports output from regressing equation (5), with varying specifications of Inflation. Data is partitioned by the year 1990 into two subsamples. Standard errors are reported in parenthesis.

**** Statistically significant at one percent.*
*** Statistically significant at five percent.*
** Statistically significant at ten percent.*

where λ captures the temporal frequency of changes in prices, θ the elasticity of substitution, $1/\sigma$ the intertemporal elasticity of substitution, ϕ the elasticity of labour supply, α the elasticity of output and β the discount factor. As certain parameters are notoriously difficult to extract from the data by way of estimation, this paper shall refrain from doing so, except to note that changes in certain parameters are more likely to have contributed to the flattening of the Phillips curve than others.

Much like other members of the OECD, labour shares of output within the United Kingdom that are used to proxy for marginal costs, have declined steadily since the 1980s (OECD, 2012; IMF, 2007; EC, 2007; BIS, 2006; ILO, 2012). In addition, profit shares of GDP increased over this period according to Toporowski (2006). Finally, literature on the frequency of price changes in the United Kingdom is mixed (see Bunn and Ellis, 2012), whose trend is therefore difficult to conclude. In this regard, a decline in the labour share and increase in the profit share would have flattened the Phillips curve, thereby corroborating our former estimation. This might explain variations in the slope, albeit the extent to which it captures the magnitude of this change requires research. Based on the existing literature, this paper assumes these trends only fractionally account for such variation.

Are changes in the slope of the Phillips curve able to explain the evolution of prices after the recession? Perhaps the only formal means of testing this is by way of counterfactual time paths for the restricted and unrestricted estimates of the Phillips curve, which are all but minor improvements to our former results; still unable to capture post crisis inflation. Finally, evidence on changes in the slope of the Phillips Curve is mixed, particularly for the United Kingdom, with studies both for and against the motion. Moreover, the extent of this change (assuming it has) is hitherto unexplained by macroeconomic theory. Given the fragility of this change in the slope and to preserve the strength of our analysis, this paper discontinues it as a potential explanation to the disinflation during the crisis within the United Kingdom. This is entirely sensible, as even if the slope was non-constant and time variant, it would only partially explain inflation during the crisis. It is therefore necessary to persist in search of a more robust explanation to this phenomenon.

VI. INFLATION EXPECTATIONS

Few explanations considered are able to capture inflation dynamics during the recession. This section now considers underlying shifts in firm inflation expectation as a potential explanation to the missing disinflation in the United Kingdom. Perhaps the greatest obstacle to this analysis is the lack of data on firm inflation expectations. However, time-series published by the Bank of England on household expectations and professional forecasts may proximate for firms, allowing us to investigate the extent to which they better explain inflation dynamics during the recession.

Alternative Expectations

The lack of data on firm expectations may bias our results with weak proximation. In this regard, it is necessary to examine differences between professional forecasts and household expectations, which may reveal their ability to capture the underlying variable for which they proxy. Figure XII plots the annual time series of both household expectations and professional forecasts surveyed by the Bank of England between 1985 to 2013. Whilst professional forecasts generally trace household inflation expectations, there are subtle differences that warrant some attention. Firstly, households on average have expected higher inflation than professionals. Secondly, there are sustained periods household expectations have been significantly greater than professional forecasts. Perhaps the most important of which is the divergence post recession, where households have reported not only higher inflation expectations than professionals but rising forecasts over time.

In the absence of firm inflation expectations, such variation between agents necessitates some caution in assuming households and forecasters are exact proxies for firms. As discussed by Coibion and Gorodnichenko (2015), their accuracy is contingent on the nature of the underlying variable for which they proxy. For instance, larger firms look unto professional forecasts to guide their decisions whereas small-medium enterprises may not be so reliant, particularly as the lack of forecasts would unlikely inhibit their trade. In this instance, households may better proxy firms. To test which better represents firm expectations, this paper estimates the following nested Phillips curve

$$\pi_t = \beta_1 E_t^H \pi_{t+h} + \beta_2 E_t^P \pi_{t+h} + \kappa x_t + v_t \tag{7}$$

which uses household expectations, professional forecasts and unemployment as regressors. If firm expectations are better proxied by households, the hypothesis would be that $\beta_1 \approx 1, \beta_2 \approx 0$, whereas the null that they are better proxied by professionals would be $\beta_1 \approx 0, \beta_2 \approx 1$. Various specifications are estimated using the rate of unemployment and unemployment gaps, including and excluding the recession with restricted and unrestricted coefficients for each forecast. Results are reported in Tables IV-VII, which prove that coefficients associated with household expectations are significantly closer to one whereas coefficients for professional forecasts are insignificantly closer to zero.

Professional Forecasts

Deviations in inflation from professional forecasts are plotted against the rate of unemployment and deviations in unemployment from the natural rate in Figures XIII and XIV respectively. The negative relationship for the former is statistically significant at the $\alpha = 10\,\%$ with an $R^2 = 0.077$, albeit the latter is insignificant at the $\alpha = 10\,\%$ with an $R^2 = 0.031$. Perhaps the most noticeable feature here is that crisis observations are now closer to the expected trend line. This is particularly evident for the year 2010, in which prices persistently deviated from what the Phillips curve predicted; an indication perhaps of the strength in professional forecasts when accounting for crisis disinflation.

Table IV. *Unemployment Rate, Unrestricted Model*

	OLS (1985-2008)	OLS (1985-2013)
$E_t^H \pi_{t+1,t+4}$	1.567***	1.422***
	(0.390)	(0.369)
$E_t^P \pi_{t+1,t+4}$	0.113	0.015
	(0.298)	(0.283)
u_t	-0.524***	-0.385**
	(0.184)	(0.166)
R^2	0.761	0.719

Table V. *Unemployment Rate, Restricted Model*

	OLS (1985-2008)	OLS (1985-2013)
$E_t^H \pi_{t+1,t+4}$	0.907***	0.953***
	(0.338)	(0.298)
$E_t^P \pi_{t+1,t+4}$	0.093	0.047
	(0.338)	(0.298)
u_t	-0.130	-0.131
	(0.121)	(0.111)
R^2	n/a	n/a

Table VI. *Unemployment Gap, Unrestricted Model*

	OLS (1985-2008)	OLS (1985-2013)
$E_t^H \pi_{t+1,t+4}$	1.384***	1.255***
	(0.328)	(0.324)
$E_t^P \pi_{t+1,t+4}$	-0.200	-0.199
	(0.328)	(0.329)
u_t^{gap}	-0.866***	-0.567**
	(0.278)	(0.249)
R^2	0.774	0.717

Table VII. *Unemployment Gap, Restricted Model*

	OLS (1985-2008)	OLS (1985-2013)
$E_t^H \pi_{t+1,t+4}$	1.291***	1.232***
	(0.323)	(0.313)
$E_t^P \pi_{t+1,t+4}$	-0.291	-0.232
	(0.323)	(0.313)
u_t^{gap}	-0.790***	-0.562**
	(0.274)	(0.245)
R^2	n/a	n/a

**** Statistically significant at one percent.*
*** Statistically significant at five percent.*
** Statistically significant at ten percent.*

Note: The restricted model is estimated with a constraint on the coefficients associated with each forecast: $\beta_1 + \beta_2 = 1$. Expectations are averaged over the following four quarters. Standard errors are reported in parentheses.

Figure XII.

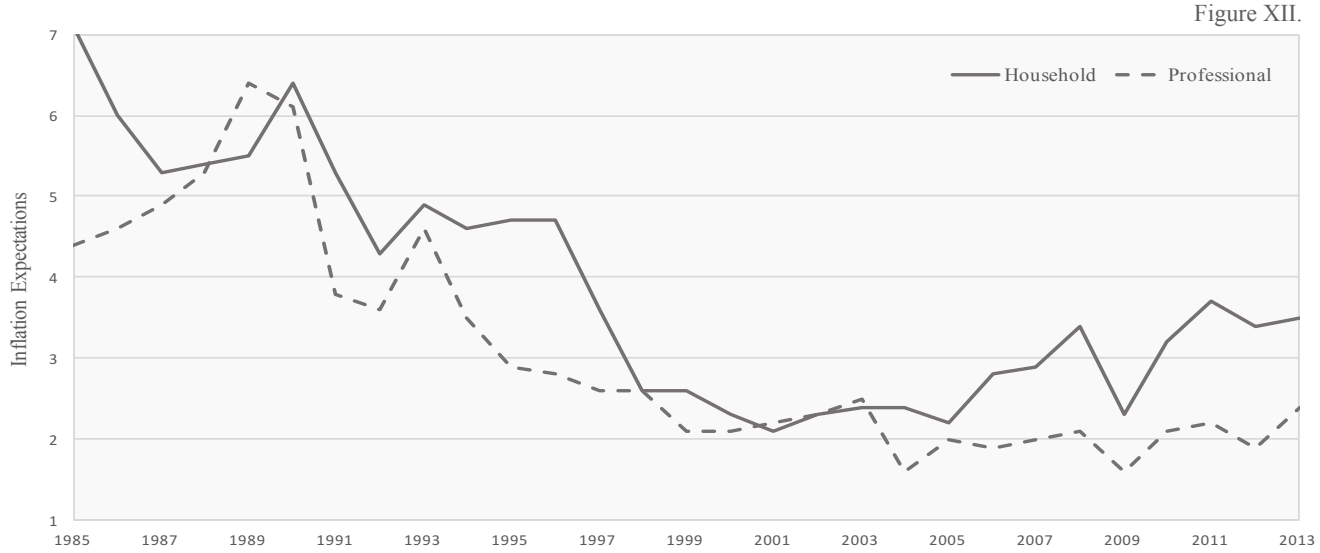


Figure XIII.

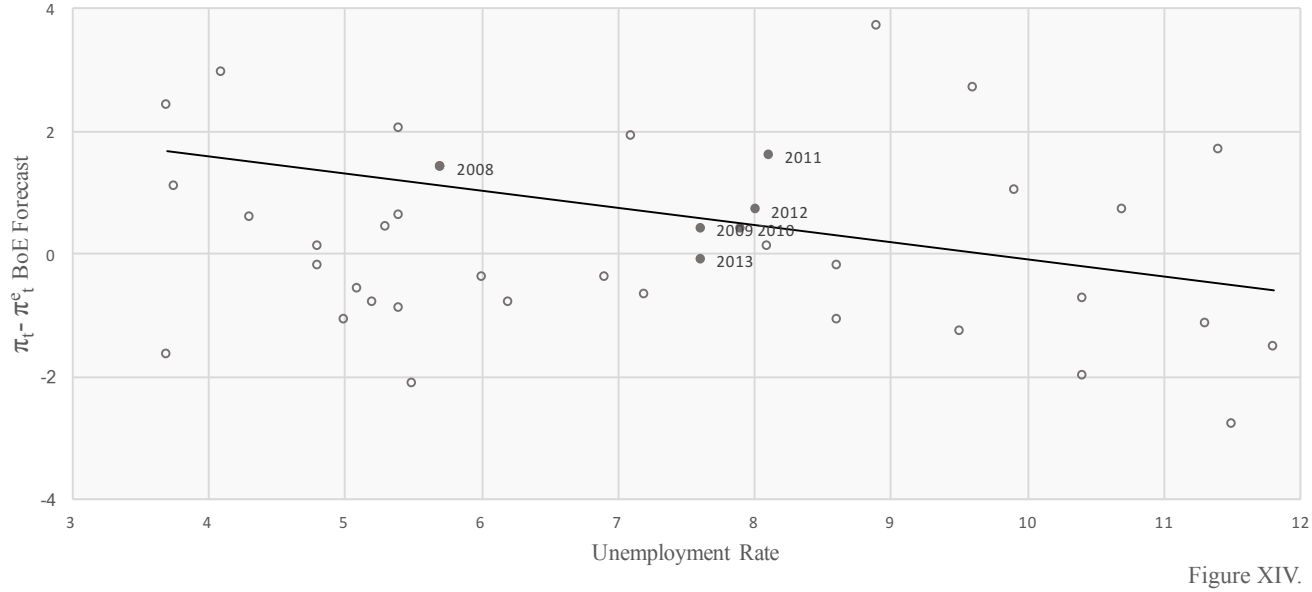
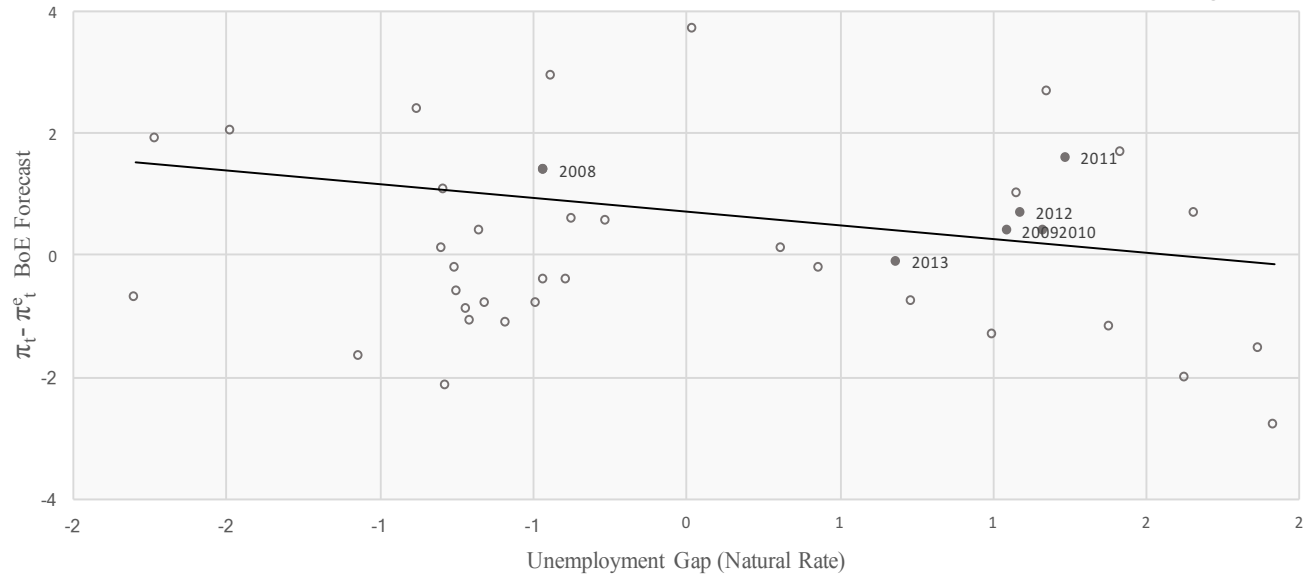


Figure XIV.



Note: Figure XII plots the time series for both household inflation expectations and professional forecasts of inflation surveyed by the Bank of England. Figures XIII and XIV plot deviations in inflation from these professional forecasts against the unemployment rate and deviations in unemployment from the natural rate respectively. The trend in this expectations augmented curve captures estimated deviations in inflation as a function of unemployment in a linear regression, whose output is detailed in the Appendix. Filled circles represent observations circa the recession.

Figure XV plots the evolution of actual CPIH inflation against the rate of inflation predicted by the Phillips curve with alternative expectations. It is apparent that the predicted rate of inflation using professional forecasts outperforms our baseline model, insofar as it is closer to the actual time series on average. In fact, during the initial stages of the crisis, the curve using adaptive expectations predicted stable inflation at a time when the United Kingdom experienced price disinflation, whereas inflation predicted using professional forecasts was consistent with the actual rate of inflation over the same period. Further still, the disinflation predicted to have been missing circa 2010 by the baseline model (which led to the subsequent periods of overshooting) is absent from the Phillips curve that uses deviations in inflation from professional forecasts as the regressor.

Household Expectations

In accordance with the aforementioned, deviations in inflation from household inflation expectations are plotted against the rate of unemployment and deviations in unemployment from the natural rate in Figures XVI and XVII respectively. As for the former, this paper finds a statistically insignificant negative relationship at the $\alpha = 10\,\%$ with an $R^2 = 0.081$. As for the latter, there exists a negative relationship that is significant at the $\alpha = 1\,\%$ with an $R^2 = 0.281$. In Figure XVI observations during the recession are clearly closer to the trend, particularly in 2010 and 2011, when prices consistently diverged from what the Phillips curve predicted using adaptive expectations. This is yet again further evidence to indicate the relative strength of household forecasts. However, Figure XVII tells a slight different story, with observations during the crisis clearly clustered away from the trend as inflation was higher than predicted by the Phillips curve using unemployment gaps.

From Figure XV, we note that the predicted rate of inflation using household expectations is clearly in some consonance with actual inflation, outperforming our baseline model. Similarly, in the initial and subsequent quarters of the crisis, inflation predicted by the Phillips curve using household forecasts is in line with the actual rate; thus missing disinflation and inflation overshooting are again absent upon accounting for household forecasts. Furthermore, despite tracing the general evolution of actual inflation over time, the predicted rate has persistently been lower during much of the financial crisis, particularly between 2008-2012. This indicates systematic underestimation by households of future inflation, which may explain why on average they underperform.

It is worth questioning here the source of variation between household inflation expectations and professional forecasts. This paper considers an answer proposed by Coibion and Gorodnichenko (2015), namely the price of oil as a core contributor to the differences between agent beliefs. Figure XVIII plots household inflation expectations and the spot oil price for West Texas Intermediate over time. Similar to the referenced paper, the former has tracked the latter very closely between 2010 to 2013 with a strong correlation coefficient of $r = 0.916$; far greater than the United States at 0.74 over the same time period. This is in contrast to the correlation coefficient between professional forecasts and oil prices, which is weaker and even negative at $r = -0.062$ as shown in Figure XIX.

This paper tests this formally by regressing differences between household expectations and professional forecast on oil prices in the United Kingdom. Tables VIII and IX report results in levels and first-differences respectively. For the former, the level of oil prices is a significant predictor of the difference in inflation forecasts at the $\alpha = 10\,\%$ with an $R^2 = 0.077$; higher oil prices are associated with higher household inflation expectations relative to professional forecasts. For the latter, change in oil prices is a statistically insignificant predictor of this difference at the $\alpha = 10\,\%$ with a weaker $R^2 = 0.004$. In this regard, the results in Table VIII offer some (albeit very weak) explanation as to why household forecasts rose during the recession relative to those of professionals, which was due to an increase in the price of oil. This greater sensitivity may be due to the fact that prices of petroleum are perhaps the most patent prices within society that influence agent beliefs on aggregate prices.

Figure XV.

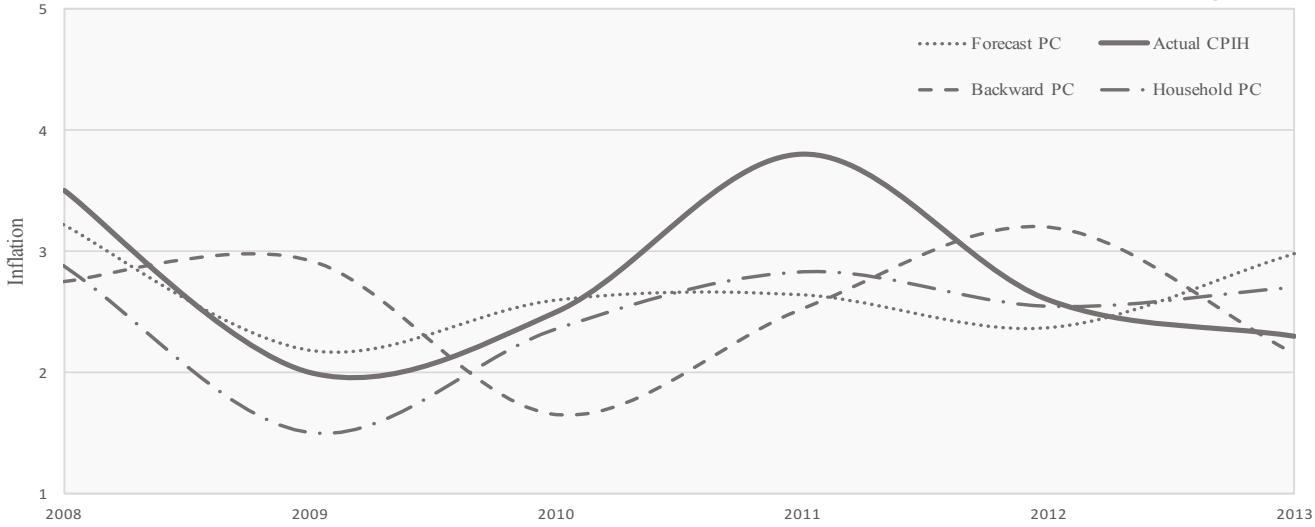


Figure XVI.

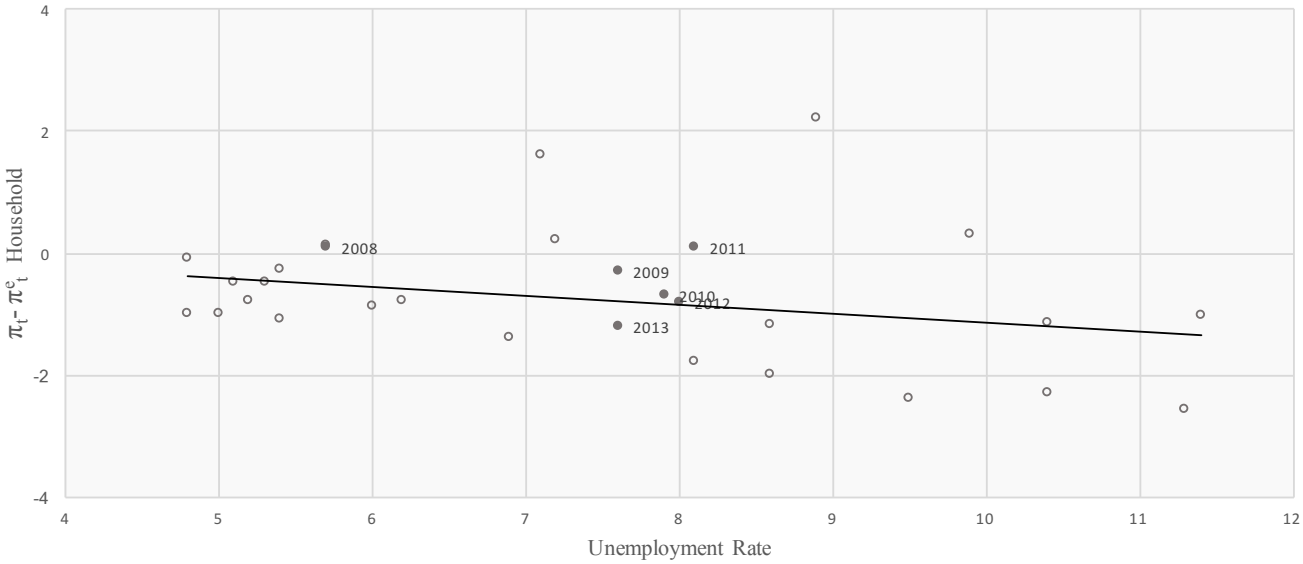
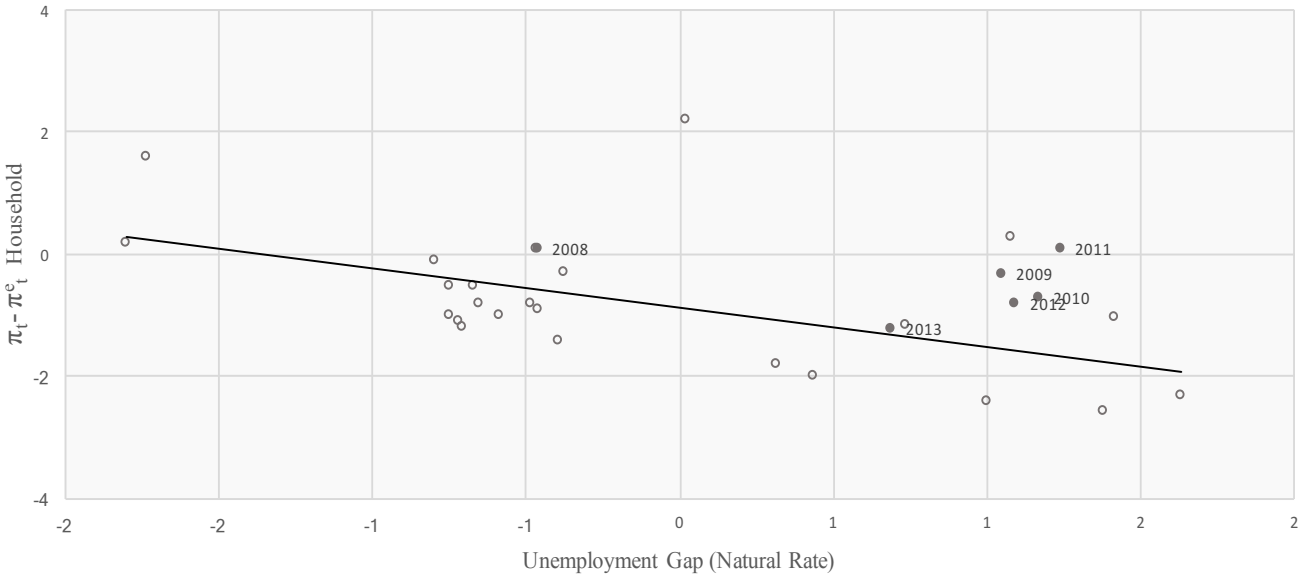


Figure XVII.



Note: Figure XV plots the actual rate of inflation and the rate predicted by the Phillips curve using alternative forms of expectations for pre-crisis data over the post-crisis period. Figures XVI and XVII plot deviations in inflation from household expectations against the unemployment rate and deviations from the natural rate respectively. The trend in this expectations augmented curve captures estimated deviations in inflation as a function of unemployment in a linear regression, whose output is detailed in the Appendix. Filled circles represent observations circa the crisis.

Figure XVIII.

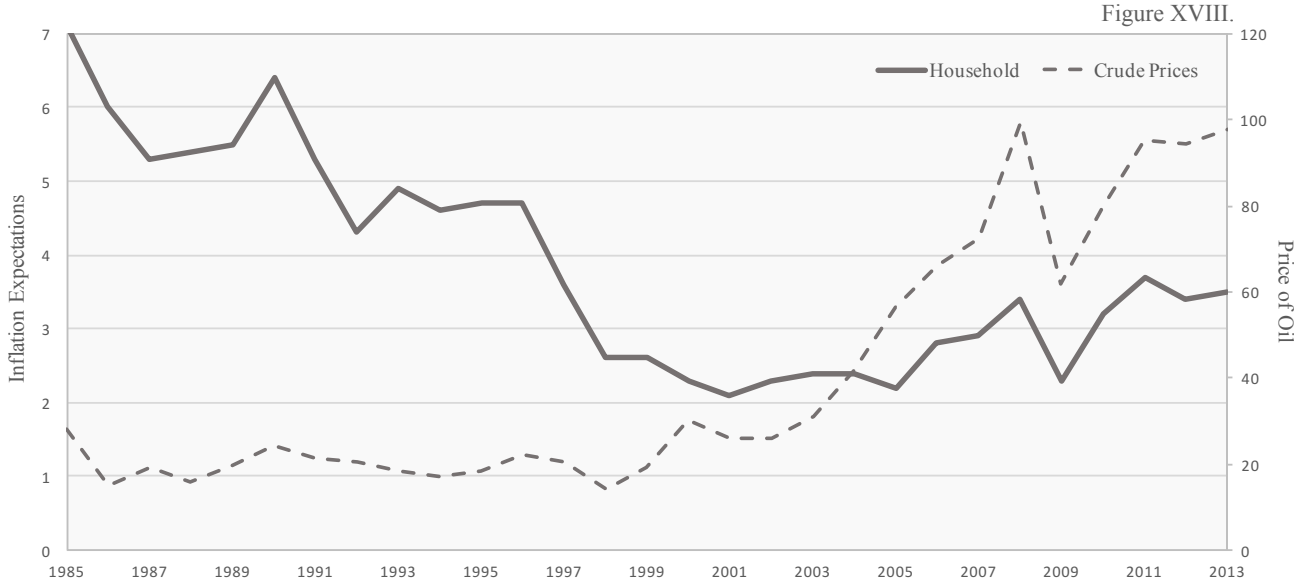


Figure XIX.

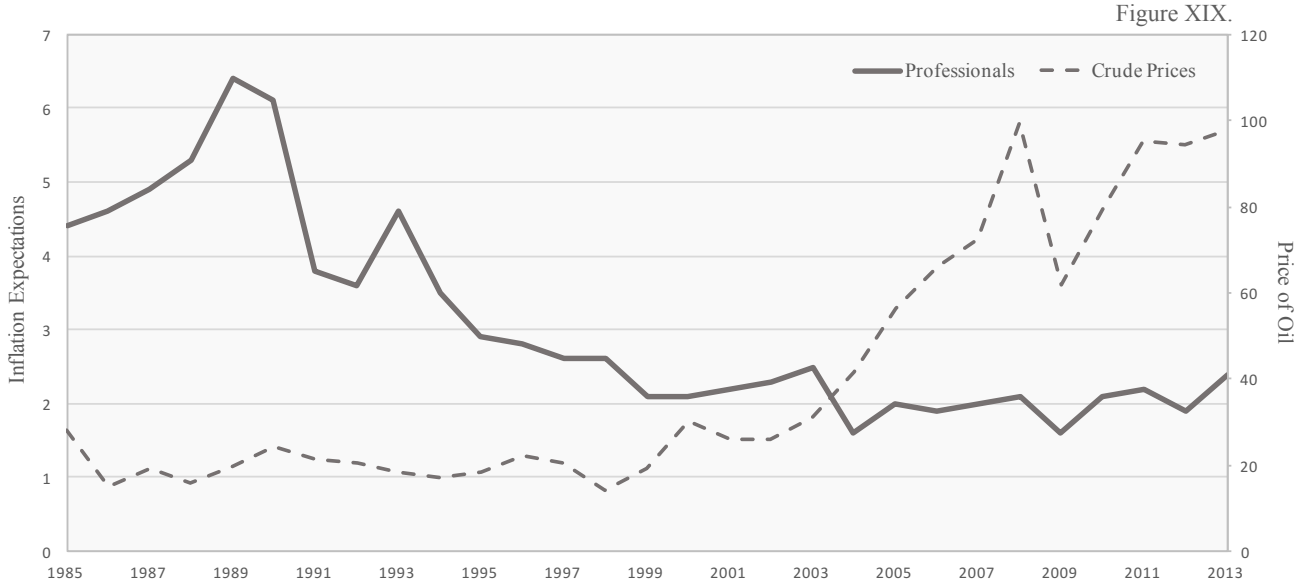


Table VIII. *Oil Price Changes on Inflation Forecasts (Levels)*

$E_t^H \pi_{t+1,t+4} - E_t^P \pi_{t+1,t+4}$	OLS
$OilPrice_t$	0.007*
	(0.005)
R^2	0.077

Table IX. *Oil Price Changes on Inflation Forecasts (Growth)*

$E_t^H \pi_{t+1,t+4} - E_t^P \pi_{t+1,t+4}$	OLS
$gOilPrice_t$	-0.004
	(0.012)
R^2	0.004

**** Statistically significant at one percent.*
*** Statistically significant at five percent.*
** Statistically significant at ten percent.*

Note: The sample period is between 1985-2013. $OilPrice_t$ is the price of oil measured by the West Texas Intermediate. $gOilPrice_t$ is the annual growth rate in oil prices. Newey-West Standard errors are reported in parentheses.

VII. DISCUSSION

This paper has proven that household inflation expectations and professional forecasts of inflation are able to account for missing disinflation and inflation overshooting during the crisis. However, these conclusions differ from that of Coibion and Gorodnichenko (2015) insofar as professional forecasts are likely to be a better proxy for firm inflation expectations than households. This is extracted from Figure XV in which the rate of inflation predicted by the Phillips curve using forecasts are closer on average to the actual rate of inflation. In particular, professional forecasts yield an average inflation rate of 2.67%, which is closer to the actual average of 2.71% than what is predicted using household inflation expectations at 2.47%. Furthermore, whilst the latter traces actual inflation over time, Figure XV demonstrates persistent underestimation relative to the backward-looking Phillips curve. Despite these results, both forecasts struggle to completely predict what inflation manifested between 2010 to 2011, which was far beyond household and professional foresight.

Although households are more sensitive to commodity prices, the effect of a rise in the price of oil on inflation expectations was not as strong in the United Kingdom, as the Phillips curve with professional forecasts is still on average more accurate in predicting the evolution of prices despite this. In other words, the divergence in agent beliefs during the crisis due to a difference in oil price elasticity, and the subsequent rise in household expectations relative to professional forecasts due to higher oil prices, is not sufficient to account for the missing disinflation, nor does it detract from the fact that professional forecasts better capture inflation over this period. Regardless, and as argued by Coibion and Gorodnichenko (2015), surges in the price of oil would have placed upward pressure on expectations, thereby suppressing any disinflation predicted by the Phillips curve.

These findings also imply that unlike professional forecasts, household expectations were not entirely anchored during the recession. In fact, although the former has proven more informative on average in predicting inflation dynamics within the Phillips curve framework, the latter rose between 2010 to 2011 and can better capture prices during these years (see Figure XVIII). In this regard, had household expectations of inflation been anchored like that of professional forecasts (see Figure XIX) as argued by the literature (Bernanke, 2010), one might have expected even sharper disinflation in the United Kingdom at the height of the recession. Nonetheless, this paper has shown that conditioning on professional forecasts that are anchored abrogates much of what is ostensibly detected as missing by the Phillips curve, lending some credence to the theory of anchored expectations.

This investigation is not without some limitation. Firstly, time series data on the natural rate of unemployment, household expectations and professional forecasts are restricted in both length and frequency for the United Kingdom, which may have inhibited the power of our estimation. Secondly, there may be substantial measurement error when surveying inflation expectations that bias estimates in the Phillips curve. Thirdly, a weak proxy for firm inflation expectations may reduce the strength of our inference on the latent variable of interest, thereby diminishing these findings. Whilst household expectations may be closer to those of firms than professional forecasts as demonstrated by Coibion and Gorodnichenko (2015), the proximity of both is difficult to establish with certainty. Finally, it is likely that other factors (aside from unemployment) influenced inflation during the Great Recession that have been omitted from this analysis, potentially undermining our estimates.

The nature of our findings also emphasises the importance of expectations and their centrality in capturing the evolution of prices over time. As Figure XV illustrates, there is substantial variation between our assumptions on how these expectations are formed. In particular, adaptive backward-looking expectations have proven inferior to those proxies for firm expectations, be they professional or household. Whilst the former may on average predict inflation more accurately in the framework of the Phillips curve, the latter also explains inflation via changes in the price of oil, particularly after the crisis; invaluable to the policymaker in targeting macroeconomic fundamentals.

VIII. CONCLUSION

Keynesian models have proved unsuccessful at solving the missing disinflation puzzle that afflicted many nations during the Great Recession. Traditional variations of the Phillips curve that capture the relationship between nominal and real activity using backward-looking expectations suggest prices ought to have been lower than they actually were post crisis. This paper finds the most problematic quarters to be between 2010Q1-2011Q4, with persistent underestimation of inflation using adaptive expectations. This irreconcilable muteness has brought Keynesian variations of the relation such as the New Keynesian Phillips Curve and its ability to model fundamentals into disrepute.

Despite numerous potential explanations to the missing disinflation puzzle, such as anchored inflation expectations, changes in the slope of the phillips curve, nominal wage rigidity and variation in marginal costs, this paper finds each to be of no avail in predicting the evolution of prices during the recession. Instead, an expectations-augmented Phillips curve that uses household and professional forecasts as a proxy for firm inflation expectations, shows little signs of missing disinflation during the crisis. In particular, whilst the rise in household expectations (caused by a fortuitous increase in the price of oil between 2009-2011) can account for much of the missing disinflation, professional forecasts are on average better able to predict the evolution of inflation over time.

The scope for future research on the United Kingdom is lucrative. Firstly, whilst it is true that certain parameters of the New Keynesian Phillips curve are notoriously difficult to extract from the data, their heterogeneity may explain changes in the slope of the Phillips curve that were unreported in this paper. In recovering such parameters and formally testing those discussed, one may conclude the extent to which structural shifts account for the flattening of the curve, albeit noting this explains little of the missing disinflation. Furthermore, given households were heavily influenced by the rise in oil prices during the recession, it is still unclear as to why professional forecasts remained relatively stable. Further study may ascertain what influences the formation of professional expectations so as to determine their dynamic during the crisis. Finally, perhaps the most natural avenue of research from this paper would be to investigate how firms form their inflation expectations altogether, which may be deduced theoretically by considering their informational problems (Reis, 2006) or more directly by using quantitative surveys to extract the formation process of expectations.

In this regard, firm inflation expectations are essential to the Phillips curve in capturing the relationship between nominal and real variation. This paper has shown by way of replication, that the Phillips curve continues to be a useful framework to capture prices and macroeconomic fundamentals in the economy. This is true not only within the United States as Coibion and Gorodnichenko (2015) have proven but also within the United Kingdom as this paper has proven, contingent however on the use of household and professional inflation expectations, the latter of which more accurately predicts the rate of inflation on average within the framework of an expectations augmented Phillips curve.

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