UK'S INFLATION DYNAMICS: THE NEW KEYNESIAN PHILLIPS CURVE

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UK’S INFLATION DYNAMICS: THE NEW KEYNESIAN PHILLIPS CURVE

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ABSTRACT

The thesis seeks to study UK's inflation dynamics through the new Keynesian Phillips curve. It follows the method of Gali & Gertler (1999), where they used the marginal cost as a proxy for real economic activity. The new Keynesian Phillips curve is unique in that it captures the effects of expectations of future inflation and by extension the inflation persistence. The data comprises of quarterly series ranging from (1980: 1 – 2018: 4), with the retailed price index (RPIX) as the inflation measure and labor income share as a proxy for marginal cost. Using the generalized method of moments (GMM) estimation technique, we can conclude that the data fits the new Keynesian Phillips curve. Both the marginal cost measure and inflation expectations were found to be statistically significant in predicting current inflation in UK. However, the backward-looking measure could not justify the existence of inflation persistence in the British economy.

Keywords: Inflation persistence, retailed price index, Generalized method of moments, Backward-looking.

ÖZET

Tez, İngiltere’nin enflasyon dinamiklerini yeni Keynesyen Phillips eğrisi ile incelemeyi amaçlamaktadır. Marjinal maliyetin gerçek ekonomik faaliyeti temsilen kullanıldığı Gali ve Gertler (1999) yöntemini izler. Yeni Keynesyen Phillips eğrisi, gelecekteki enflasyon beklentilerinin etkilerini ve enflasyonun sürekliliğini artırarak yakalaması bakımından benzersizdir. Veriler, (1980: 1 - 2018: 4) arasında değişen üç aylık serilerden oluşmaktadır ve enflasyon ölçüsü olarak işgücü fiyat endeksi (RPIX), işgücü geliri pay oranını temsilen marjinal maliyet kullanılmaktadır. Genel moment yöntemi (GMM) tekniğini kullanarak, verilerin yeni Keynesyen Phillips eğrisine uyduğu sonucuna varabiliriz. Hem marjinal maliyet ölçüsü hem de enflasyon beklentileri, İngiltere'deki mevcut enflasyonu tahmin etmede istatistiksel olarak anlamlı bulunmustur. Bununla birlikte, geriye dönük enflasyon ölçüsü, İngiliz ekonomisinde enflasyonun sürekliliğini aciklayamamaktadir.

Anahtar Kelimeler: Enflasyon sürekliliği, perakende fiyat endeksi, Genelleştirilmiş momentler yöntemi, Geriye dönük bakış.

DEDICATION

To my parents and family

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CHAPTER 1

Introduction

This chapter is meant to give us a teaser of the successes and limitations of the new Keynesian Phillips curve literature. From it we will also learn about the objectives and significance of this study.

1.1 Background

The term New Keynesians was coined by Michael Parkin (1982) in his New Keynesian theory and Edmund S. Phelps (1986) – New Keynesian Model. The concept of the New Keynesian was first used in a scholarly article by Ball, Mankiw and Romer (1988)[1] (Gordon, 1990). They paved the way for other researchers who later extended the theory. Some of the New Keynesian Models in relation with the Phillips curve, are the models of staggered contracts developed by Taylor (1979, 1980) and Calvo (1983). Another notable one is Rotemberg's model of quadratic price adjustment cost (1982). Apparently, the models mentioned above have a common formulation to the expectations-augmented Phillips curve of Friedman and Phelps, (Roberts, 1995). Generally, the new Keynesian Phillips curve model establishes a precise relation between current and future inflation together with structural variables such as the output gap and marginal cost (Gali & Gertler, 1999). The key idea of the New Keynesian Phillips curve is built around the impact of expectations of future inflation on current inflation rate.

The New Keynesian Phillips curve (NKPC) explains how current inflation depends on the expectations of future inflation (core inflation) and output. There are two features of this Phillips curve that distinguishes it from the traditional and accelerationist Phillips curve. First, it is derived by aggregating the behavior of price-setters facing barriers to price adjustment. Second, the form of inflation expectations term is different from previous Phillips curves. The accelerationist

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[1] Title: The New Keynesian Economics and the Output-Inflation Trade-Off
Authors: Laurence Ball, N. Gregory Mankiw, David Romer, George A. Akerlof, Andrew Rose, Janet Yellen and Christopher A. Sims.

Phillips curve, captures last period's inflation while the Lucas supply curve, includes expectations of current inflation. The new Keynesian Phillips curve is indeed new, because it takes in current expectation of next period's inflation into consideration. These differences are important in studying the literature of the Phillips curve (Romer, 2012).

The early empirical literature of the NKPC clearly focused on modelling and estimating the inflation expectations. Various researchers used different forms of expectations, some of which are the distributed-lag hypothesis, adaptive-expectations, extrapolative-expectations and rational-expectations. When tested with South African data, the simplified adaptive-expectations hypothesis was able to forecast the inflation rate fairly accurately in 1992 but was not able to predict the deceleration in the inflation rate a year later. The accuracy of the forecast under the adaptive expectations hypothesis was, however, slightly better than that obtained by the distributed lag and actual inflation rate. The extrapolative hypothesis performed marginally weaker than the adaptive-expectations and the distributed-lag hypotheses. It also predicted the inflation rate based on previous values of inflation only and was unable to forecast the turning-point in the inflation rate in 1993. However, both versions of the rational expectations models clearly outperformed the other hypotheses which were based only on historical inflation rates, in terms of the forecast accuracy of inflation expectations. The price-formation process in South Africa is particularly dependent in changes in labor cost, which is largely driven by inflation expectations (Pretorius & Smal, 1994).

The concept of rational expectations can be rooted from John Muths' (1961) brilliant but long neglected paper. Economist routinely assume that firms rationally maximize profits and consumers rationally maximize utility. By itself the assumption of rational expectations has no empirical implication just as the assumption of utility maximization has no direct empirical implication (Mankiw, 1990). However, the assumption of rational expectations implies that people cannot be surprised by events and policies in the economy. Sargent and Wallace (1975), argued that systematic monetary policy can only influence expected and not unexpected inflation. Therefore, policy cannot affect unemployment under unexpected inflation. If their claim is true, then monetary policy will be ineffective even under recessions (Mankiw, 1990).

The rational-expectations models of inflation suggest that the expected inflation rate in any period is based on all information available to decision-makers at that moment. This information includes past performance of the economy and expectations of future policies that are likely to be followed by the authorities. Changes in key variables such as the money supply, the exchange rate and the budget deficit, serves as indicators of economic policies which may influence inflation expectations. The inflation expectations of agents depend on inflation rates recorded in the past and the behavior of policymakers. Romer (2012) conclusively indicates that expectations formed in a rational way by duly recognizing the intentions of policymakers are likely to be closer to the mark than those based on historical inflation rate patterns only. To further strengthen this point, the estimated inflation expectations in both models estimated in this paper were positively signed and statistically significant. The expected inflation measure is based on rational expectations where all current and past information were known to the agents. Roberts (1998) instead argues that the New Keynesian Phillips Curve fits reasonably well when survey measures of inflation expectations are used, but it does not fit well under the hypothesis of rational expectations.

Models measured with error variables and most dynamic models involving expectations tend to fail the orthogonality test which renders ordinary least squares to lose its credibility as an estimator. The method of instrumental variables could estimate linear models with such issues, and it is second in popularity only to OLS. However, the presence of heteroscedasticity makes the generalized method of moments (GMM) a more appropriate estimator than the instrumental variable technique, as it corrects for the problem. As proposed by Hansen (1982), this paper uses the efficient GMM estimator for the estimation of the New Keynesian Phillips curve and its hybrid version. However, econometric analyses would improve considerably if inflation expectations were directly observable and could be measured.

Roberts Lucas (1976) states that a structural model to estimate the Phillips curve needs to include a dependent variable that would be determined by explanatory variables and it should have impact on a system of these variables. Lucas pointed out, if it is not the case, then an empirical estimation of policy change cannot be substantiated. This idea is known as the famous “Lucas critic”[2]. Considering this view there could be an econometric problem in estimating the slope coefficients in new Keynesian Phillips curve and its hybrid version. For example, a contractionary monetary policy, will impact the coefficients and concurrently income level. Ultimately, changes in income will alter a system of macroeconomic variables including price level. Under such circumstances,

[2] See Lucas (1976)

policymakers will be unable to identify the real effect of the monetary policy. This econometric limitation was Lucas' main concern (Romer, 2012).

1.2 Research Objective

This paper takes its inspiration from the well celebrated work of Gali & Gertler (1999). They estimated the new Keynesian Phillips curve and its hybrid version using marginal cost as a proxy for real economic activity. Marginal cost was measured using the labor income share. Studying the New Keynesian Phillips curve and its hybrid version helps to keep tract of the dynamics of inflation and most importantly, inflation inertial. Following the method of Gali & Gertler (1999), this study used the GMM estimation technique to understand UK's inflation dynamics.

The main objective of the research is to capture the impact of monetary policy or precisely the effects of the central bank's actions in controlling inflation. This is in line with the goal of the new Keynesian Phillips curve, as it explains the impact of monetary policy. The Bank of England uses two main tools in conducting monetary policy. First, they set the interest rates charged to banks for borrowing, which is known as the *bank rate*. Second, they use what is called *asset purchasing* (*quantitative easing*), i.e. to create money digitally to buy corporate and government bonds. These policies are at the disposal of the bank as they aim to control money supply and ultimately keep inflation at bay.

According to Gali and Gertler's formulation of the hybrid new Keynesian Phillips curve, current inflation depends on a combination of expected future inflation and lagged inflation. The lagged term is meant to capture the inflation persistence and it indicates that disinflation could be costly. The motivation of the hybrid approach is highly empirical. However, it has limited success, particularly, the relation does not seem to provide a good characterization of inflation dynamics under quarterly data[3].

Broadly speaking, inflation persistence is the tendency for inflation to be comparatively high (low) in one period, having been comparatively high (low) in previous periods. Unfortunately, this appears to have been the exception, rather than the rule. Inflation is found to have been very highly

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[3] This is consistent with the results of this study, see chapter 5 for more details.

persistent only during the period between the floating of the pound and the introduction of inflation targeting[4] (Benati, 2006).

Given these limitations, the study seeks to investigate the existence of inflation persistence in UK's economy.

1.3 Significance of Study

One of the most talked about issues in macroeconomics is the impact of monetary policy on the real economic variables such as the GDP and unemployment. There is a continuing debate as proponents of monetary neutrality try to claim that monetary policy has no long run effects in the economy. Keynesians on the other hand have a different view – they believe that central bank's actions can influence the economy, particularly, under conditions of recession. My study will add to the unending debate of the literature through the new Keynesian Phillips curve.

1.4 Scope of the Thesis

The rest of the paper is organized as follows; the next chapter provides a brief historical background of inflation in the economy of UK. Chapter 3 presents the empirical literature and the theoretical facts of the new Keynesian Phillips curve. Chapter 4 explains the methodology employed to estimate the model. Chapter 5 takes us through the interpretation and analysis of the results and ultimately, chapter 6 concludes.

[4] The bank of England adopted the policy of inflation targeting in October 1992.

CHAPTER 2

Recent tracks of UK's inflation

This chapter presents us with a brief historical background of the oscillations of inflation in the United Kingdom. The various monetary regimes used by the Bank of England. Most impressively, it will show us, how they were able to maintain a very low inflation level in the past three decades.

2.1 Recent trend of inflation in the U.K

The UK monetary policy framework has experienced several changes over the period (1970 – 2000). The Bank of England is responsible for setting monetary policy to stabilize inflation in the economy. They have two main tools at their disposal to carry out this responsibility: First, they charge commercial banks an interest rate known as the bank rate, for borrowing. Second, they create money digitally to buy corporate and government bonds – an action known as asset purchasing or quantitative easing.

In the mid-1970s, the bank followed frameworks for monetary policy that were explicitly set out to target nominal magnitudes in reaction to a sharp increase in inflation. The late 1980s were a period of strong economic growth, a combination of large wage increases and a rising real exchange rate for the sterling. The United Kingdom joined the exchange rate mechanism (ERM) in October 1990, they later suspended their membership on a 'black Wednesday' in September 1992. The sterling was later linked to other European currencies and officially adopted inflation targeting the same year. From October 1992 to date, the inflation rate targeting has been the monetary policy framework for the Bank of England. Furthermore, the bank was later given operational independence in 1997 and the monetary policy committee (MPC) was established as a result. However, the British government has the mandate to set the target inflation rate and allow the bank to set monetary policy such that the target is achieved. The current inflation target for the UK is set at 2%, as they continue to aim for low and stable inflation rate.

The post 1992 inflation targeting regime is considered as the most stable macroeconomy environment recorded in UK history. Since then business cycle components and inflation measures have been systematically lower than the previous monetary regimes. The inflation targeting regime was introduced in October 1992, to replace the floating of the pound. The introduction of the inflation targeting led to 70% fall in the inflation rate.

UK experienced a high level of inflation in the latter half of the 1980s, known as the ‘Lawson boom’. Unfortunately, inflation peaked in 1991, which many related to the increase in the value added tax (VAT). Although inflation has generally been lower since the early 1990s, it has clearly not flat-lined around the current target of 2%. Various inflation measures have fallen below 0% and above 5% at different points in time. For example, in the period (2010 – 2011) most inflation measures were above the target 2% as a result of the sharp depreciation in the sterling. Meanwhile, 2014 through 2015, produced measures that fell below the current target of 2%, results that were associated to the sharp fall in global commodity prices (Forbes, Kirkham, & Theodoridis, 2017).

Inflation in the United Kingdom has been quite volatile in the period (2007 – 2017). Consumer price inflation spiked to 5.2% in September 2008, and then fell to 1.1%, exactly a year later. Apparently, inflation rose back to 5.2% in September 2011. As these oscillations continued, inflation fell below 0% in 2015, but later rose to 2.9% in 2017 Forbes et al. (2017). This high level of volatility can be related to international factors like changes in oil prices, and index of commodity prices. These factors seem to have significant impact in explaining core and headline inflation. Changes in the sterling exchange rates also seem to have significant yet meaningful effects in explaining core and headline inflation Forbes et al., (2017).

However, recent economic history of the United Kingdom must deal with the puzzle of low inflation given low relative unemployment, or relatively high growth. For example, Balakrishnan & López-Salido, (2002) stated that the retailed price index (RPIX) inflation has recently been around or below the target level of 2.5%, yet unemployment was still falling from a very low base of around 5% until the second half of 2001. Given these outcomes, it is not surprising that traditional Phillips curve estimates have tended to overpredict inflation.

As UK is a more open economy compared to the Euro area and United States, it is prone to external shocks that might impact the economy negatively. World prices of oil play a key role in UK’s inflation dynamics. Albeit, the nominal price of oil is determined by the worldwide demand and supply for oil, it can be thought of as exogenous to output and inflation within the economy. Various researchers used different econometric models to measure the relationship between inflation and oil price shocks. Millard, (2011), estimated a dynamic stochastic general equilibrium (DSGE) model of energy, costs and inflation in the United Kingdom, to determine how variations in energy prices affect UK's inflation. He acknowledges that the increase in world oil prices during the financial crisis (2007 – 2010) caused large swings in UK's inflation. For example, from 2007 third quarter to 2008 second quarter, oil prices rise from $75 per barrel to $121 per barrel. The associated change in consumer price index (CPI) inflation ranges from 1.8% to 4.8%, the same period. Such fluctuations of inflation are exorbitantly high and could have potential negative spillovers in the economy (Millard, 2011). Moreover, policy makers have a tough job in controlling such rare occurrences in the economy. They find it tough, because these shocks are exogenous in nature. Policymakers must learn how to deal with such shocks and mitigate their effects in the economy. Because of its openness, inflation rate tends to be more sensitive to movements in international prices. UK's inflation is found to be less persistent and somewhat more volatile than the US.

Forbes et. al. (2017), suggested that trend inflation plays a substantial role in explaining inflation measures such as headline and core inflation. According to them, trend inflation explained 39% and 46% of the variation in headline and core inflation respectively. Inflation expectations were found to be positive and significantly correlated with inflation but with a small magnitude. Surveys of one year ahead household inflation expectations have fallen by between 0.4 and 0.9 percentage points, while financial market measures, such as inflation swaps, and professional forecasters' one year ahead expectations for CPI inflation have also fallen. The CPI inflation fell from 1.8% in April 2014 to - 0.1% in exactly a year later (Domit, Jackson, & Roberts-Sklar, 2015).

Inflation in the United Kingdom has been characterized by different monetary regimes that impacted the economy differently. The economy is also vulnerable to shocks because of its nature. This was clearly manifested during the world financial crisis in 2007 and its aftermath.

CHAPTER 3

Literature Review

This chapter presents the empirical and the theoretical literature of the thesis. The empirical literature is indeed revealing in terms of explaining inflation dynamics through the New Keynesian Phillips curve. This paper is inspired by the work of Gali & Gertler (1999), where they estimated the NKPC and the Hybrid NKPC using GMM estimator.

3.1 Empirical Literature

The papers most closely related to the current study are, Gali & Gertler (1999), Gali et al. (2001), Balakrishnan & López-Salido (2002) and Arruda et al. (2018). Based on the formulation of the new Keynesian Phillips curve, these papers have a similar approach in that they take the marginal cost as the measure of real business cycle[5] activity. They also went further to estimate a hybrid version of the model by introducing a variable that could capture the inflation persistence. Like this study, they all resorted to the generalized method of moments (GMM) estimation technique. Generally, they all tend to generate different conclusions, but the good news is that, they all found the variable of interest (marginal cost) to be positive and statistically significant in explaining inflation dynamics.

The new Keynesian Phillips curve has a common formulation to the expectations augmented Phillips curve of Friedman and Phelps (1968). Roberts (1995), shows the common formulation between the New Keynesian models of staggered contracts and the expectations-augmented Phillips curve. The estimated model reveals how central the labor market is to aggregate nominal rigidities. Nominal rigidities are imperfections such as barriers and limitations to the adjustment of nominal prices or wages in business cycle models. However, they are not enough for monetary expansion to have real effects, there must be some departures from perfect competition in the labor or goods markets. We tend to get standard results when producers exercise some degree of market

[5] The name “real business cycle” is drawn from the claim that monetary policy is irrelevant to economic fluctuations, i.e. the concept of monetary neutrality. See Mankiw, (1990).

power. With a certain degree of market power, they are able to set prices as a markup over marginal cost, with the size of the markup determined by the elasticity of demand (Romer, 2012).

The Taylor (1979) and Calvo (1983) models of staggered contracts differ from the Fischer (1977) model in one important respect. In Fischer's model prices are predetermined but not fixed[6], on the contrary, prices are fixed in Taylor and Calvo's models[7]. However, their models differ in that, opportunities to change prices arrive deterministically in Taylor's model, but randomly in Calvo's. Price level does not fully respond to changes in the money supply in the Calvo model, because there are fixed number of firms that can change prices at any given time. Thus, in Taylor's model, nominal rigidity leads to gradual adjustment of the price level, and real rigidity magnifies the effects. That is, inflation is determined by the fraction of firms that change their prices and the relative price they set (Romer, 2012).

Gali & Gertler (1999), tried to be direct with measuring marginal cost, using a Cobb-Douglas production function, they concluded that marginal cost is proportional to the labor income share. When output is above normal, marginal costs are high, which increases desired relative prices. Notwithstanding, Rudd & Whelan (2005) claim that in practice, labor's share is low in booms and high in recessions. Their claim suggests that, Gali and Gertler's framework would mean – booms are times when flexible-price level of output rises above actual output, and marginal costs are unusually low. According to Mazumder (2010), the labor income share is an imprecise measure of marginal cost because of two reasons. First, labor share is counter cyclical as it rises during recessions, but short run marginal cost is procyclical. Second, it is based on an overly restrictive assumption that labor adjustment could be costless[8].

The possibility of having the wrong measure for marginal costs, let some researchers to resort to the output gap measure instead. Furuoka & Harvey's (2015) empirical estimates indicate that the output gap was statistically significant in both the NKPC and its hybrid version for Malaysia. According to Arruda et al. (2018), both the firms' real marginal cost and the unemployment gap were statistically significant with the expected signs, in explaining inflation in Brazil. Chowdhury

[6] i.e. when a multiperiod contract sets prices for several periods, it can specify a different price for each period.
[7] A contract must specify the same price each period it is in effect.
[8] Intuitively, wages are dependent on the hours of work, yet those hours are not adjusted at a fixed wage rate then varying the hours necessitates that firms give their workers overtime pay.

& Sarkar (2014) observe the output gap to be insignificant in explaining inflation dynamics in all the four countries they studied (South Africa, Brazil, Russia and India).

Gali and Gertler's use of the marginal cost instead of an ad hoc output gap was justified by the fact that marginal cost has the desirable feature to directly account for the impact of productivity gains on inflation, a factor that simple output gap measures often miss. Rudd & Whelan (2005), on the other hand, reveal the possibility of having more plausible forces responsible for moving labor's share over the business cycle, therefore, it serves as a poor proxy for marginal costs. However, Batinia et al. (2005) estimates of labor share were found to be strongly significant with a coefficient of 0.16. Furthermore, Nason & Smith (2008), observed that US inflation does not Granger-cause real marginal cost but there is strong evidence of predictability in both directions in the UK. Canadian inflation Granger-causes real marginal cost but the reverse does not hold. Mazumder (2010), claims that labor income share is an imprecise measure of marginal cost, because of its countercyclicality and over restrictive assumptions. His optimal instrument GMM estimates, show that marginal cost was highly negative and significant. Thus, even if the potential structural factors were removed from the model, the cyclicality of marginal cost still matters. Neither marginal cost nor output gap appeared to be a key driving force to Australian inflation dynamics according to Abbas & Sgro (2011).

Another issue that keep researchers active on this literature is the behavior of expectations and how to deal with it. Sbordone (2001) argued that rational expectations model of price setting with nominal rigidities does indeed provide a quite good approximation to the actual inflation dynamics. The misspecification in the new Keynesian Phillips curve is not as a result of the forward-looking component of the model, instead, it's the imprecision of the assumed proportionality between marginal costs and measures of the output gap. This contradicts Gali & Gertler, (1999) conclusion on the marginal cost measure. According to them, the use of the marginal cost perfectly fits in the estimation of the new Keynesian Phillips curve.

Gali & Gertler (1999), revealed that the data fits the model well with real marginal cost as the measure of real business cycle activity. Their forward-looking variable (inflation expectations) was found to be significant with the expected signs. Batinia et al. (2005) also concluded that inflation in the U.K was highly forward-looking and significant, with a coefficient on expected inflation equal to 0.69. Nason & Smith (2008), through the Anderson-Rubin test statistics, reveal little evidence of forward-looking expectations driving US or UK inflation. Rudd & Whelan (2005) argued that due to the highly serially correlation of inflation, any small violations of the conditions needed for the estimation procedure to be valid can generate substantial upward bias in the coefficient on expected future inflation. Abbas & Sgro (2011) found the forward-looking new Keynesian Phillips curve to be stable and better explains inflation dynamics in Australia.

Gali & Gertler (1999) acknowledge the impact of backward-looking inflation in the US economy, it was found to be statistically significant but with a small magnitude. However, Gali et al. (2001) found backward-looking price setting to be a relatively unimportant factor behind the European inflation dynamics. Therefore, they concluded that businesses in the United States are more forward-looking in setting their prices. On a similar study, Gali et al. (2001), revealed less persistence in European inflation dynamics compared to the United States. Consistent to using the marginal cost, they found that the output gap formulation of the New Keynesian Phillips curve cannot account for inflation persistence for neither the U.S nor the Euro area. Arruda et al. (2018) suggest that the more sensitive inflation is to business-cycle fluctuations, the larger the inertial component, with lower degrees of foresight from economic agents. Their results favored backward-looking expectations and suggest that inflation dynamics retains a significant initial component. Meanwhile, Abbas & Sgro (2011) observe that inflation in Australia are both forward as well backward looking over a sub sample (1983 - 2009). Similar results were obtained by Chowdhury & Sarkar (2014) for a study on inflation dynamics in South Africa, Brazil, Russia and India.

Nason & Smith (2008) generalized method of moments (GMM), could not identify the hybrid new Keynesian Phillips curve for UK, US and Canada, even when shocks are persistent. Gali & Gertler (1999), Gali et al. (2001) and Gali et al. (2005), obtained similar results. Chowdhury & Sarkar (2014) detected structural stability of the new Keynesian Phillips curve. The model was found to be stable in all four countries involved (Brazil, Russia, India and South Africa). Arruda et al. (2018) found the new Keynesian Phillips curve and its hybrid version to be stable in explaining Brazil's inflation dynamics.

Other researchers have considered an extension of the NKPC by including variables that they think will have a significant impact. Batinia et al. (2005) added the changes in real prices of oil and it turn out to be an important determinant of United Kingdom's inflation. Roberts (1995) used annual percent change in the CPI as a measure of changes in price, and the producer price index for crude petroleum deflated by the gross national product (GNP) deflator as a measure of real crude oil. Oil prices were found to be statistically significant and consistent with the share of oil and oil substitutes in the production of consumer goods.

Mavroeidis et al. (2014) reviewed the main identification strategies and empirical evidence on the role of expectations in the New Keynesian Phillips curve. More than hundred papers on the specification of the new Keynesian Phillips curve literature were compared. Unfortunately, the literature was not able to pin down the role of expectations in the inflation process. Because macro data is subject to severe weak instruments, they proposed an estimation method that uses revisions to NKPC data as external instruments. Rondina (2018) estimated inflation expectations were relatively persistent, and not characterized by permanent shifts. Household expectations were strongly correlated with the model consistent expectations. However, robustness checks performed by replacing the CPI with core or headline Personal Consumption Expenditure (PCE) delivered comparable results. Pretorius & Smal (1994) concluded that the rational expectations hypothesis was the best fit to the South African data. While, Salemi (1999) estimated that a 1% increase in expected inflation increases nominal wage growth by an estimated coefficient of 0.65 in the United States. Pretorius & Smal (1994) further suggested that rational-expectations models of inflation considered expected inflation rate in any period as all the information available to decision-makers at that moment.

To deal with such a complex environment under expectations, the Bank of England adapted a system of inflation targeting in 1992, and ever since, it has averaged around 2%. The Bank's Monetary Policy Committee (MPC) sets monetary policy to meet the 2% inflation target, such that sustain growth and employment is attained. At its meeting on 1 May 2019, the MPC voted unanimously to maintain the Bank Rate at 0.75%. Hines (2001) found that the level and rate of change of unemployment were significant determinants of the rate of change of money wage rates in the UK during (1862-1912). In their quest to explain inflation dynamics in the UK, Balakrishnan & López-Salido (2002) detected an over prediction of inflation with the standard specifications of the traditional Phillips curve. Furthermore, the overprediction was mitigated by the introduction of external shocks but still leaves a problem of misspecification. The Bank of England has experienced several changes in monetary policy framework over the past 40 years. By the mid-

1970s, in reaction to a sharp increase in inflation, frameworks for monetary policy set out to target nominal magnitudes explicitly. Different measures of the money supply, with varying degrees of emphasis was adopted during 1976 – 86. The exchange rate was targeted implicitly in 1987 – 88 shadowing the DM and explicitly in 1990 – 92 within the ERM. Since 1992, the inflation rate has been targeted, with the Bank of England given operational independence in 1997.

Although the new Keynesian Phillips curve has many virtues, it also has one striking vice: It is completely at odds with the facts. It cannot come even close to explaining the dynamic effects of monetary policy on inflation and unemployment (Mankiw, 2001). For example, when firms observe a contractionary monetary policy shock, they realize that disinflation is underway. Thus, firms are expected to respond immediately by setting lower prices. Anyways, this does not necessarily happen, because the impulse response function for inflation indicate a delayed and gradual response shock(s). It can be understood how price stickiness can easily explain why society faces a short-run tradeoff between inflation and unemployment. However, the dynamic relationship between inflation and unemployment remains a mystery because new Keynesian Phillips curve is appealing from a theoretical standpoint, but it is ultimately a failure. It is not at all consistent with the standard stylized facts about the dynamic effects of monetary policy (Mankiw, 2001).

3.2 Theoretical Literature

This section gives an explicit derivation of the new Keynesian Phillips curve and its hybrid version. They are both grounded from microeconomics foundations.

3.2.1 The New Keynesian Phillips Curve

The British economist A.W Phillips in (1958), revealed that there exists a negative tradeoff between the rate of change of money wages (inflation) and unemployment in the short run, (Hines, 2001). This relationship came to be widely known as the Phillips curve. Someone may be tempted to ask what is the "inflation – unemployment tradeoff"? The answer does not necessarily depend on whether the model fits the data neither the scattered plot shows a downward sloping relationship. Rather, it is a concern of how changes in monetary policy pushes inflation and unemployment to move in opposite directions, (Mankiw, 2001). Apparently, studying the Phillips curve, is the same as observing the effects of the central bank's actions in controlling inflation in the economy. The short run tradeoff between inflation and unemployment can be proven theoretically and observed empirically. The idea that nominal variables could affect real variables was heavily criticized in the second half of 1960. Phelps (1967, 69) and Friedman (1968, 77) argue that the curve seeks to analyze the growth of nominal wages in relation to unemployment, which contradicts the idea that economic agents are rational. This was an attack on the traditional conventional Phillips curve[9], because the behavior of real variables is only determined by real forces in the long run. They recommended that the Phillips curve needed a component that captures inflation expectations.

The example below set some light on how inflation expectation could be captured in the Phillips curve. Under the assumption of low unemployment and thus high inflation, workers would perceive that actual inflation is above expected and would negotiate wages based on this new expectation. Such economic conditions provide room for agents' expectations to play a key role in the Phillips curve. Consequently, this kind of expectations formation could lead to system forecast errors. Anyways, this led to the introduction of the forward-looking rational expectation hypothesis in the Phillips curve, attributed to Sargent (1971) and Lucas (1972). Economic agents make predictions based on all available information., thus, expectations are assumed to be rational Arruda et al. (2018).

Taylor (1980) and Calvo (1983) laid the foundations for the modern analysis of inflation by examining price and wage choices from the perspective of forward-looking families and businesses. In the absence of friction or adjustment costs, firms would set prices equal to marginal cost in each period (Arruda et al., 2018). Gali & Gertler (1999) show that there is a relation between the marginal cost and the output gap, indicating that the new Keynesian Phillips curve can be measured with marginal cost, furthermore, they notice that it lacks the element to explain inflation persistence. This led to the introduction of a backward-looking component based on past inflation and ultimately gave birth to the hybrid new Keynesian Phillips curve (Gali & Gertler, 1999). The

[9] In short, the natural-rate hypothesis states that there is some "normal" or "natural rate" that monetary policy cannot keep unemployment indefinitely below a certain level.

desirability of structural modelling of inflation is as important as all other aspects of macroeconomic framework. Recently, considerable efforts have been devoted towards deriving an aggregate relation for inflation, based on individual optimization. This approach is based on staggered nominal price-setting, built in the spirit of earlier work by Taylor (1980) and Fischer (1977), (Mankiw, 2001)[10].

Fortunately, the aggregated New Keynesian Phillips curve, has a lot more to offer than just measuring the static relationship between inflation and unemployment. It describes how past inflation, expected future inflation, and a measure of real aggregate demand drive the current inflation rate (Nason & Smith 2008). The traditional Phillips curve equation cannot explain dynamic price adjustments, while the new Keynesian Phillips curve can be viewed as a dynamic extension of the static new Keynesian models of price adjustment. The object of the New Keynesian models in interpreting the Phillips curve is to emphasize the role of explicit nominal rigidities, i.e. the impact of nominal wage rigidities on inflation[11]. The dynamic model of the NKPC can be derived from the relationship of three basic concepts: the firm's desired price (price that will minimize quadratic loss), the average price level of firms in the economy and the fraction of firms that can adjust prices at period t. The model sets a relationship that captures the key elements of models of staggered contracts developed by Taylor (1979, 80) and Calvo (1983), and Rotemberg's model of quadratic price adjustment cost (1982). These models are said to be time-dependent because staggered contracts show that firms set prices for fixed periods of time (Roberts, 1995).

Under perfect competition, a contractionary monetary policy causes a fall in price and an increase in real wage, as a result, businesses lay off workers. Mankiw (2001), argued that firms lay off workers not because of the increase in real wages but because they cannot sell all their goods at the market clearing price. The hypothesis of sticky prices forces us to think about firms' price adjustment decisions and the degree of market power they might have. When firms have market power, they charge prices above marginal cost. Then goods markets are always in a state of excess

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[10] Price-setting is based on optimization by individual firm subject to constraints on the frequency of price adjustment. While aggregating across the decision rules of firms then leads to an aggregate Phillips curve relation.
[11] Without nominal rigidities these models will resort to the traditional Phillips Curve.

supply. Taylor (1997), argues that firms set prices as a constant markup over marginal cost and wages are the only source of nominal rigidity.

The firm chooses an optimal price level at time t to maximize expected discount profits. In setting prices, firms consider expected future nominal marginal cost and the fact that the price may remain fixed for multiple periods ahead. They adjust prices proportional to marginal cost given perfect price flexibility ($\theta = 0$)[12]. Future marginal cost becomes relevant only if there is price rigidity ($\theta > 0$). The link between inflation and marginal cost can be related to Benabou's (1992) finding using retail trade data that inflation is inversely related to the markup, which he measured as the inverse of the labor share). He interpreted the findings as evidence that the markup may depend on inflation, yet we can understand from Gali & Gertler (1999) that causation runs from marginal cost to inflation.

Specification of the NKPC has important implications for monetary policy, particularly how central banks should react to real events while maintaining inflation targets.

3.2.2 Derivation of the New Keynesian Phillips Curve

The new Keynesian Phillips curve presented in this study, is derived from the Calvo staggered contracts model (1983), which was built on micro foundations. Calvo's model of staggered contracts suggest that each firm keeps its price fixed until it receives a random signal that it can make any changes. Because, prices are staggered, firms consider the prices of other firms and past prices when setting their own prices. Calvo assumes that firms choose the log of price P_t to minimize a quadratic loss function defined in equation (1).

$$L(\bar{P}_t) = \sum_{k=0}^{\infty}(\theta\beta)^K \; E_t(\bar{P}_t - \; P^*_{t+K})^2 \qquad (1)$$

Where β is the subjective discount factor, and P^*_{t+K} is the log of the optimal price that the firm would set in period (t + K) if they were able to set prices in every period. In the same vein, θ represent the number of firms that cannot change prices at a given period. Thus, the optimal reset price can be derived from differentiating the loss function with respect to $\bar{P}_t$.

[12] Fraction of firms that cannot change prices at a given time.

$$\bar{P}_t = (1 - \theta\beta)\ \sum_{k=0}^{\infty} (\theta\beta)^K\ E_t P^*_{t+K} \qquad (2)$$

Equation (2), gives the final optimal price level of every firm in period t, while equation (3) below gives the optimality of the definition of the optimal level of price for firms.

$$\bar{P}_t = \ \theta\beta E_t \bar{P}_{t+1}\ (1 - \theta\beta) P^*_t \qquad (3)$$

To determine the aggregate price level, firms are assumed to be identical except that θ percent will not be able to choose their price at time t. Gali and Gertler (1999) show that the aggregate price level P_t evolves as a convex combination of the lagged price level $P_{t-1}$and the optimal reset price $\bar{P}_t$. The average log price in the Calvo economy is shown in equation (4).

$$P_t = \theta P_{t-1} + (1 - \theta)\bar{P}_t \qquad (4)$$

From equation (4) we can deduce that the average price level in the economy is determined by firms that are able to adjust their prices in period t and another group of firms that cannot adjust their prices. $(1 - \theta)$ is the fraction of firms that can adjust prices at period t. The new Keynesian Phillips curve can be derived from equation (4), with current inflation as the dependent variable.

$$\pi_t = \beta E_t \pi_{t+1} + \gamma y \qquad (5)$$

Equation (5) presents the new Keynesian Phillips curve model derived from Calvo (1983) staggered contracts. Current inflation can be explained through the pricing behavior of the individual firms. Inflation in period t depends on the current expectations of future inflation rate and the output gap (difference between real output and its potential trend). β serves as the elasticity of expectations or precisely, it measures the level of forward-looking firms in the economy while γ is a parameter equal to, $\frac{[(1-\theta)(1-\theta\beta)]}{\theta}$. It is the elasticity of the output gap, herein measuring the real economic activity.

3.2.3 Hybrid New Keynesian Phillips Curve

The new Keynesian Phillips curve implies that anticipated disinflation is associated with an output boom. The view that high inflation tends to continue unless there is a period of low output is often described as inflation inertia. Inflation inertia refers not to inflation being highly serially correlated, but to it being costly to reduce. The new Keynesian Phillips curve and other models of staggered price-setting implies that there is "anti-inertia" (Romer, 2012). Traditional explanations of inertia (costs of disinflations) rely on some form of 'backwardness' in price setting. The addition of the lag term in the hybrid Phillips curve, is designed to capture the inflation persistence that is unexplained in the baseline model. A further implication of the lag term is that disinflations now involve costly output reduction.

Gali & Gertler (1999) argue that extending the Calvo (1983) model, will shed more light on the role of inflation inertia in the economy. They assume that certain group of firms use a backward-looking rule of thumb in setting prices. The economy comprises of forward-looking and backward-looking price setters. This specification of the model was called the hybrid new Keynesian Phillips curve. It can easily spell out the fraction of firms that use forward as well as backward-looking price setting in the economy. The hybrid New Keynesian Phillips curve (NKPC) describes how past inflation, expected future inflation and the measure of real aggregate demand affects current inflation.

3.2.4 Theoretical Formulation of the Hybrid NKPC

The assumption in Calvo's model still holds, meaning each firm has a fixed probability $(1-\theta)$ of adjusting their prices irrespective of what time prices were fixed. We assumed that two types of firms coexist as in Gali & Gertler (1999). A fraction of the firms $(1-\omega)$ behave like firms in the Calvo model, they adjust prices optimally based on the timing of adjustment and all available information to predict future marginal cost (output gap). The remaining firms (ω), simply use a rule of thumb based on the recent history of aggregate price level. This fraction of firms is referred to as the backward-looking price setters. The models developed in this paper are time dependent. Equation (6), presents the aggregate price level under such dynamic economy.

$$P_t = \theta P_{t-1} + (1-\theta)\bar{P}_t^* \qquad (6)$$

$\bar{P}_t^*$is an index of newly set prices at time t, it composes of prices set by forward-looking firms (P^f) and backward-looking firms (P^b) at period t. The index of newly set prices is expressed as the sum of the two types of firms in the economy.

$$\overline{P}_t^* = (1-\omega)\, P_t^f + \omega P_t^b \qquad (7)$$

Forward-looking firms behave exactly as in the Calvo model, they determine prices using equation (2). On the other hand, the backward-looking behavior rule of thumb has two features: in a steady state equilibrium, the rule is consistent with optimal behavior and the price in period t depends only on information dated period (t - 1) or earlier. We also assume that the firm is unable to decide which competitor is backward-looking or forward-looking. Their prices are determined as follows:

$$P_t^b = \overline{P}_{t-1}^* + \pi_{t-1} \qquad (8)$$

Backward-looking firms set prices based on the most recent price adjusted for inflation. The rule converges to optimal behavior over time, so long as inflation is stationary. The rule incorporates forward-looking information as a useful feature which is explained by the price index ($\overline{P}_{t-1}^*$). By combining equation (6) and (8), we obtain the hybrid new Keynesian Phillips curve.

$$\pi_t = \lambda y + \delta_f E_t \pi_{t+1} + \delta_b \pi_{t-1} \qquad (9)$$

Gali & Gertler (1999) assumed that a fraction of the firms [θ] could change prices but choose not to. Contrary to the Calvo framework, where a fraction of firms [θ] are not allowed to change prices each period. $\delta_f$measures the effect of a change in expected future inflation while $\delta_b$show the magnitude of the inflation inertia. Given that $\phi = \theta + \omega[1 - \theta(1 - \beta)]$. The mapping between these structural parameters and the reduced form parameters is presented below.

$\lambda = [(1-\omega)(1-\theta)(1-\theta\beta)]/\phi, \qquad \delta_f = \beta\theta/\phi, \qquad \delta_b = \omega/\phi$

Structural parameters: θ, β, ω.

Reduced form parameters: λ, δ_f, δ_b.

All the coefficients are an explicit function of three parameters: θ measures the degree of price stickiness, ω measures the degree of backwardness in price setting and β is the discount factor. The special case about the hybrid version is that, when ($\omega = \theta$), the model converges to the benchmark new Keynesian Phillips curve. Secondly, if the discount factor ($\beta = 1$), then the two (δ_f and δ_b) sum up to 1 if the output gap is used as the forcing variable.

CHAPTER 4

Methodology

This chapter deals with the estimation technique used in the paper. It shows how OLS and instrumental variables techniques are special cases of the GMM estimator. Generally, it investigates the application of GMM on the New Keynesian Phillips curve (NKPC) and its hybrid version.

4.1 Instrumental variable (IV) Technique

Instrumental variables estimator also known as the two-stage least squares estimator, is a generalized method of moments estimator that uses a weighting matrix constructed under homoskedasticity. The estimation strategy of IV is developed such that a set of variables (Z_i) called instruments are generated to replace a set of endogenous variables (X_i) that are correlated with the error term. Endogeneity is a pertinent issue in models that involve expectations. Equation (10) demonstrates how to use instrumental variables technique as an estimator. It is presented in matrix form where X is an $n \times K$ matrix of regressors, and n represents the number of observations. The error term is distributed with mean zero and the covariance matrix θ is an $n \times n$.

$$\mathcal{Y} = \mathrm{X}\beta + \upsilon \qquad E(\upsilon\upsilon') = \theta \tag{10}$$

Most dynamic models with expectations fail the orthogonality condition and the New Keynesian Phillips curve is not an exception. The endogeneity of some regressors, necessitates IV estimation, because the orthogonality condition $E(X_i u_i) \neq 0$ holds no more. The regressors are then partitioned into two, $[X_1 \;\; X_2]$ with K_1 regressors, X_1, considered endogenous and the $[K - K_1]$ remaining regressors, X_2, are assumed to be exogenous. The set of endogenous variables are then replaced by a set of instrumental variables Z, with the matrix $n \times l$ that are exogenous and orthogonal to the error term, thus $E(Z_i u_i) = 0$. We partition the instruments $[Z_1 \; Z_2]$, where the L_1 instruments Z_1 are excluded, and the remaining $[L - L_1]$ instruments, $Z_2 \equiv X_2$ are the included instruments or exogenous regressors (Greene, 2003).

The choice of instrumental variables is often ad hoc, because there is a bit of a dilemma in what stands the test for a good instrument. It's suggested that the best choices of instruments are variables that are highly correlated with the exogenous variables (X). However, if a selected instrument happens to be highly correlated with the problematic columns of X, then the less defensible the claim that they are uncorrelated with the disturbances. Therefore, a good instrument is expected to satisfy the orthogonality condition and be highly correlated to the unproblematic columns of the exogenous variables (X). Good instruments should be both relevant and valid – correlated with the endogenous regressors and at the same time orthogonal to the errors. Solving the endogeneity problem, requires at least as many excluded instruments as there are endogenous regressors ($L \geq K$)[13]. Should in case the number of excluded instruments is equal to the endogenous regressors ($L = K$), the equation is said to be exactly identified[14]. Otherwise it is overidentified if there are more excluded instruments than endogenous regressors ($L > K$), (Baum, Schaffer, & Steven, 2003).

To derive the IV estimator let P_z denote the projection matrix $Z(Z'Z)^{-1}Z'$, then the instrumental variables estimator of β can be written as:

$$\hat{\beta}_{\text{iv}} = \{X'Z\,(Z'Z)^{-1}\,Z'X\}^{-1}\,X'Z\,(Z'Z)^{-1}\,Z'\mathcal{Y}$$

$$\hat{\beta}_{\text{iv}} = (X'PzX)^{-1}\,X'Pz\mathcal{Y} \tag{11}$$

This estimator is referred to differently by various researchers, it is sometimes called instrumental variables estimator and for some it's called the generalized instrumental variable estimator (GIVE). Given the fact that it can be calculated in two step procedure, it also comes with the name two stage least squares estimator (2SLS). However, for the purpose of this paper I decide to call it instrumental variable (IV) estimator rather the other alternatives, because the idea of instrumenting is central, this is in line with Baum et al., (2003).

[13] The equation is fully identified under this condition.
[14] When $l = k$, the k equations can be solved to obtain the simple IV estimator by setting the sample moments equal to zero. Check (Mankiw, The Inexorable and MysteriousTradeoff between Inflation and Unemployment, 2001), for more details.

4.2 Generalized Method of Moments (GMM)

The population mean or population average usually denoted by (μ) is the moment that measures central tendency. If y is a random variable describing the population of interest, the population mean can be written as E (y); the expected value of y also known as the first moment of y. The population variance usually denoted σ^2, is defined as the second moment of y centered about its mean: $\sigma^2 = E[(y - \mu)^2]$. The variance, also called the second central moment, is widely used as a measure of spread in a distribution. However, Hansen (1982) demonstrated that these moment conditions could be exploited very generally to estimate parameters consistently under weak assumptions. He essentially showed that every previously suggested instrumental variable estimator, could be cast as a GMM estimator. Perhaps even more important, he showed how to choose among the many possible method of moments estimators in a framework that allows for heteroskedasticity, serial correlation and nonlinearities (Wooldridge, 2001).

The Generalized Method of Moments (GMM) estimation technique was introduced by Hansen in 1982. The technique was primarily intended for time series applications and has the advantage of allowing for the (GMM) weighting matrix to account for serial correlation of unknown form and heteroskedasticity. The issue of serial correlation can be minimized by using lagged values of dependent and independent variables as instruments in the context of models estimated under rational expectations. Ultimately, the error term in the equation will be uncorrelated with all variables dated at or earlier time periods. However, the use of poor instruments[15] leads to poor performance of the efficient GMM estimator, (Wooldridge, 2001).

The standard IV estimator developed in the previous section is a special case of the Generalized method of moments (GMM) estimator. By the standards of GMM, the exogeneity of the instruments implies L moment conditions (orthogonality conditions), that will be satisfied at the true value of β. The true parameter of the GMM estimator, can be obtained by finding the elements of the parameter space that sets linear combinations of the sample cross products as close to zero as possible, (Hansen, 1982). Equation (12) below implies that with L instruments there will be L moments conditions. Each of the L moment equations corresponds to a sample moment. The L sample moments is presented in equation (12), where g_i is $L \times 1$.

[15] Instruments that are irrelevant and invalid.

$$g_i(\hat{\beta}) = Z_i' \hat{u}_i = Z_i' (\mathcal{Y}_i - X_i\hat{\beta})$$

$$\bar{g}(\hat{\beta}) = \frac{1}{n}\sum_{i=1}^{n} g_i(\hat{\beta}) = \frac{1}{n}\sum_{i=1}^{n} Z' (\mathcal{Y}_i - X_i\hat{\beta}) = \frac{1}{n} Z'\hat{u} \quad (12)$$

The intuition behind GMM is to choose an estimator for β that solves $\bar{g}(\hat{\beta}) = 0$. If the equation to be estimated is exactly identified, then it is possible to find a β that solves $\bar{g}(\hat{\beta}) = 0$, and this GMM estimator is in fact the IV estimator. However, if the equation is overidentified, then we have more moment conditions than there are parameters to be estimated. Cragg (1983) showed that GMM has an important feature in that it allows parameters to be overidentified (Wooldridge, 2001). Generally, it will not be possible to find a β that will set all L sample moment conditions to exactly zero. A solution can be found by taking an $L \times L$ weighting matrix W to construct a quadratic form in the moment conditions. This gives us the GMM objective function[16] in equation (13). The weighting matrix (W) accounts for the correlations among $\bar{g}(\hat{\beta}_{GMM})$when the errors are not independently and identically distributed i.i.d.

$$J(\hat{\beta}_{GMM}) = n\bar{g}(\hat{\beta}_{GMM})' W \bar{g}(\hat{\beta}_{GMM}) \quad (13)$$

The GMM estimator for β is the $\hat{\beta}$ that minimizes $J(\hat{\beta})$. Solving for K order conditions $\frac{\partial J(\hat{\beta})}{\partial \hat{\beta}} = 0$ from equation (13) yield the GMM estimator of an overidentified equation.

$$\hat{\beta}_{GMM} = (X'ZWZ'X)^{-1} X'ZWZ'\mathcal{Y} \quad (14)$$

The GMM estimator will be the same for weighting matrices that defer from a constant of proportionality. There are many GMM estimators as there are choices of weighting matrix W. Amongst the choices there exists an optimal choice of the weighting matrix that could be found using the covariance matrix. Equation (15) denotes the covariance matrix (S) of the moment conditions g, where S is an $L \times L$ matrix.

$$S = \frac{1}{n} E(Z'uu'Z) = \frac{1}{n} E(Z'\Omega Z) \quad (15)$$

The efficient GMM estimator is the estimator with an optimal weighting matrix W, one that minimizes the asymptotic variance of the estimator. This is achieved by setting the weighting

[16] Check Baum et al. (2003), for detail explanation.

matrix equal to the inverse of the covariance matrix of the moment conditions, ($W = S^{-1}$) (Baum, Schaffer, & Steven, 2003).

The efficient GMM estimator can be expressed as:

$$\hat{\beta}_{EGMM} = (X'Z\,S^{-1}\,Z'X)\,X'\,Z\,S^{-1}\,Z'\mathcal{Y} \tag{16}$$

With the asymptotic variance,

$$V(\hat{\beta}_{EGMM}) = \frac{1}{n}(Q'_{XZ}\,S^{-1}\,Q_{XZ})^{-1}$$

The efficient GMM estimator in equation (16), is not yet a feasible estimator, because the matrix S is unknown. Technically, this estimator can only be implemented given the estimate for the covariance matrix (S). For one to estimate S, we need some assumptions about (Ω) the covariance matrix of the disturbance term. Baum et al., (2003), assumed an estimator of S denoted $\hat{S}$. They used standard 2SLS estimation to generate parameter estimates and residuals. Furthermore, they define the feasible two step GMM estimator (FEGMM) using an assumption about the structure of Ω to produce $\hat{S}$ from those residuals:

$$\hat{\beta}_{FEGMM} = (X'Z\,\hat{S}^{-1}\,Z'X)\,X'\,Z\,\hat{S}^{-1}Z'\mathcal{Y} \tag{17}$$

The efficient GMM estimator brings with it the advantage of consistency in the presence of arbitrary heteroskedasticity, but at a cost of possibly poor finite sample performance (Nason & Smith, 2008). To obtain an efficient GMM estimator, one must have overidentifying restrictions. Under time series, moment conditions can be added by assuming that past values of explanatory variables, or even past values of the dependent variable, are uncorrelated with the error term. The drawback to finding moment conditions in this way is that it restricts the dynamics in the model. Notwithstanding, using lagged values of dependent and independent variables is better under rational expectations models. A case which will render the error term uncorrelated with all variables dated at earlier time periods (Wooldridge, 2001). A technique to estimate rational expectations models was developed by Hansen and Sargent (1991), which assumes that the disturbance terms are serially correlated but orthogonal to current and past values of a subset of variables which are not strictly exogenous (Baum, Schaffer, & Steven, 2003).

4.3 Econometric Specification of Marginal Cost estimates

This paper used marginal cost instead of the output gap as a measure for real economic activity. Hence the marginal cost is derived from a Cobb-Douglas production function, where the ratio of the wage rate to the marginal product of labor gives the real marginal cost. As it's empirically difficult to measure real marginal cost of firms, the thesis uses labor income share as its proxy. The labor income share (real unit labor cost), is the ratio of the real marginal cost to the share of labor. Therefore, nominal marginal cost is equal to the percentage deviation of labor income share from its steady state, ($mc_t = s_t$). The empirical model to be estimated takes the labor income share in the place of the real marginal cost as the forcing variable. Consider a simple Cobb-Douglas production function from which a measure of real marginal cost is obtained.

$$Y_t = Z_t K_t^{\alpha} L_t^{1-\alpha} \tag{18}$$

From equation (18), Y_t indicates output, Z_t is technology, K_t denotes capital and L_t is total labor, all measured at time t. As mentioned earlier, the real marginal cost (Γ_t) is given by the ratio of the wage rate to the marginal product of labor.

$$\Gamma_t = \frac{W_t}{P_t \frac{\partial Y_t}{\partial L_t}}$$

Hence, given the production function above, the real marginal cost will take the shape below.

$$\Gamma_t = \frac{\frac{W_t}{P_t}}{(1-\alpha)\frac{Y_t}{L_t}} = \frac{S_t^n}{1-\alpha}$$

Where: $S_t^n = \frac{W_t L_t}{P_t Y_t}$, is the labor income share and can be equivalently referred to as the real unit labor costs. This implies that: $\widehat{mc}_t = \widehat{\Gamma}_t = \widehat{S_t^n}$. The hat on top of the variables implies percentage deviation from steady state. Intuitively, the equation above shows that marginal cost in nominal terms is the same as the real marginal cost and is also equal to the labor income share (Balakrishnan & López-Salido, 2002).

The econometric specification for the New Keynesian Phillips curve and its hybrid version is presented in equation (19) and (20).

$$\pi_t = \lambda_1 \widehat{S_t^n} + \gamma^f \pi_{t+1} + \varepsilon_t \tag{19}$$

$$\pi_t = \lambda_1 \widehat{S_t^n} + \gamma^b \pi_{t-1} + \gamma^f \pi_{t+1} + \varepsilon_{t+1} \tag{20}$$

Equation (19) implies that current inflation is determined by the current expectations of future inflation and the labor income share. β is a structural parameter, that measures how well current expectations of future inflation predict the current inflation, while the reduced form coefficient γ = $\frac{(1-\theta)(1-\theta\beta)}{\theta}$, gives information on how current inflation reacts towards variations in the labor income share.

The error term in both equations (19) and (20) is equal to the deviation of actual future inflation from current expectations of future inflation, $\varepsilon_{t+1} = E_t\{\pi_{t+1}\} - \pi_{t+1}$. The error term as specified herein, is said to be uncorrelated with information available at time t under rational expectations. It follows that variables dated t and earlier are valid instruments for estimation of equation (10) above. Under rational expectations the error forecast in the expected future inflation (π_{t+1}) is uncorrelated to information dated t and earlier. The GMM estimation techniques for the NKPC and the Hybrid NKPC are explored in the subsequent sections.

4.4 Reduced-form estimates

To obtain an econometrics specification that is nonlinear in the structural parameters of θ and β, we substitute the structural parameters into equation (19). Normalization of the orthogonality condition for nonlinear estimates of GMM with small sample comes with issues. However, this study used large sample to mitigate any potential issue to be pose by small sample GMM. According to (Hansen, 1982), large sample properties permits the disturbances used in the orthogonality condition to be serially correlated and conditionally heteroscedastic. We will follow Gali and Gertler's normalization, where they appear to minimize the nonlinearities and normalize the inflation coefficient to unity.

The specifications take the form of equations (21) and (22):

$$E_t\{(\theta\pi_t - \theta\beta\,\pi_{t+1} - (1-\theta)\,(1-\theta\beta)\,S_t)Z_t\} = 0 \tag{21}$$

$$E_t\{(\pi_t - \beta\,\pi_{t+1} - \theta^{-1}(1-\theta)\,(1-\theta\beta)\,S_t)Z_t\} = 0 \tag{22}$$

From the equations above, Z_t is a vector of instrumental variables, dated period t and earlier and are orthogonal to the inflation surprise in period (t + 1). This orthogonality condition forms the basis for the generalized method of moments (GMM) estimation, (Gali & Gertler, 1999). The structural parameters θ and β are estimated using nonlinear instrumental variables estimator. Generally, we expect the structural estimates to have the same sum effect as the reduced form coefficient. The structural coefficient on the real marginal cost should be positive according to the new Keynesian theory. The estimate on θ will indicate how long will it take prices to adjust, hence the level of price rigidity in the UK.

The Hybrid New Keynesian Phillips curve is an extension of the NKPC, where the additional variable (π_{t-1}), is the inflation that existed in the previous period. Introducing this variable in the model helps in explaining the inflation persistence or inflation inertia in the United Kingdom. It's coefficient (γ^b) gives an idea of how backward-looking firms are in the UK. Backward-looking firms reexamine the price setting mechanism in the last period and then make a correction for inflation, using lagged inflation as the predictor variable.

Following Gali & Gertler (1999), the structural parameters (θ, β and ω), embedded in the reduced form coefficients can be estimated using nonlinear generalized method of moments (GMM). The same set of instruments was used for both estimates. The GMM estimator presented in equation (23) normalizes the inflation coefficients ($\gamma^b \ and \ \gamma^f$) to unity, but the estimator in equation (24) does not.

$$E_t\{(\pi_t - \phi^{-1}\beta\, \pi_{t+1} - \theta^{-1}(1 - \omega)(1 - \theta)\,(1 - \theta\beta)\, S_t)Z_t\} = 0 \qquad (23)$$

$$E_t\{(\phi\pi_t - \theta\beta\, \pi_{t+1} - (1 - \omega)(1 - \theta)\,(1 - \theta\beta)\, S_t)Z_t\} = 0 \qquad (24)$$

Equation (23) and (24) forms the orthogonality condition for the proper estimation of the hybrid NKPC. Given moment conditions, a necessary condition for identification of the reduce form coefficients requires valid instruments as parameters. Identification requires that future inflation could be predicted with at least one variable other than [π_t, π_{t-1}, $\hat{S}$], (Nason & Smith, 2008). The instruments must be uncorrelated with the GMM residuals, which are essentially forecast errors. Furthermore, the instruments should possess an incremental information on π_{t+1} for their validity.

4.5 Fundamental inflation – goodness of fit

As noted above, the adjusted measure of labor share served as a good proxy for marginal cost. This implies we can follow Gali & Gertler (1999) and compare the evolution of 'fundamental inflation' to actual inflation, to get a sense of the model's goodness of fit. As in Gali & Gertler, (1999), fundamental inflation is the solution to the hybrid model difference equation in inflation, equation (19). This is given by:

$$\pi_t = \delta_1 \pi_{t-1} + (\frac{\lambda_1}{\delta_2 \gamma_f}) \sum_{k=0}^{\infty} (\frac{1}{\delta_2})^k E[\widehat{mc}_{t+k} | Z_t] \qquad (25)$$

Where $\delta_1$and $\delta_2$are the stable and the unstable roots respectively, to equation (20) and $Z_t$is the information set available at time t. An intuitive meaning of the fundamental inflation can be drawn from an illustration for the basic forward-looking model.

$$\pi_\mathrm{t} = \beta\, \pi_{\mathrm{t+1}} + \lambda \widehat{mc}_t + \varepsilon_t \qquad (26)$$

Fundamental inflation is obtained by iterating equation (26) above.

$$\pi_t = \lambda_1 \sum_{k=0}^{\infty} \beta^k E_t[\widehat{mc}_{t+k}] \equiv \pi_t^* \qquad (27)$$

From equation (27), fundamental inflation is a discounted stream of expected future marginal costs. The measure of inflation pressure stemming from real sector activity is a discounted stream of expected real marginal costs. Intuitively, firms set prices based on the expected future path of marginal costs, because their prices might be locked for a period. The movement in marginal costs affects the rate of inflation, as opposed to the price level, because firms change prices at different times. To the extent that the baseline New Keynesian Phillips Curve model is correct, and inflation depends on real marginal costs, fundamental inflation will capture the dynamics of inflation. Thus, fundamental inflation is not a measure of core inflation, but a measure of the model's goodness of fit, which can serve as an alternative to the R squared (Balakrishnan & López-Salido, 2002).

A key question is how to measure the expected discounted stream of marginal costs? This discounted stream can be forecasted using the information available at time t.

$$\pi_t^* = \lambda \sum_{k=0}^{\infty} \beta^k E_t\{\widehat{mc}_{t+k} | Z_t\} \qquad (28)$$

We choose the vector of instruments, Z_t to be the same as that used in the GMM estimation of the reduced-form models, i.e. based on current and past values of inflation, marginal cost, the output gap and wage inflation and used the reduced-form estimates of the hybrid model in equation (20).

CHAPTER 5

Data and Results Analysis

This chapter will shed light on the data set used for the analysis of the econometric models specified in the previous chapter. It also gives an exclusive presentation and interpretation of the results obtained. Based, on the available data set, this chapter will further explain the fluctuations of UK's inflation compared to previous researches.

5.1 Data description

The data set was obtained from two main sources: Office for National Statistics (ONS), and the Bank of England. The data are in quarterly time series over the sample period 1980:1 – 2018:4. Below is a highlight of the important nuances of the data, which emanated from the various measures of inflation, the output gap, and labor income share. Hence, the log labor income share, is used as the measure for marginal cost. The output gap, which is the deviation of output from its trend, was measured as the GDP detrended with the Hodrick-Prescott (HP) filter. This is consistent with methods used by Balakrishnan & López-Salido, (2002).

5.1.1 Inflation measures

Inflation was measured using the retailed price index (RPIX) and the wage inflation represents the measure for inflation expectations. The retail price index (RPIX) excludes mortgage interest payments, and it forms the inflation target of the Bank of England (Balakrishnan & López-Salido, 2002). The Bank's inflation target focuses on a basket of consumers' goods and services and could be measured by the consumer price inflation. The wage inflation constitutes the forward-looking element in the New Keynesian Phillips curve and the hybrid version. Studying the different measures of inflation highlighted above, will help us understand the dynamics of UK's inflation. The one period lag of the GDP deflator served as the backward-looking measure in the hybrid version. The GDP deflator measures the price of domestic value added in the economy. However, it has a downside of not including the price of imports in its measure of inflation, but the domestic value added, includes value addition in the export sector. This portion of the GDP deflator captures the external effects of domestic firms' pricing decisions. Export price will be directly affected by import prices because around a quarter of the components used in production of export goods, are in fact imported.

5.1.2 Marginal cost measures

Various measures of the marginal cost have been captured in the literature; however, this paper follows the method of measurement used by Gali & Gertler, (1999) and Balakrishnan & López-Salido (2002), where they establish a strong connection in the relation between marginal costs and the labor income share as a measure of the real economic activity. Thus, the major part of constructing marginal cost measures involves measuring the labor income share. The labor income share is given by the following formula, $ls = \frac{wn}{py}$, where: w represents nominal wages, herein, equivalent to the average weekly earnings index measured by the office of national statistics (ONS). n is the total number of employed people from age 16 and above, with the inclusion of the self-employed. Finally, y is real GDP at factor cost and p is the GDP deflator. However, Rotemberg & Woodford (1997) have shown that, under certain restrictions on technology, within the neighborhood of the steady state, real marginal costs are proportionately related to the output gaps (Balakrishnan & López-Salido, 2002).

5.1.3 Instruments

The vector of instruments Z_t includes four lags of inflation, the output gap, wage inflation, GDP deflator and unemployment rate, all dated on or before time t. This is in line with the choice of instruments used by Arruda et al., (2018). Using lagged instruments moves forecasting platform back in time (Gali & Gertler, 1999). As the measures for inflation and the marginal cost have already been discussed in the previous section, it's only fitting to delve into the measure of the output gap. According to Balakrishnan & López-Salido, (2002), the output gap can be measured from the data on the real GDP at factor cost. This thesis adapted an output gap measured as nominal GDP detrended with the Hodrick-Prescott filter, with a smoothing parameter (1,600). Two methods of measuring the output gap were considered though. Firstly, I regress real GDP on three factors (a constant, a time trend and a quadratic time trend) and used the residuals as a measure for the output gap. Secondly, in line with the standard value chosen in the business cycle literature, I employed the Hodrick-Prescott (HP) filter with a smoothing parameter (1,600). The output gap can be precisely seen as a measure of excess demand and can also mean the unemployment gap, a connection that exist through the Okun's law[17]. A standard way of measuring the output (unemployment) gaps is to use a Hodrick-Prescott (HP) filter. Balakrishnan & López-Salido, (2002), argued that it is unlikely that such a method could capture the rich dynamics underlying recent UK labor market performance. Consequentially, they suggested alternative measures such as the IMF or OECD estimates of the output gap. Unfortunately, this study has not gone thus far to using these alternative measures. Other instruments comprise of the implied inflation, which is the "end month level of yield from British Government Securities, 5-year inflation implied forward". The real GDP and the GDP deflator completes the set of instruments.

Table 5.1 below is a precise presentation and description of the variables and their sources. The objective of the paper is to estimate UK's inflation dynamics through the New Keynesian Phillips curve and its hybrid version. The data series runs from 1980:1 to 2018:4.

Table 5.1 Description of the variables

Indicator	**Variable**	**Representative Variable**	**Source**
Inflation	Inflation	Retailed Price Index (RPIX)	Bank of England
Expectations	Forward-looking Expectations	Wage inflation measured as the unit wage cost	Office of National Statistics
	Backward-looking Expectations	Lag GDP deflator	Office of National Statistics
Business Cycles	Marginal cost	Log Labor income share	Office of National Statistics
Instruments	Output gap	Nominal GDP	Office of National Statistics
	Unemployment	Unemployment rate	Office of National Statistics
	Wage inflation	Unit wage cost	Office of National Statistics
	GDP deflator	GDP deflator	Office of national statistics

[17] Okun's Law describes the relationship between production output and employment. For manufacturers to produce more goods, they must hire more people. The inverse is also true.

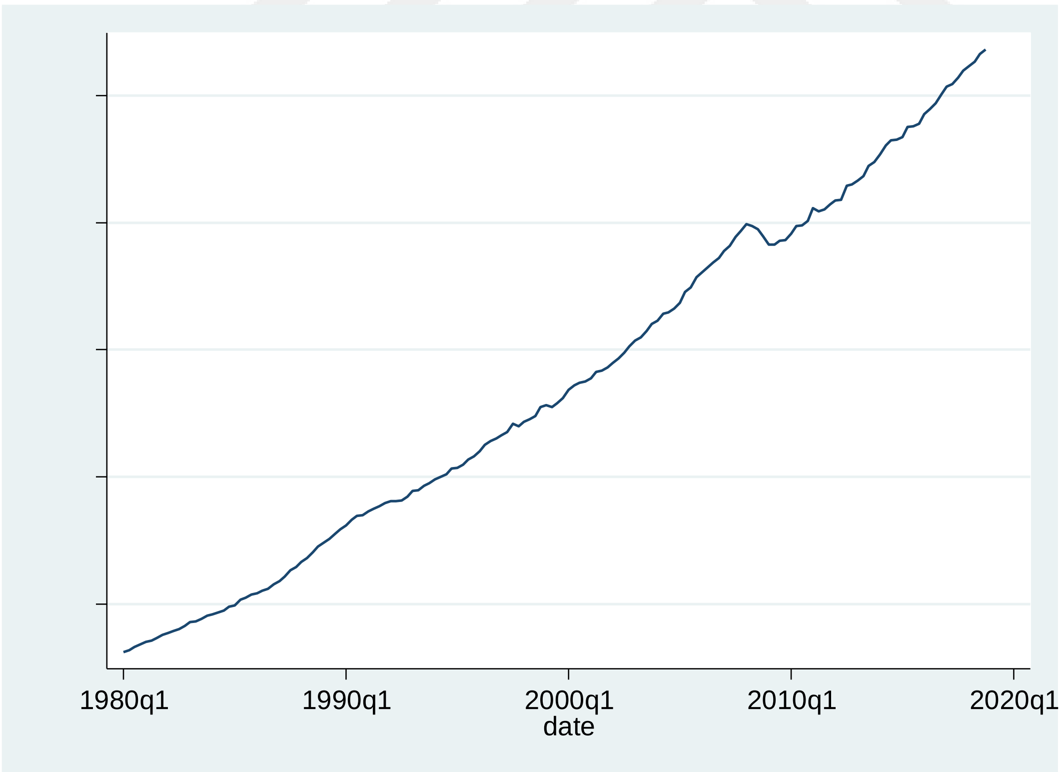
	Implied inflation	Yield from British government securities	Office of National Statistics

Source: Author.

5.2 Analysis and discussion of results

This section gives a succinct presentation of the result that were obtained from the data. All graphs and tables presented were produced by the author. The quarterly series for all the variables contains 156 observations, except for the average earnings and consumer price inflation, which contain 76 and 120 observations respectively. Figure 5.1 shows a graphical presentation of the behavior of nominal GDP over time. The graph gives a clear indication of the existence of an upward trend in GDP in the United Kingdom.

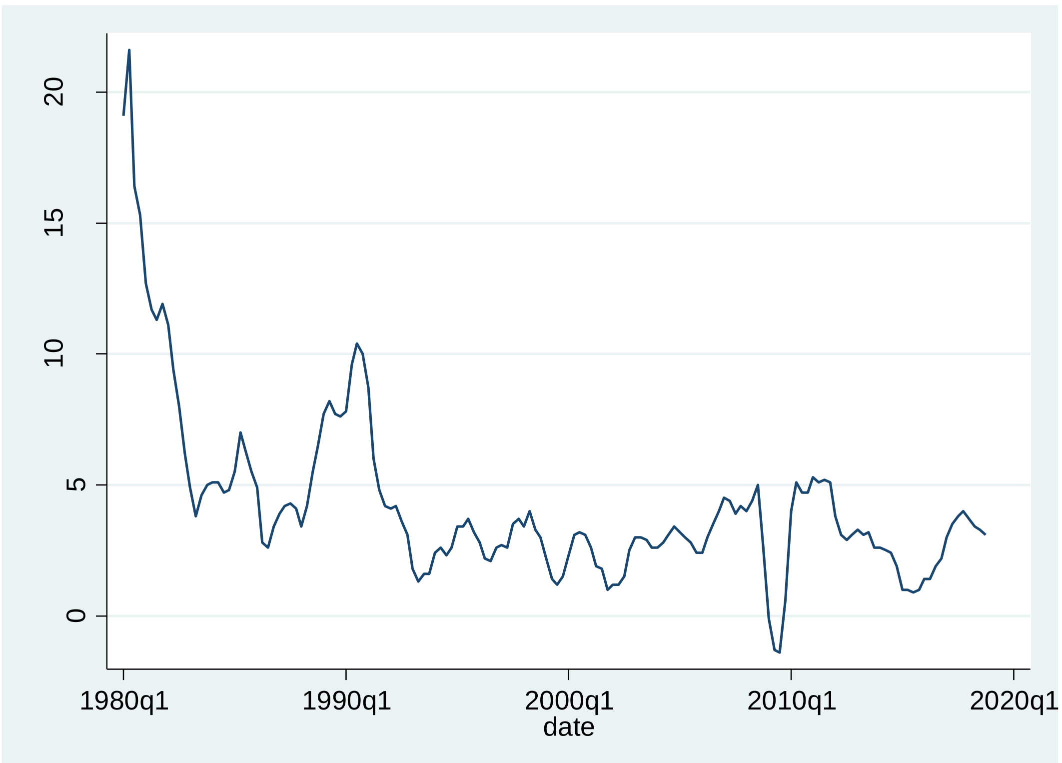
Figure 5.1 Nominal GDP



Source: Author

Nominal GDP exhibits an upward trend which necessitated the used of the Hodrick-Prescott (HP) filter to extract the cyclical component. This produce the output gap measure that was used as an instrument in the estimation. In line with the Gali and Gertler's (1999) framework, the output gap is not acting as a measure of real economic activity, but it serves as an instrumental variable. Figure 5.2 visualize the fluctuation of the cyclical component of GDP in UK.

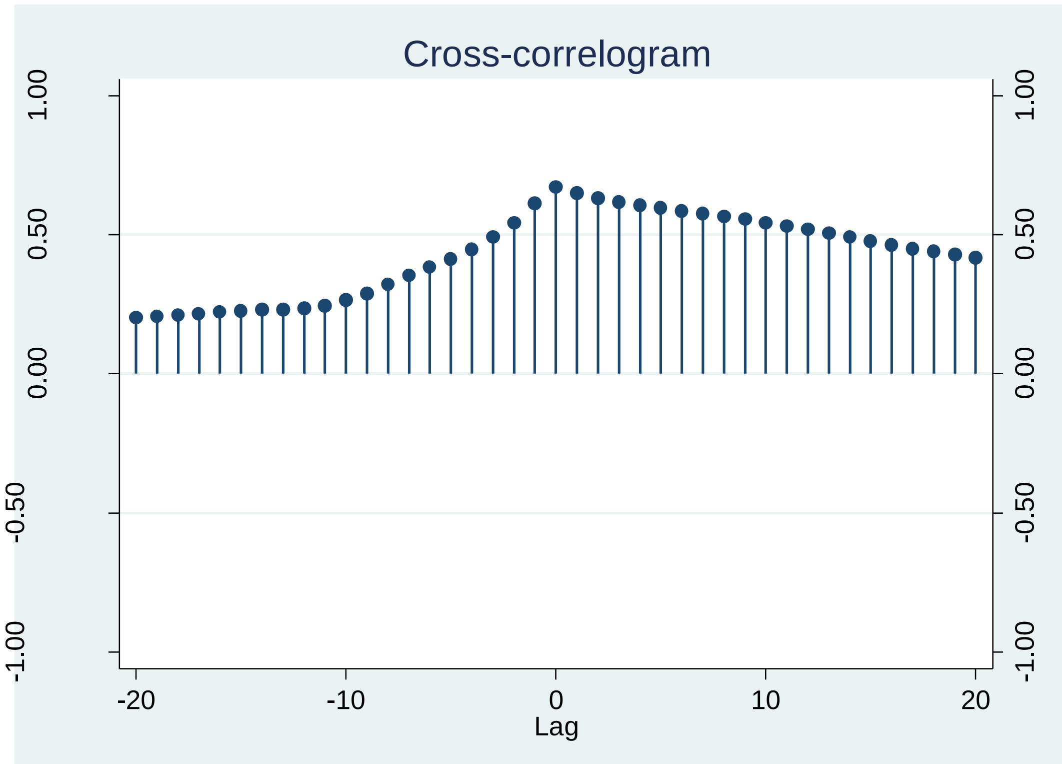
Figure 5.2 Inflation (retailed price index)



Source: Author

The figure above shows the fluctuation of inflation in UK as measured by the retailed price index. UK's inflation displays a somehow stable inflation in the past three decades. It mainly fluctuates between 0% to 5% indicating that the Bank of England is doing a good job in achieving the British government's inflation target which is currently set at 2%. However, the economy experiences a spike in inflation in the early 1990's, where it rose to 10%. This is an unusual level of inflation in the British economy. Another unusual case also happened during the world financial crisis of (2008 – 2010), which recorded the lowest possible level of Inflation in the period under study. The levels recorded was below 0%, which is to say, the economy experienced negative inflation rate. This were the two spikes that occurred within the period under study and they are considered unusual in relation to the trend of UK's inflation. Formulation of the inflation targeting policy in 1992 has played a key role in shaping UK's recent inflation dynamics.

Figure 5.3 Cross- correlogram



Source: Author

Figure 3.5 indicates that log labor income share is positively related to both past and future values of inflation. This result further corroborates Arruda et al., (2018) and Gali & Gertler's (1999) idea that the labor income share as a proxy for marginal cost makes a better measure of real economic activity than the output gap. The relationship increases as the measure moves closer to current inflation from the past and starts to decrease as it moves away from current inflation towards further future values of inflation. This is indicative of a strong relationship between the marginal cost measure and current inflation.

5.3 Pre-Estimations Tests

This section intends to reveal the strengths and weaknesses of the data set. It will explain how well the data fits the New Keynesian Phillips curve and its hybrid version in the UK.

5.3.1 Unit Root

I employed two widely used stationarity tests in the literature of the new Keynesian Phillips curve, (Augmented Dickey-Fuller and Phillips-Perron). The unit root tests show a stationary pattern in all the variables, which were evaluated at their level. Both the augmented Dickey-Fuller and the Phillips-Perron tests establishes stationarity of the variables. This means the variables have the potential of producing stable and reliable results. All the variables but the retailed price index, have similar statistics for both tests. The retailed price index seemingly has different statistics in the two tests but remains stationary in both. The results of both tests are presented in table 5.2.

Table 5.2 Unit Root tests

Series	Augmented Dickey-Fuller	Phillips-Perron
GDP deflator	-8.257	-8.257
	(0.0000)	(0.0000)
Inflation (Retailed price index)	-6.988	-4.894
	(0.0000)	(0.0000)
Log labor income share	-7.253	-7.253
	(0.0000)	(0.0000)
Wage Inflation	-9.650	-9.650
	(0.0000)	(0.0000)
Implied Inflation	-2.967	-2.967
	(0.0381)	(0.0381)
Real GDP	-10.718	-10.718
	(0.0000)	(0.0000)

Source: Author.

Note: P-values in parentheses

However, in the absence of a trend break, the well-known augmented Dickey-Fuller test has the highest power than any other alternative test and is most appropriate for testing the presence of unit roots in a time series.

5.4 Reduced form estimates

In this section, the structural estimates of the two models are presented. These estimates were generated from the IV regression and the GMM estimates. Nonetheless, the models were estimated with OLS, but the results were found to be heteroskedastic, consequently, making it an inconsistent measure. The Breusch-Pagan / Cook-Weisberg test for heteroskedasticity was employed. The inconsistency of the OLS leads to an alternative estimation technique known as the instrumental variables (IV) estimator. The IV estimation provides room for more variables to be included in the prediction of inflation. The equations (29) and (30) are the results obtained from the IV regression. Note the numbers in the parenthesis are p-values.

$$\pi_t = \underset{(0.265)}{1.475\,\widehat{S_t^n}} + \underset{(0.001)}{3.136\,\pi_{t+1}} \tag{29}$$

$$\pi_t = \underset{(0.047)}{1.809\,\widehat{S_t^n}} + \underset{(0.011)}{1.757\,\pi_{t+1}} + \underset{(0.008)}{0.806\,\pi_{t-1}} \tag{30}$$

Table 5.3 presents the results of the new Keynesian Phillips curve and its hybrid version computed from the IV regression. The set of instruments comprises of the log real GDP, GDP deflator, Output gap and four lags of inflation. The NKPC is stable and consistent with the prediction of the theory. However, the labor income share was found to be statistically insignificant but positive in explaining the variation in inflation. On the other hand, the results of the hybrid are different from the NKPC, which could be as a result of the introduction of the backward-looking inflation. Log labor income share and the expected inflation stays positive and significant as was in the baseline NKPC. Furthermore, the backward-looking measure was statistically significant in explaining inflation dynamics in the United Kingdom. For the purpose of this study, lag GDP deflator was used as the backward-looking inflation measure. However, the variable has a small economic magnitude which indicates that UK's inflation is not purely forward-looking. This result further signifies that UK's inflation is more forward-looking, meaning businesses focus more on expectations of future inflation to determine prices.

Furthermore, the slope coefficient on the variable of interest (labor income share) is positive in both models. This is consistent to the prediction of new Keynesian Phillips curve, and further strengthen the results obtained by Balakrishnan & López-Salido, (2002) and Gali & Gertler (1999). Meanwhile, UK's inflation has a strong forward-looking component, as can be seen from the hybrid NKPC. Inflation expectations in both models proves to be a key factor of firms' price level setting. We can argue that this strong effect could be as a result of the Bank's policy to regulate money supply through inflation targeting. The Bank of England uses a set of factors in setting this target, some of which, are the retail price index (RPIX), consumer price inflation, wage inflation etc. (Balakrishnan & López-Salido, 2002).

Table 5.3 Structural estimates (IV)

Model	**Parameter**			**Sargan statistics Hansen**	**Heteroskedasticity Pagan and Hall**
	λ	γ_f	γ_b		
NKPC	1.475	3.136		15.093	6.286
	(0.265)	(0.001)		(0.057)	(0.790)
HNKPC	1.809	1.757	0.806	13.250	4.894
	(0.047)	(0.011)	(0.008)	(0.0662)	(0.898)

Source: Author

Note: p-values in parenthesis

Equations (31) and (32) presents the results of the GMM estimates. The variables are positive but not necessarily significant. The log labor income share which serves as the real economic activity measure was found to be statistically insignificant. On the other hand, the inflation expectations variable plays a significant part in explaining inflation dynamics in UK. By extension, the estimates of the hybrid NKPC shows similar results in that all the variables are positively signed. Notwithstanding, the real economic activity and the inflation expectations variables are not statistically significant in predicting the inflation rate. The backward-looking measure was found to be statistically significant.

$$\pi_t = \underset{(0.194)}{1.631}\,\widehat{S_t^n} + \underset{(0.000)}{3.425}\,\pi_{t+1} \quad (31)$$

$$\pi_t = \underset{(0.211)}{1.966}\,\widehat{S_t^n} + \underset{(0.523)}{0.685}\,\pi_{t+1} + \underset{(0.000)}{4.484}\,\pi_{t-1} \quad (32)$$

The results from the GMM estimation are explicitly presented in table 5.4.

Table 5.4 Structural estimates (GMM)

Model	**Parameter**		
	λ	γ_f	γ_b
NKPC	1.631 (0.194)	3.425 (0.000)	
HNKPC	1.966 (0.211)	0.685 (0.0523)	4.484 (0.000)

Source: Author

Note: p-values in parenthesis

The results presented in table 5.5, were obtained from the instrumental variables estimator implemented using the Generalized Method of Moments (IV-GMM). This method is applied with robust standard errors to control for heteroskedasticity in the errors. The IV-GMM estimate is more efficient than the robust 2SLS estimates (Baum, 2013).

Table 5.5 Structural estimates (IV-GMM)

Model	**Parameter**			**Hansen J Statistics**
	λ	γ_f	γ_b	

NKPC	7.637	1.799		13.158
	(0.002)	(0.036)		(0.1065)
HNKPC	6.768	1.810	0.323	11.591
	(0.018)	(0.078)	(0.540)	(0.1148)

Source: Author

Note: p-values in parenthesis

The IV-GMM estimates generated statistically significant results for both variables in the new Keynesian Phillips curve. The results are consistent with the IV estimates as they continue to reconcile with the prediction of theory. Furthermore, the estimated hybrid model on the other hand does not provide enough evidence to rely on the backward-looking parameter. UK's inflation remains to be more forward-looking, as firms are believed to set prices based on the expectations of future price levels. Unlike the IV estimator, the IV-GMM uses the Hansen J test for overidentification of excluded instruments. The models were estimated with the same choice of instruments with the IV estimates. The Hansen J test for both models fails to reject the null hypothesis, which is an indication that the choice of instruments is valid. The NKPC model is overidentified by eight (8) degrees of freedom with one endogenous regressor and nine (9) excluded instruments. In the same token, the hybrid model was overidentified by seven (7) degrees of freedom and eight (8) excluded instruments.

The insignificance of the backward-looking measure is a course for concern, as it claims that UK has no inflation inertia. In other words, UK's policy makers can achieve costless disinflation. However, Arruda et al. (2018), show that inflation is more susceptible to inertia in a low foresight environment than otherwise. Thus, as noted by Sicsú (2002) and Mendonça (2002, 04), the lower the ability of economic agents to forecast the future, the higher the cost of a disinflation policy. Therefore, the result could be reliable given that firms in the UK have a better forecast of the future. Furthermore, Benati (2006) claims that under inflation targeting, inflation exhibits little or no persistence based on all the price indices they considered. They have the compelling view that high inflation persistence is not an intrinsic, structural feature of the British economy. Instead, the extent of inflation persistence may crucially depend on the monetary regime in place over the sample period.

5.5 Diagnostic Tests

In this section we intend to reveal some of the estimation issues in fitting the New Keynesian Phillips curve to the data.

5.5.1 Heteroskedasticity

In the context of an equation estimated with instrumental variables, the standard diagnostic tests for heteroskedasticity and autocorrelation are generally not valid. Pagan and Hall proposed a test that is appropriate in IV estimation where heteroskedasticity may be present in more than one structural equation. The Pagan-Hall general test statistics fails to reject the null hypothesis which indicates homoscedastic errors. The heteroskedasticity test from the estimates has a resulting p-value of (0.790). Thus, in relation to the overidentification test we can rely on the choice of instruments as they are not correlated to the error term. Heteroscedasticity does not affect the consistency of the coefficient estimates, but the standard errors are inconsistence preventing valid inference. This will further invalidate the diagnostic test of overidentification and endogeneity.

5.5.2 Overidentification

The IV regression reports the Sargan test statistics which is an overidentification test for all instruments. The p-values for both models were not statistically significant to reject the null hypothesis of overidentified instruments. The hybrid model is overidentified by seven (7) degrees of freedom, as there is one endogenous regressor and eight (8) excluded instruments. While the NKPC was overidentified by eight (8) degrees of freedom with one endogenous regressor and nine (9) excluded instruments. Different sets of instruments were used as the GDP deflator was dropped as an excluded instrument in the estimation of the hybrid NKPC. The rationale in the difference of choice of instruments is set on the bases that the lag GDP deflator is already captured as an included instrument. Instrumental variables techniques are powerful, but if a strong rejection of the null hypothesis of the Sargan–Hansen test is encountered, you should strongly doubt the validity of the estimates. It is important to understand that the Sargan–Hansen test of overidentifying restrictions is a joint test of the hypotheses that the instruments, excluded and included, are independently distributed of the error process *and* that they are properly excluded from the model.

5.5.3 Endogeneity test

The C test was done on the estimated equations with IV-GMM, to challenge the endogeneity of the specified endogenous variable in the model. The specified endogenous variable in both models is the expected inflation measure. The null hypothesis of the C test states that the variable is exogenous. Failure to reject the null means that the models can be estimated with OLS. In the case of which if the OLS estimates of the equations are consistent, they should be preferred to the IV estimates (Baum, 2013). In the pretext of the results, it appears that the equations cannot be consistently estimated with OLS techniques, as the null hypothesis that the endogenous variable (inflation expectations) can be treated as exogenous was strongly rejected by the data. The C test statistics is distributed χ^2 with (1) degree of freedom and it reported a p-value (0.0021).

5.5.4 Weak identification

Instrumental variables methods rely on two assumptions: the excluded instruments are distributed independently of the error process, and they are sufficiently correlated with the included endogenous regressors. Stock & Yogo (2005) propose testing for weak instruments by using the *F*-statistic form of the C–D statistic. Their null hypothesis is that the estimator is weakly identified in the sense that it is subject to bias that might be too large to be accepted. Under weak identification, the test rejects too often. For the purpose of this study I estimated the Cragg-Donald Wald statistics. According to the result, all the critical values of the Stock-Yogo are greater than the estimated Cragg-Donald F-statistics. Meaning that the choice instruments does not have explanatory power, thus they are weak. This assumes that the critical values for the Cragg-Donald F statistics have i.i.d errors.

CHAPTER 6

Conclusion

The term New Keynesians was coined by Michael Parkin in his New Keynesian theory (1982) and Edmund S. Phelps – New Keynesian Model (1986) and was first used in a scholarly article by Ball, Mankiw and Romer (1988). The model has micro foundations that are rooted from the Keynesian models of staggered contracts. It explains how current expectations of future inflation and a measure of real economy activity affects current inflation. As shown by Gali & Gertler (1999), the new Keynesian Phillips curve can be extended to capture the impact of inflation inertia. The models are estimated with GMM, an estimation technique that utilizes instrumental variables to cater for the inflation expectations. Quarterly series that covers a period of 38 years (1980:1 – 2018:4) used for the analysis. The results are in close proximity with the prediction of the new Keynesian theory. They also reaffirm the conclusion obtained by Gali & Gertler (1999) about the use of the marginal cost as a measure of real economic activity. The IV-GMM estimates generated statistically significant results for both variables in the new Keynesian Phillips curve. Furthermore, the estimated hybrid model on the other hand does not provide enough evidence to rely on the backward-looking parameter. UK's inflation remains to be more forward-looking, as firms are believed to set prices based on the expectations of future price levels.

The statistical insignificance of the backward-looking measure in the IV-GMM estimates is a course for concern, as it doesn't support the existence of inertia in UK's inflation. the result are rather strange but Arruda et al. (2018), found that inflation is more susceptible to inertia in a low foresight environment than otherwise. Thus, as noted by Sicsú (2002) and Mendonça (2002, 04), the lower the ability of economic agents to forecast the future, the higher the cost of a disinflationary policy. Therefore, the result could be reliable given that firms have a better forecast of the future. Furthermore, Benati (2006) claims that under inflation targeting, inflation exhibits little or no persistence based on all the price indices they considered. They have the compelling view that high inflation persistence is not an intrinsic, structural feature of the British economy. Instead, the extent of inflation persistence may crucially depend on the monetary regime in place over the sample period.

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Appendices

Appendix A

Table A1: Summary Statistics

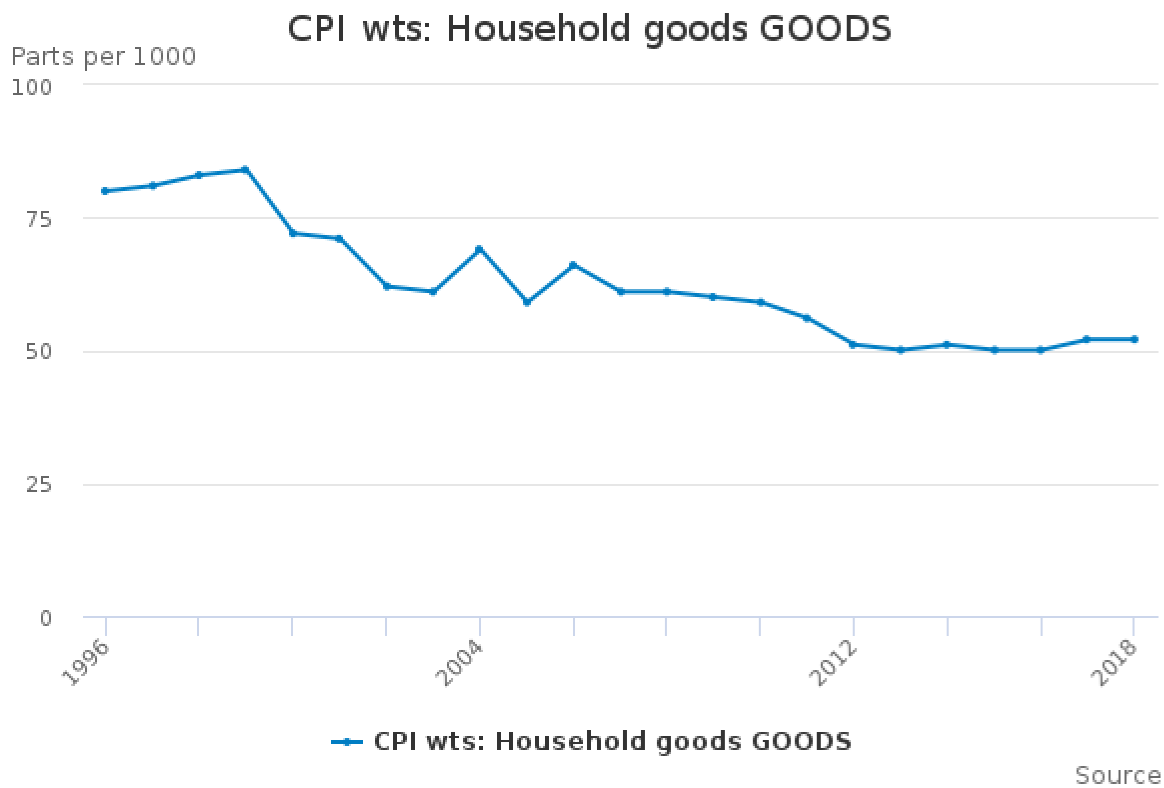
Variable	Obs	Mean	Std. Dev.	Min	Max
Inflation	156	4.249359	3.337113	-1.4	21.6
GDP_def	156	.8833333	.9979226	-1.8	5
Wage_infl	156	.8320513	1.25739	-2.2	5.8
Lab_shr	156	10.25912	3.947513	6.166729	23.00961
lnLab_shr	156	2.265777	.3415072	1.819169	3.135912
Unemp_rate	156	7.485897	2.279883	4	11.9
Output_wrk	156	83.26603	14.37012	55.9	101.7

Table A2: Correlation

variable	Inflation	inLab_shr	real_GDP	GDP_def	wage_infl	Output_wrk	unemp_rate
Inflation	1.000						
lnLab_shr	0.6806	1.000					
real_GDP	-0.1408	-0.2879	1.000				
GDP_def	0.7351	0.6229	-0.1405	1.000			
wage_infl	0.5079	0.3961	-0.0060	0.4313	1.000		
Output_wrk	-0.6298	-0.9718	0.2891	-0.5848	-0.3815	1.000	
unemp_rate	0.2250	0.6890	-0.1612	0.2520	0.0558	-0.7517	1.000

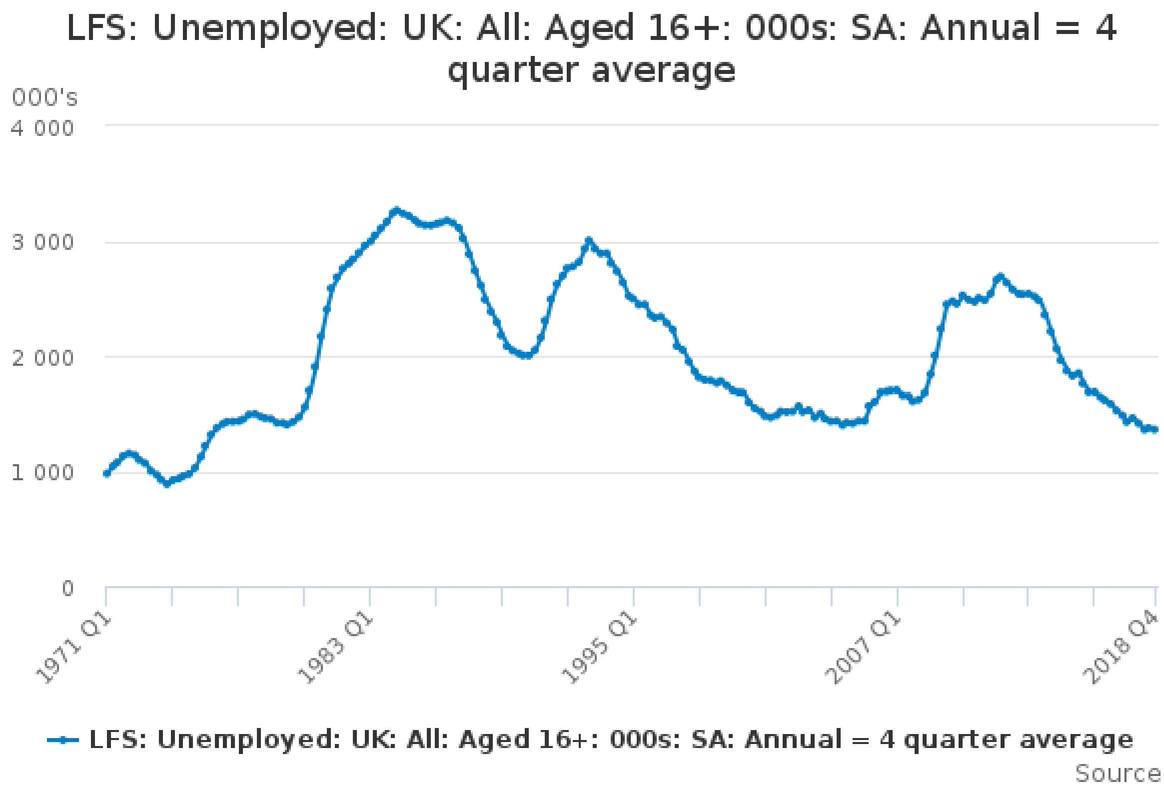
Appendix B

Figure B1: Consumer price inflation



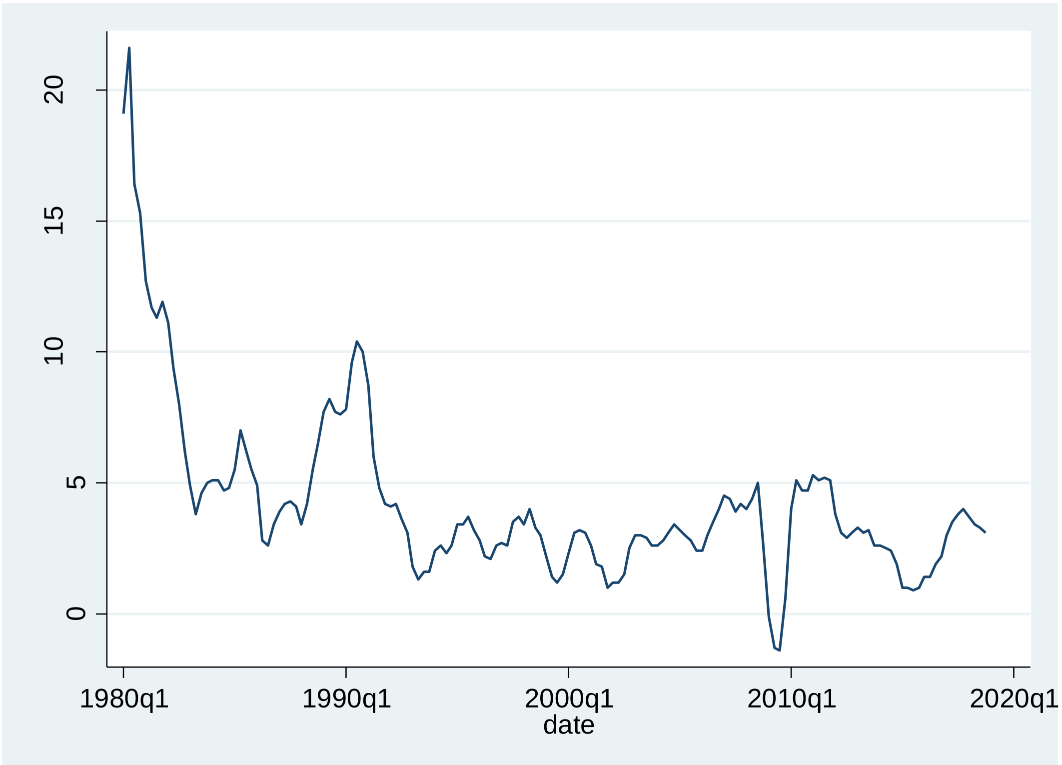
Source: Office of National Statistics

Figure B2: UK's Unemployment age 16 and above.



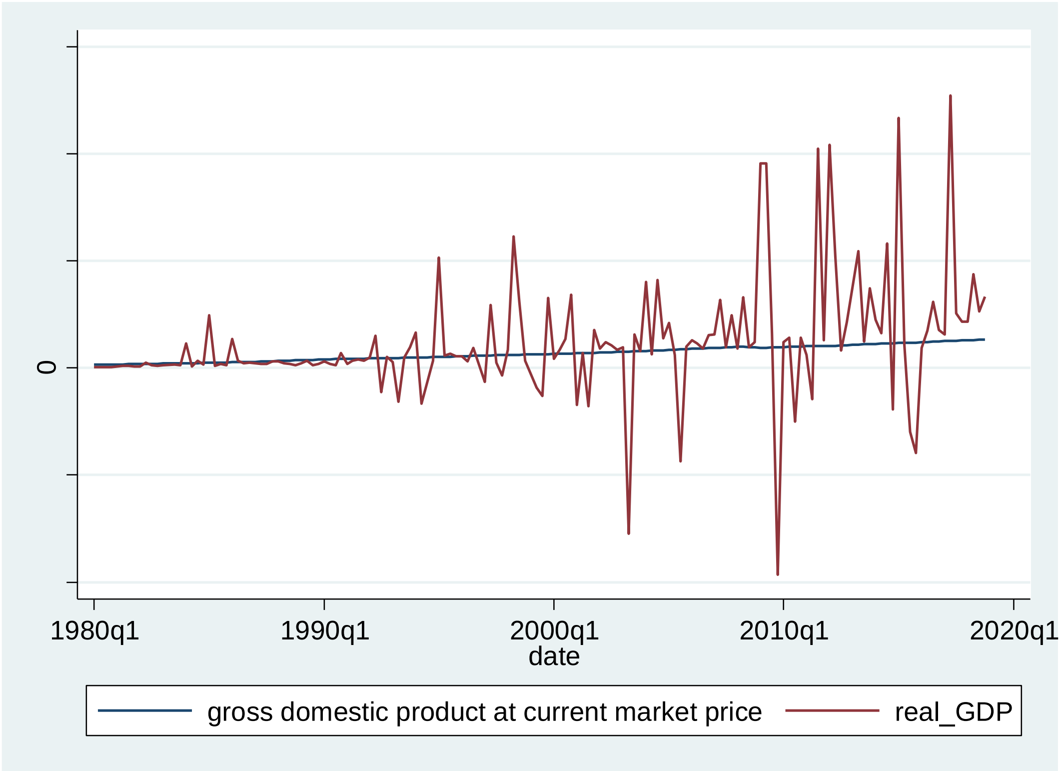
Source: Office of National Statistics

Figure B3: Inflation (retailed price index)



Source: by the author

Figure B4: Nominal and Real GDP



Source: by the author