The Hybrid New Keynesian Phillips Curve: A case study of Ghana

Lydia Hanson
May 2017

University of Oslo
Department of Economics

Master Thesis for Master of Philosophy in Economics
© Lydia Hanson

2017

Title: The Hybrid New Keynesian Phillips Curve, A case study of Ghana

http://www.duo.uio.no/

Press: University of Oslo

II
Abstract

This thesis is an empirical investigation and application of the hybrid New Keynesian Phillips Curve (hybrid NKPC) on Ghanaian economy from 1993 to 2015. The paper seeks to test the ability of the hybrid NKPC in explaining the inflation dynamics of Ghana. The estimating method used is the Generalized Instrumental Variable Estimator (GIVE).

The study begins with a description of the key concepts of the hybrid NKPC, reviews of some relevant evidence of the ability and controversies of the hybrid NKPC as well as the GIVE approach used to estimate the hybrid NKPC. The endogeneous variables used in the study are the broad money supply, the Ghana cedi to the US dollar exchange rate, the crude oil price, the actual gross domestic product (GDP). We then used the Hodrick-Prescott filter (HP) to estimate the output gap and also applied the Augmented Dickey-Fuller (ADF) test to test for stationarity/autocorrelation in all the variables except real GDP. We further estimated the expected future inflation term using broad money supply, the Ghana cedi to the US dollar exchange rate and the crude oil price as explanatory while the lagged inflation term was estimated from the actual inflation rates. Afterwards, we applied the GIVE to estimate the hybrid NKPC using the estimated output gap, expected future inflation term and the lagged inflation term.

The estimation of the Hybrid NKPC using the Generalized Instrumental Variables Estimator (GIVE) showed that hybrid NKPC fitted the Ghanaian data well. Thus, both the lagged and expected future inflation plays important roles in inflationary pressures in Ghana. The estimated coefficients of approximately 0.6 and 0.5 points for lagged inflation and the expected future inflation respectively with the former dominating. However, the study found no effect of growth in gross domestic Product (GDP) or output gap on Ghana’s inflation rates for the period under consideration. In addition, the broad money supply, the Ghana cedi to the US dollar exchange rate and crude oil price were found to be the driving forces for expected future inflation rate and therefore indirectly affects inflation rate of today.

The study recommends that to maintain low and steady inflation, the Bank of Ghana (BoG) in collaboration with policymakers as well as governments policies should gear towards controlling lagged and expected inflation first.

Keywords: lagged inflation, expected future inflation, hybrid NKPC, GDP and GIVE
Acknowledgement

Thanks be to God for guiding me throughout my study period. I am also grateful to my supervisor, Professor Ragnar Nymoen for his patient guidance, constructive suggestions, comments and timely feedbacks which were helpful for the completion of this thesis. I am thankful to my parents, husband and siblings for their undying financial support and words of encouragements during the study period. My warmest gratitude goes to my friends in Norway and Ghana who contributed by proof reading. Lastly, I say big thanks to my colleagues and lecturers at the Department of Economics in the University of Oslo, who made my stay here wonderful.
# Table of Contents

1. Introduction ............................................................................................................. 1  
2. Economic History of Ghana since independence – a short review ....................... 4  
   2.1 Inflationary trends in Ghana: a review 1960-2015 ................................................. 4  
   2.1.1 The immediate post-independence period (1957-1966)................................. 4  
   2.1.2 Privatization and International Monetary Fund (IMF) programme (1966-1972) 6  
   2.1.3 Military Rule and Poor Expansionary Economic Policies (1972-1982) .......... 8  
   2.1.4 International Monetary Fund (IMF) and World Bank (WB) Recovery Programs (1982-2004) ................................................................. 9  
   2.1.5 The democratic Era (2004-2015) ................................................................. 9  
3. Literature Review .................................................................................................... 11  
   3.1 Categorization of inflation Determinants ............................................................. 11  
   3.1.1 Demand - Pull Inflation .................................................................................. 11  
   3.1.2 Cost- push inflation ...................................................................................... 12  
   3.1.3 Future inflation expectations and inertial inflation .......................................... 13  
   3.2 The Phillips Curve Model ................................................................................... 13  
   3.2.1 The New Keynesian Phillips Curve ................................................................... 15  
   3.2.2 The hybrid NKPC ....................................................................................... 19  
3.3 A review of hybrid NKPC estimates for some countries ....................................... 21  
3.4 Generalized instrumental variable estimator (GIVE) ............................................. 23  
4. Methodology .......................................................................................................... 25  
   4.1 Data .................................................................................................................... 25  
   4.1.1 Broad money supply .................................................................................... 25  
   4.1.2 Global crude oil prices ................................................................................ 26  
   4.1.3 The potential GDP and actual GDP (The output gap) .................................... 26  
   4.1.4 The exchange rate ...................................................................................... 26  
   4.1.5 Future inflation expectations and inertia inflation ........................................... 27  
4.2 Estimation strategies and findings ......................................................................... 27  
   4.2.1 Output gap estimation using Hodrick-Prescott (HP) filter ............................... 27  
   4.2.2 The Unit root testing (ADF-test) of the variables .......................................... 29  
   4.2.3 Estimating for the expected future inflation rate ($\pi_{t+1}$) ............................ 31  
   4.2.4 Estimating for the lagged inflation rate term ($\pi_{t-1}$) .................................... 32
5  Empirical results and discussions ................................................................................. 33
5.1  The estimated NKPC for Ghana .................................................................................. 33
5.2  The estimated hybrid NKPC for Ghana ...................................................................... 34
6  Conclusion and recommendations ................................................................................ 36
References .......................................................................................................................... 38
Appendix ............................................................................................................................. 41

Figure 1. Inflation rate, average consumer price (%) in Ghana and other West Africa countries, 2006-2015 ........................................................................................................ 1
Figure 2. Ghana consumer price index inflation (1980-2016) - inflation average consumer price (percentage) ........................................................................................................ 6
Figure 3. Inflation rate in Ghana from 2001 -2015. .............................................................. 10
Figure 4. A Phillips curve – showing relationship between wage inflation and unemployment (percentages). ........................................................................................................ 14
Figure 5. Output gap ........................................................................................................... 28
Table 1. ADF test .................................................................................................................. 29
Table 2. ADF test .................................................................................................................. 30
Table 3. Ordinary Least Squared (OLS) Estimate ................................................................. 31
Table 4. Estimate for the NKPC using GIVE ...................................................................... 33
Table 5. Estimate for the hybrid NKPC by GIVE ............................................................... 34
Table 6. The study data ....................................................................................................... 43
1 Introduction

Ghana’s inflation experience since independence in 1957 has been unstable and very high in some periods. According to Ahmad (1970) the first five years, 1957-1962 after independence, Ghana saw relatively small stability in price determination as inflation hung around a single digit. In an article “The Great Inflation in the 1970” Bresiger (2015) noted that in the 1970s and early 1980s, Ghana experience a very high inflation phases and unstable macroeconomics eras. Also, in Ocran (2007), we find that Ghana’s inflation has exceeded 100% on four occasions between July 1977 and March 1983. Surprisingly, stabilization policies implemented did little to reduce the persistence rise in inflation rates in the country at the period (Ocran, 2007). However, Taborda (2016) emphasized that inflation rate in Ghana averaged 17.11% from 1998 to 2015, reaching as high as 63% in March of 2001 and as low as 0.40% in May of 1999.

Figure 1. Inflation rate, average consumer price (%) in Ghana and other West Africa countries, 2006-2015

**Source:** International Monetary Fund- 2016 Economics Outlook

Figure 1 shows that Ghana has inflation rates higher than its neighboring countries. This high inflation rates in Ghana has raised many different views from both researchers and non-
Some of their arguments are: price of crude oil, exchange rates, world food prices, cocoa prices and energy cost are influencers of inflation in the Ghanaian economy. Most of these views are based on thoughts and perceptions rather than empirical work, therefore Ghana need a more structured model to analyze the inflation rates which will empirically examine these variables to serve as a reference point for policy makers.

However, in this 21st century, one of the structural models of inflation studies is the New Keynesian Phillips Curve (NKPC) because it’s a good first approximation to the dynamics of inflation (Gali & Gertler, 1999). Recently, the NKPC and the hybrid NKPC have attracted a great deal of interest in analyzing the causes of inflation by policymakers. The reason been that this model thus NKPC describes the relationship between expected future inflation and marginal cost or output gap by (Karahan, Çolak, & Bölükbaşı, 2012). Also according to Morley, Piger, and Rasche (2011), the NKPC highlights the inflation persistence by emphasizing the role of inflation expectations. Gali and Gertler (1999) improved the NKPC by incorporating lagged inflation resulting in the new version of NKPC called hybrid NKPC. Remarkably, many advanced countries have tested the ability of the hybrid NKPC in explaining their economy’s inflationary pressures. However, to the best of my knowledge, there has not been an empirical application of the hybrid NKPC on Ghana. Therefore, this thesis seeks to test empirically the hybrid NKPC in explaining the high inflationary pressures in Ghana. The study will investigate the whether the backward looking rule/lagged inflation and the forward looking rule/expected future inflation are crucial in explaining inflation rates in Ghana which is the benchmark of the hybrid NKPC.

Although, there are various approaches used in estimating NKPC namely: the dynamic stochastic general equilibrium (DSGE) with price adjustments frictions, the single-equation method called generalized method of moments (GMM) proposed by Hansen (1982) uses rationalized expectations hypothesis e.g. Garli and Gertler (1999); King and Watson (2012) and Leith and Malley (2007). Another approach is to adopt the full information system estimation using the Bayesian maximum likelihood (ML) procedure e.g. Wouters (2003) and Adolfson et al., (2007). But in this paper we will use the Generalized Instrumental Variables Estimator (GIVE) which is similar to the GMM. The GIVE is straight forward and easily applied when the purpose is to test the empirical NKPC.

The structure of this thesis is as follows: chapter 2 gives a brief history of inflation in Ghana from 1960 to 2015. Chapter 3 describes the theoretical framework used in this thesis and
relevant literature. Chapter 4 describes the data, econometric model and pre-estimations. Followed by the empirical results of the research problem in chapter 5. Chapter 6 concludes the thesis.
2 Economic History of Ghana since independence – a short review

This chapter gives a background history of inflation in Ghana from 1960 to 2015 and describes the economic development of the Ghanaian economy with the emphasis on inflation.

2.1 Inflationary trends in Ghana: a review 1960-2015

Ocran (2007) offered a perspective that describes Ghana’s inflation experiences since independence as periodic and identified four different phases from 1960 to 2003. These phases are the immediate post-independence period ending 1966, Post Nkrumah regime between 1966 and 1972, the deterioration phase between 1972 and 1982 and lastly, the stabilization phase 1982-2003. In addition, Alagidede, Coleman, and Adu (2014) studied the inflation trend of Ghana from 2004-2009 and described the inflation trend as moderation phase

2.1.1 The immediate post-independence period (1957-1966)

The immediate post-independence period began after Ghana gain self-rule in 1957 (Ahmad, 1970). Ghana exited the West African Currency Board (WACB) and resorted to printing its own currency. Prior to independence, taxes and borrowing within the country financed the country; since printing of currency was the duty and privilege of WACB. In 1959, the government announces new five-year development plan, which amounted to the equivalent of 700 million USD at the time and that between 1957-1966, marked a massive industrialization initiative that the country had ever recorded historically (Ocran, 2007). There were very high investments in infrastructure, coupled with establishment of import replacement industries on a large scale, with the intention of meeting the needs of the people. This industrial expansion also incorporated subsidized social services in education, health and housing. The purpose was restructuring Ghanaian economy to a modernized and competitive (Ocran, 2007). This unfortunately put the country into huge current account deficits. In a situation of this nature, a cut in expenditure was required; however, the government instead maintained the huge development expenditures but continued it through deficit financing and loans from abroad.
These foreign loans were possible because the country was not under WACB’s strict expansionary fiscal and monetary policies.

These major phases in the economic history of Ghana were quite widely known outside Ghana. Furthermore, Ahmad (1970) also noted that the five-year development plan (1959/64) by the government in March 1959 ushered Ghana into an era of conscious effort of economic development. In 1960, when government capital expenditure increased substantially, development also increased. As a tool for financing deficits to mitigate the continuous rise in government budget deficit, which the country faced in 1960, Ghana resorted to issuing a new national currency, called Ghanaian cedi. In 1961, two years after introducing the five-year development plan, the government abandoned the second five-year plan, nevertheless, expenditures in capital stocks (buildings, machines and infrastructure) continued to be high. Chung, Wright, and Charoenwong (1998) claimed that the increases in capital expenditure positively affected the stock prices of firms with valuable asset opportunities. Therefore, the high capital formation could still be positive for Ghana’s development.

The government further introduced a seven-year development plan (1963/70), but net investment continued to rise at an unsustainably high rate. However, these economic plans came to a halt in February 1966 when the government was overthrown. As the literature shows, the main adverse effects of deficit financing in developing countries are inflation and balance of payment instability (Ahmed, 1970). In spite of this, deficit financing was useful in financing the various government’s expenditures because of the narrow tax-base at the time. The low incomes of the people, coupled with high public expenditures may have forced the government to deficit financing. Although, the deficit financing yield good results in employment, its adverse effect was a rise in inflation. As noted in Ocran (2007) that Ghana’s pre-independence inflation rate was at single digit level due to the strict structure of WACB’s fiscal and monetary policies and that inflation rates were estimated be to less than 1%. With high public expenditure and increased finance deficits, the inflation rate of the country began to rise such that between 1960 and 1968, annual rate of inflation was 8% and more than double between 1964 and 1966 at 23% according to (Ocran, 2007).
Figure 2. Ghana consumer price index inflation (1980-2016) - inflation average consumer price (percentage).

Source: https://knoema.com/atlas/Ghana/CPI-inflation

Figure 2 shows a graph for CPI inflation from 1980 to 2015. Inflation reached its highest in the year 1983 and lowest in the year 2010 respectively. In addition, inflation rate keeps rising after 2011 then fluctuates afterwards.

2.1.2 Privatization and International Monetary Fund (IMF) programme (1966-1972)

The immediate Post Nkrumah regime (1966-1972) saw a rise in inflation. This was when Nkrumah’s government was overthrown. The military group that overthrew the government in 1966, adopted an IMF macroeconomic stabilization program to calm down the economy and stabilize or reduce the high inflation rates (Ocran, 2007). According to Ocran (2007) as way of liberalizing and stabilizing the economy, the new government adopted IMF programmes by
reducing governments extensive involvement in the production sector and also tightens monetary and fiscal policies. In addition to the IMF programme, another noticeable action at the period was the devaluation of the Ghanaian cedi (₵), by 30% against the US dollar ($). Generally, one positive side of devaluation was an improvement in the currents account balance through higher exports and lower imports. Usually, a spell of increased inflation is expected to occur following devaluation. However, the effect of devaluation on inflation depends on spare capacity in the economy. For example, in a boom, devaluation is likely to intensify inflation. Firms shifting increased import costs onto consumers during devaluation of a country currency are not the only determinants of inflation but also wage increase (Pettinger, 2016). However, the wage bill decreased as the public sector retrenchment resulted in a 10% reduction in employment for wage earners (Hutchful, 2002). The combined effect of the fiscal and monetary policy coupled with the devaluation of the currency led to 8% deflation in 1967, an inflation average within the period stood at 2.3% per annum between 1967 and 1969 (Ocran, 2007). Compared to 23% rate of inflation in 1966, we observe a major drop in inflation because of the implementation of the contraction in fiscal and monetary policies. However, the low rate of inflation of the first stabilization period also came with a significant decline in economic growth (Ocran, 2007). This low growth is possible, if there were no labour-force quality improvement measures that were embarked on by the government for the remaining public sector workers who were not laid off by the policy. Havi, Enu, Osei-Gyimah, Attah-Obeng, and Opoku (2013) analysis of macroeconomic development of Ghana using a co-integration approach, found that physical capital and foreign aid had positive effects on Ghana’s growth in real domestic product per capital between 1970 and 2011. In general, the important factors to economic growth are the level of investment in physical and human capital, good macroeconomics policies, governments spending, research and development in the business sector as well as financial market and international trade (Bailey, 2003). Based on the above studies above, we can conclude that inflation affected the economic growth indirectly. Between 1969 and 1972 when government encouraged the participation of the private sector in the economy, inflation was in check although fiscal policy was relatively ‘loose’ and this was because monetary policy was still contractionary in orientation details in (Ahmad, 1970). The government economic policies supported import supplies mainly in machinery or intermediary products/materials, which led to an impressive growth (Ocran, 2007). Nevertheless, from a low of 3%, inflation increased to 10% in 1970 but decreased in 1971 and unfortunately, the government was overthrown by military consequently in January 1972. In conclusion, we see that in 1966, the decreased in
inflation rate saw a decline in economic growth, similarly, between 1969 and 1972, the increased in economic growth was accompanied by high inflation. Therefore, we see the reverse causality between inflation and economic growth in the Ghana during the period.

2.1.3 Military Rule and Poor Expansionary Economic Policies (1972-1982)

The third phase of Ghana’s inflationary era was between 1972 and 1982 which (Ocran, 2007) described as the deterioration was a period of changing military and civilian governments. The military government that overthrew the previous government reversed the economic policy direction. Among the notable actions of the government was the revaluation of the cedi by 42%, development levy of 7% was curtailed, enforcements of external trade controlled whilst benefits and some allowances to the civil servants that had been withdrawn by the previous government were reinstated (Ocran, 2007). Also, the very high prices in gold and cocoa which led to an improved balance of payments position of Ghana in 1971/72 was reduced by the 1973 global oil price shock (Ocran, 2007, p. 8). Hence, Ocran (2007) emphasized that this shock led to a gap in the government budget which forced the government to finance its expenditures through borrowing from the Bank of Ghana. The impacts of deficit financing through currency printing fueled inflation as deficit increased from ₴17 million in 1971 to ₴781 million in 1977 in addition to total money supply of over 500% cumulatively over the period (Hutchful, 2002). These high broad money supply and deficit financing by the government resulted in inflation of 117% by 1977, and government resorted to price control mechanisms to help decrease the inflation (Ocran, 2007). Afterwards, Ghana had four subsequent governments that adopted reckless expansionary economic policies in controlling inflation. For instance, the Limans Administration tripled the public sector wage overnight and doubles the producer price of cocoa as well as the devaluation of the national currency again by 58% (Ocran, 2007). The salient features of these military governments were the deepening of the liberalization policies initiated by the previous government, as well as loosening the grip on fiscal policies by the use of foreign reserves and loans to pursue economic stimulation programs (Ocran, 2007). In conclusion, subsequent military regimes characterized by general mismanagements, large expansionary economic, loose monetary policies, weak production base and low output exerted pressure on domestic prices, resulted in a further increase in inflationary experience in the period 1972-82 were the final remarks of Ocran (2007).
2.1.4 International Monetary Fund (IMF) and World Bank (WB) Recovery Programs (1982-2004)

The fourth inflation period, the stabilization was caused by international economic politics and drought. In 1983, Ghana faced a cut in crude oil supplies, increased immigrants and a prolonged drought which pushed the country into a historic famine that lasted for two years from 1983-84 see details in (Ocran, 2007) and as a result, the government adopted IMF and WB support programs. Meanwhile, a high inflation rate of 123% was recorded in 1983 due to the above issues but it was also partly influenced by the devaluation of the Ghanaian cedi of 991% from ₵2.75 to ₵30 to the US dollar (Ocran, 2007). The IMF and the WB launched an Economic Recovery Programs (ERP) in April 1983 to help resolve the high inflation, these ERP include increasing private investment sector and liberalization of trade (IMF, 2015). Subsequently, a Structural Adjustment Programme (SAP) in 1986 were adopted by the government via IMF and WB, these programs constituted a stabilization package aimed at reducing inflation, restoring external financial balances, market distortions, encouraging production and reestablished good economic and social infrastructure (Ocran, 2007). During the reform years from 1987-1993, the average inflation rate was reduced to 27% which was a remarkably decline (IMF, 2015). Finally, the fourth phase of the reform (1993-2000) had macroeconomic targeted at 8% growth and the reduction of inflation to 5%. These targets were unsuccessful as the inflation rate at the end of the entire period averaged 34%, although there were instances when the rate of inflation came down as low as 10% in 1985 but not sustained (Ocran, 2007).

2.1.5 The democratic Era (2004-2015)

The paper by Alagidede et al. (2014) studied the inflation trend of Ghana from 2004-2009 and described the inflation trend as moderation phase. They emphasized that in the year 2004, Ghana joined the Heavily Indebted Poor Countries (HIPC) as a result of previous economic mismanagement in fiscal and monetary policies. As explained by the government at the time, the decision to go HIPC was not political but based on the poor economic situation of the country as well as the government’s attempt to pursue medium and long time goals in economic development. Ghana benefited from debt cancellations and reliefs from HIPC and multilateral debt relief initiatives (MDRI) respectively coupled with new aid flows and external loans as inward private transfers by the Bank of Ghana (Alagidede et al., 2014). These measures resulted
in a downward trend in inflation rates, as inflation lowered near to 10% in 2006, and stabilized until late 2007 (Alagidede et al., 2014).

In view of, Adu and Marbuah (2011) the low inflation trend could also be attributed to the inflation targeting policy by BoG had adopted, which after 2008 had led to well anchored inflationary expectations in its new policy agenda of maintaining price stability. In 2009, the shock wave of the global financial crises and high food prices influenced the inflation stability that the country had been enjoying as these crises resulted in a deficit of 13.9% of Gross Domestic Product (GDP) and rising exchange rates depreciation (Adu & Marbuah, 2011). Considering the facts that 2008 was an election year and a consequent change of government in January 2009 resulted in a sustained downward trend for eighteen months. The inflation rate was at 20.7% in June 2009 but the trend in inflation continued to fall to a single digit in 2014, where the trend reversed (Adu & Marbuah, 2011).

**Figure 3.** Inflation rate in Ghana from 2001 -2015.

![Inflation rate in Ghana from 2001 -2015.](source: www.tradingeconomics.com)

From figure 3, inflation rate of Ghana goes up and down throughout the period of 2009 to present. This could be as the result of fluctuations in global oil prices coupled with monetary and fiscal policies from the Bank of Ghana. With inflation rate of 20.7% in June 2009, the years that followed had downward inflation rate and then it has going up and down. It could be realised that, if a line of best fit is drawn from mid-2010 to 2015, the slope will be positive.
3 Literature Review

This chapter reviews the relevant literature on inflation for the study. The chapter includes theories of inflation, the Phillips curve model with detailed description of New Keynesian Phillips Curve (NKPC) and the hybrid-NKPC which is the basis of this thesis. This chapter also discusses some empirical estimations results from other countries and finally describes the GIVE approach which will be used for this study.

3.1 Categorization of inflation Determinants

A theoretical discussion of causes of inflation is an important background of analysis of inflation dynamics. Therefore, this section highlights the three broadly causes of inflation namely: demand-pull inflation, cost-push inflation and future inflation expectations and inertia inflation

3.1.1 Demand - Pull Inflation

This type of inflation is caused by an increased shift in aggregate demand. Aggregate demand refers to all spending in the economy whilst aggregate supplied is the total production or output in a country. When a country’s quantity of goods and services demanded exceeds the quantity supplied, we have what is called output gap. Output gap measures the deviations of aggregate demand from the economy’s potential supply, thus given the full utilization of production a country’s actual gross domestic product (GDP) can fall below/above the potential GDP (Jahan & Mahmud, 2013). We have negative output gap when potential GDP is below actual GDP. Whenever this occurs, producers’ takes advantage of consumers and charge higher price which leads to inflation. According to Jahan and Mahmud (2013), output gap is as much used operationalization (measurement) of the degree or extent of demand pressure. The output gap is however, directly unobservable, but can be estimated by the use of the Hodrick- Prescott filer (HP-filter), unemployment rate or other indirect methods. Orphanides and Van Norden (2005) gave evidence that indicate a stable and predictable relationship between inflation and output gap which is useful for understanding movements of aggregate demand and subsequent movements in inflation.
Meanwhile, other factors such as an increase in wages, tax reduction or fallen interest rate encourages consumers to spend more as their purchasing power increases will lead to an increased in aggregate demand over aggregate supply which causes a continuous rise in prices. This is because the rise in aggregate demand is not coupled with an increase in supply, it leads to continuous increased in prices leading to what we refer to as demand-pull inflation.

However, the New Keynesians and monetarist have their distinct views of demand-pull inflation which are not far from the above. According to the New Keynesian, excess aggregate demand for goods and services over and above the aggregate supply in an economy is the main source of inflationary pressures. In the view of monetarist, if the growth rate in money supply exceeds the growth in rate of GDP, inflation will result. This is because people have access to a lot of money which increases their purchasing power and this will result in more money chasing fewer goods leading to inflation. Machlup (1960), for instance noted that if a reserve bank charges too low interest rate or encourages too large volumes of free reserves, it enables consumers and producers to get access to large credit from the member banks and this leads to money supply exceeding GDP.

3.1.2 Cost- push inflation

The cost-push approach is of the view that prices rising are due to increasing cost of production. This high cost of production is caused by suppliers of raw materials charging high prices/or labour unions demanding excessive wage increases (Pettinger, 2016)

Other things remaining the same, under perfect competition, when the prices of the factors of production increases, for instance the wage cost, the quantity produced is reduced and consequently leading to high prices of goods and services. Nevertheless, monopolistic firms will cease the opportunity to produce more at high prices with the aim of maximizing profit. Meanwhile, when nominal of wage costs per unit produced increases, firms are able to compensate by adjusting the price of their products. When “all firms” do this, this assumes imperfect completion of course.

Another cause of cost-push inflation is currency devaluation. This is because, devaluation implies an increased in import prices as well as the high cost of borrowing due to high interest rates. In the case of Ghana, cost- push inflation was very common between the periods 1982 to 2004 where the Ghanaian cedi was devaluated at 991% from ₵2.75 to ₵30 to the US dollar.
As confirmed by the so-called Structuralist, who believe that causes of inflation is due to institutional features of business environment or structural maladjustments in a country. We can confirm this from chapter 2.1.4 and 2.1.5 that changes in governments in Ghana with their different policies, affected businesses in the country. It is no surprise that inflation rates were high during the period 1980 to 1995. Also, cost-push inflation occurs when cost increases independent of aggregate demand. In addition, cost-push inflation can be triggered by demand-pull inflation. Thus, when producers decrease quantity produced due to high cost of production, with aggregate demand remaining unchanged. This will lead to aggregate demand exceeding aggregate supplied which is the basis of demand pull inflation.

### 3.1.3 Future inflation expectations and inertial inflation

Future inflation expectation is a type of inflation which arises from people’s expectations of the next periods. People form expectations based on wage increase, past inflation rates and so on. These expectations influence people’s purchasing behavior in a way that has a long-term impact on inflation. With these expectations about real wage increase, workers will demand a wage increase. This increases the cost of firms, which leads to inflation. In addition, there are cases where people use current information, for instance if people believes that a devaluation in a country’s currency will cause inflation (Pettinger, 2016). They will anticipate the effect such that any small devaluation will lead to high cost. Thus, any devaluation of the country’s currency tends to lead to inflation after a while. This is true case, Ghana imports a lot and any devaluation the cedi to the dollar will definitely cause inflation. This was evident in 1980 to 1994 Ghanaian economy. This high rate of exchange rate will increase the cost of importation of firms leading to high prices, see details in Pettinger (2016).

Inertial inflation is when people uses past inflation to increase prices without any structural reasons that it may happen. For example, labour unions’ use past year inflation to negotiate for an increase in wages. Such rise in wages generates some new inflation which influences inflation for the coming year.

### 3.2 The Phillips Curve Model

Phelps (1968) based on UK data to establish that there is an inverse relationship between rate of unemployment and inflation. According to Atkeson and Ohanian (2001) the idea was that,
over a long historical period, a lower rate of unemployment (full employment) is associated with higher nominal wage rate. When Phillips establish his curve, there was no evidence of the curve being independent of institutional/policy changes, so it had very little impact on research and none on economic policies in its own time. The Phillips curve often used to represent a possible trade-off between inflation and unemployment. In view of this, government macroeconomic policies is often presented as trying to achieve full employment and stable but with low inflation (Ames, Brown, Devarajan, and Izquierdo (2001)). One key issue policymakers’ encountered was a danger of increasing inflation in the state of full employment. Thus, the question of what level of unemployment ensures stability in price level. In as much as advanced and developing/underdeveloped countries governments seeks to ensure full employment for their citizens, then they cannot do away with inflation as depicted by the Phillip’s curve.

**Figure 4.** A Phillips curve – showing relationship between wage inflation and unemployment (percentages).

![Phillips Curve Diagram](https://www.google.no.url)
It shows a simple graphical presentation of the inverse relation between wage inflation and unemployment. For example, a country aiming at full employment/reducing unemployment (output) to 2% should expect a 3% increase in wage inflation depicted in figure 4.

Thus, the earlier Phillip’s curve studies used unemployment to explain wage change. During the postwar era, some macroeconomics models claimed that minimum unemployment level could be maintained by either stable prices or rising prices. Nevertheless, after the postwar era, many researchers criticized the Phillip’s curve; among them was Phelps (1968). This was because; expected inflation term was unconsidered in the model. They argued that in the long-run if the expected inflation variable term is incorporated into the model then the relationship between inflation and output gap will not exist. In this, Phelps and others overlooked the fact that economics of the 1940s and 1950s were well aware of the importance of price expectations. Alternatively, this paradox in the literature is not important for them.

This criticism led to an advancement of the Phillip’s curve called ‘traditional Phillip’s curve which relates current inflation to lagged inflation and output gap. The traditional Phillip’s curve also faces numerous critiques from researchers. Such as, the critique made by Lucas (1976), who was of the premise that the coefficients/parameters of the traditional Phillip’s curve model will remain constant across policy regimes. In the model formulation, inflation depends positively on the output gap and the cost-push term (wage) which reflects the influences of expected inflation. A concern raised by Sargent (1971) about the traditional Phillips curve model formulation was that it was not sufficient to capture the forward-looking rationality of individual behavior in an economy. This therefore calls for a more emphasizes on the key endogenous variables of inflationary pressure.

In response to these shortcomings, the Keynesian economists developed the new version of traditional Phillip’s curve called the ‘‘New Keynesian Phillips Curve -NKPC’’ version.

3.2.1 The New Keynesian Phillips Curve

The NKPC model of inflation was based on an assumption about rational future expectations, see Rudd and Whelan (2005). The NKPC states that inflation is the expectations of future inflations that firms hold today and the excess demand or marginal cost. The basic feature of NKPC is the forward-looking assumption rule under price rigidity. (Bårdsen, Øyvind, Jansen, & Nymoen, 2005) gave a simple illustration of the NKPC below:
\[ \Delta P_t = \varphi_1 E_t \Delta P_{t+1} + \varphi_2 X_t + \varepsilon_t \]  \tag{3.1} \]

Where, \( \Delta P_t \) is the inflation rate at time \( t \), \( \varepsilon_t \) is the stochastic or error term, \( X_t \) is the marginal cost, \( \varphi_1 \) and \( \varphi_2 \) are the coefficients whilst \( \Delta P_{t+1} \) refers to expected future inflation.

According to the NKPC, firms will base their current price setting today, on future expected inflation (given their information set today). There are several methods of deriving NKPC, but the approach of Calvo (1983) has the standard. In the same spirit as the above, Gali and Gertler (1999) used the early work of Calvo (1983) as the benchmark to formulate NKPC.

**Calvo’s pricing settings**

In the theory underlying the NKPC, the pricing adjustments of a firm is influenced by the pricing decisions of other firms (Calvo, 1983). The model assumes that monopolistic competitive firms pricing decisions are constraint by the time factor and firms gets to change their price only when a signal is given. Thus, it can be very costly for firms to change their prices outside the signal time. On the other hand, there are also costs of being out of equilibrium (Wickens, 2008). The emphasis of NKPC with regard to price setting by firms is on price adjustment. Calvo (1983) simplifies the price adjustments by aggregation problems by assuming a probability of \( (1-\theta) \) of firms that adjust their prices during the period and a probability of \( \theta \) of firms have their price unchanged. The average time over which the price is fixed is

\[
(1 - \theta) \sum_{k=0}^{\infty} \theta^k = \frac{1}{(1-\theta)} \tag{3.2}
\]

\( k \) denotes time.

The aggregate price level \( P_t \) comprises of the past periods aggregate price level \( P_{t-1} \) and the price selected by firms that have their prices changed at \( t \) denoted as \( P_t^* \) (i.e. optimal reset price), as follows

\[
P_t = \theta P_{t-1} + (1 - \theta) P_t^* \tag{3.3}
\]
According to Calvo (1983), firms without price rigidity will set optimal price as a function of fixed

\[ P^* = \alpha_t + mc_t \tag{3.4} \]

Similarly, Wickens (2008, p. 220) emphasizes that pricing under imperfect competition, the optimal price firms set is a markup over the marginal cost in continuous time and this can be written as \( P^*_t = \alpha_t + mc_t \). With \( mc_t \) denoting, the log of marginal cost and \( \alpha_t \) is the mark up over marginal cost. The more elastic the demand, the less the mark up value. For example, using labour as the input factor of production, the less elastic the supply of labour function, the higher the marginal cost. Furthermore, in a paper titled ‘Inflation Dynamics’ by Galì and Gertler (1999), it is shown that by combining and manipulating equations (3.2), (3.3) and (3.4), the optimal “reset-price” under the rigidity price assumption is:

\[ P^*_t = (1 - \beta \theta) \sum_{k=0}^{\infty} (\alpha_t + mc_{t+k}) \tag{3.5} \]

\( \beta \): discount term, where \( \beta \) lies between 0 and 1.

Implies that prices are perfectly flexible and that the representative firm adjusts its price according to the current marginal cost movements and \( \theta > 0 \) means future price becomes important in today’s pricing.

Denote \( \pi_t = P_t - P_{t-1} \) as the inflation rate at \( t \), and \( mc_t \) real marginal cost of firms at time \( t \) (today). We can derive the new Keynesian Phillip’s curve version by combining and summarizing equations (3.3) and (3.5) to get an inflation equation of the form:

\[ \pi_t = \left( \frac{(1-\theta)(1-\beta \theta)}{\theta} \right) mc_t + \beta E_t \pi_{t+1} \]

Inserts \( \lambda = \left( \frac{(1-\theta)(1-\beta \theta)}{\theta} \right) \) to get

\[ \pi_t = \lambda \eta X_t + \beta E_t (\pi_{t-1}) \quad \text{NKPC} \tag{3.6} \]

From Equation (3.6) we observed that the NKPC is a function of next period’s expected inflation rate, \( \pi_{t+1} \) and real marginal cost \( mc_t \), as well as a benchmark theory which assumes that inflation should equal a discounted stream of next period marginal cost, see Galì and Gertler (1999, p. 200)
Marginal cost and output gap

According to the traditional Phillips curve, output gap is a relevant indicator of real economic activity. In other words, there is an assumed relationship between output gap and marginal cost, see Galí (2002).

Let us assume that:

\( y_t \): Log of GDP at time \( t \)

\( y_t^* \): Log of actual GDP at time \( t \)

\( x_t = y_t - y_t^* \) Output gap

\( mc_t = \eta x_t \) \hspace{1cm} (3.7)

Where \( \eta \) refers to output elasticity of \( mc_t \) and combining equations (3.6) and (3.7) yields an inflation rate equation of the form below:

\[ \pi_t = \lambda \eta x_t + \beta E_t(\pi_{t-1}) \] \hspace{1cm} NKPC \hspace{1cm} (3.8)

Equation (3.8) shows the relationship between output gap and marginal cost.

Another proxy of marginal costs is the average cost, or the wage share, but I will use the output-gap in this study.

As the literature shows, the “pure NKPC” in (3.8) faced certain challenges such as the inability of the model to explain the importance of lagged or the back-ward looking inflation in determining inflation analysis; details are given in Rudd and Whelan (2005). In addition, from the model, one prediction is that the ability of a country to deflate is associated with a huge output cut, and that this is a loss to the country. According to Fuhrer (2005), the benchmark of NKPC implies inflation should lead to positive/negative output gap over the cycle but the application of the model to the US data gave opposites pattern. Thus, current output gap affects future inflation positively and negatively with respects to the lagged inflation. By quoting “the shock that enters the NKPC, while often difficult to motivate economically, is large and is critical in distinguishing the sources of inflation persistence. While these observations help to clarify the behavior of inflation in NKPCs, they raise other fundamental questions about how to model inflation” Fuhrer (2005, p. 1). This and many more questions by researchers like
Nymoen, Swensen, and Tveter (2010) and Rudd and Whelan (2005) have similar opinions about the modelling of inflation.

However, in recent years, the pure NKPC has failed to explain the high rate of inflation persistence in countries. This inability of the purely forward-looking NKPC model gave rise to many questions as to what other factors actually contribute to the causes of inflation aside the NKPC model specification. In the light of these shortcomings, the hybrid new Keynesian Phillip’s curve was proposed.

### 3.2.2 The hybrid NKPC

The hybrid NKPC is an extension of the NKPC by Gali and Gertler (1999) built on the purely forward-looking NKPC. It is a model of inflation that allows a fraction of firms to use a backward – looking rule to set prices while the remaining firms’ prices are unchanged. Thus, the unanswered question regarding the role of persistence of inflation in the NKPC model is what the hybrid NKPC manages to capture or represent by incorporating the backward-looking term (lagged inflation term). In the empirical estimation of the hybrid NKPC, the real marginal cost is used instead of the ad hoc output gap. The reason was that, marginal cost measure directly captures productivity gains on inflation rate, which cannot be done by output gap. The model states that inflation, defined as $\pi_t = P_t - P_{t-1}$, determined by $E_t\pi_{t-1}$ expected inflation next period, $E_t\pi_{t+1}$ lagged inflation, and marginal cost $\eta X_t$ at time $t$.

$$\pi_t = \lambda \eta X_t + \delta_t^f \pi_{t-1} + \delta_t^b \pi_{t-1} + \epsilon_t$$  \hspace{1cm} (3.9)

Where $\epsilon_t$, refers to stochastic error term, $\delta_t^f$ coefficient of the forward-looking term or expected future inflation and $\delta_t^b$ the coefficient of the lagged inflation term.

Assumptions:

- Monopolistic competitive firms
- Marginal cost is used instead of ad hoc output cost
- Constant price elasticity
Aggregate price $P_t$ is a convex combination of lagged price level, $P_{t-1}$ and optimal reset price $P_t^*$ at time $t$.

Note that the first three assumptions, applies to the pure NKPC and the fourth assumption is an additional assumption under the hybrid NKPC.

The reduced form hybrid NKPC parameters derived from the Calvo’s price adjustment model:

\[
\pi_t = \lambda \eta X_t + \delta^f_t \pi_{t-1} + \delta^b_t \pi_{t-1} \\
\delta^f_t = \beta \theta / \phi \\
\delta^b_t = \omega / \phi \\
\lambda = \left( \frac{(1-\omega)(1-\theta)(1-\beta\theta)}{\phi} \right)
\]

Where $\omega$ refers to fraction of firms that do not change prices in a given period and the remaining proportion of firms $1 - \omega$ are assumed to be forward looking and therefore changes their prices.

In the literature, the estimation of the structural parameters $\theta$ (price rigidity), $\beta$ (discount factor) and $\lambda$ in the hybrid NKPC are done by instrumental variable methods. Given the econometric specification of the model, instrumental variable (or GIVE in the case of over identification) delivers consistent estimators of the parameters of the linear-in-parameter NKPC. Due to the induced residual autocorrelation, the generalized method of moments (GMM) – estimator is statistically more efficient. However, in practical application GMM estimation can suffer from non-robustness, in the sense that small variations in the technical implantation (for example the “whitening of the residual”) can affect the parameters estimated unduly. Therefore, the more robust GIVE is used a reference in deriving the hybrid NKPC in the study.
3.3 A review of hybrid NKPC estimates for some countries

The use of hybrid NKPC has become increasingly popular. Many researches on the validity of the model have spurred up in recent years. Profoundly, the developers of the model claimed that the hybrid NKPC, which takes into account both the expected future inflation and lagged inflation, describes well the inflationary pressures in US and EU area. Also, Gali, Gertler, and Lopez-Salido (2005) used the hybrid NKPC to described the inflationary pressures in the US and the EU. However, several estimations of the hybrid NKPC using the generalized method of moments (GMM) approach indicate that the purely forward-looking term is not significantly different from zero but the backward looking term is significant but not very important. For example, Fuhrer (1997) finds that expected inflation term in the model is unimportant in explaining price inflation in the US. Also, Norkute (2015) application of the hybrid NKPC using Euro Area data, showed that there is no clear evidence of the forward-looking term tends to be having higher weight than the associated backward-looking inflation.

On the other hand, recent estimation results of the hybrid NKPC using data for Vietnam (using GMM) supports the hybrid NKPC (Le, 2011). In the estimation of the hybrid NKPC model, Le (2011) used output gap, broad money supply, global food and oil prices as the parameters and finds that all variables were significant under the period of consideration from 1995q1 to 2009q4. This means that in analyzing inflation dynamics, the hybrid NKPC can be a useful tool.

In a similar manner, a study on inflation dynamics in Turkey data by (Saz, 2011) using GMM approach to estimates both the NKPC and hybrid NKPC showed that the NKPC model does not give a weighty description of Turkish inflation. Firstly, he showed that commonly used labour income share as a proxy variable for marginal cost in the Turkey economy is weak and therefore proposed the marginal cost index as suggested also by hybrid NKPC assumption. The results showed that the output gap of Phillips curve and the expectation augmented Phillips curve provides only a weak explanation of Turkish inflationary pressures from 2005 to 2009. Contrary, the traditional and the hybrid NKPC are found to give better descriptions of Turkish inflationary scenario.

Although, the hybrid NKPC model have been found to give better descriptions of inflation dynamics for the period under consideration in the countries mentioned above, there still
remains some researchers who think otherwise of the study based on the hybrid NKPC Model by Gali and Gertler (1999). In a study Rudd and Whelan (2005) claimed that using the GMM approach to estimates the hybrid NKPC by the inclusion of both the lagged and future inflation contradicts the findings of Gali and Gertler (1999). The findings of Gali and Gertler (1999) was lagged inflation term have significant weight because they comprises information about the future values of the driving variable. Rudd and Whelan (2005) empirical results reported smaller values on the coefficients on the lagged inflation and that the power of the lagged inflation against the future expected inflation is weak. They argued that misspecification and over identifying restrictions are the reason and recommends that when using instrumental variable to estimate equation (3.10), we should not interpret it as giving convincing evidence that inflation expectations are mainly forward-looking in nature. However, an empirical results for the interpretation of the NKPC model of inflation dynamic in Nymoen, Swensen, and Tveter (2012) stated: ‘‘Both the rational expectations solution of the structural New Keynesian Phillips curve, NKPC, and the reduced form VAR analysis of the multivariate time series properties give insight about the joint implications of the evidence in the NKPC literature’’. Among their findings is also the dependency of rational expectations outcomes on presence of dynamic (in) homogeneity and the size of the forward-looking coefficients in the NKPC. In a nut shell, the empirical applications of both the NKPC and the hybrid NKPC have been investigated more often than not, with some researchers confirming the validity or controversies of the appropriateness of the method used.

Now to estimate the NKPC, there have been popularly three approaches as stated in chapter one, namely the DSGE, ML and the GMM. However, the GIVE which is similar to the GMM will be used to estimate the hybrid NKPC in this study. The GMM is an extension of the GIVE that accounts for heteroscedasticity and autocorrelation. Put simply: GMM does to GIVE what weighted least squares does to Ordinary Least Squared (OLS), it corrects for heteroskedasticity and/or autocorrelation in the residuals. For this reason, this thesis uses the GIVE to estimates the hybrid NKPC. Thus, GIVE is consistent and solves the problem of endogeneity. It is more transparent and easy for people to repeat the approach easily. Although, GMM estimates will not lead to a big difference from the GIVE estimates but only change is the efficiency. I, will therefore estimates, the hybrid NKPC by GIVE.
3.4 Generalized instrumental variable estimator (GIVE)

Let start by giving a simple time series model and its assumptions proposed by Stock and Watson (2015):

\[ Y_t = \beta X_t + \epsilon_t \quad \text{Model} \]

Assumptions:

- E = (\epsilon_t/X_t) \quad \text{Instrument exogeneity}
- \text{var}(\epsilon_t/X_t) = \sigma^2 I_n \quad \text{Homoskedasticity variance}
- \text{Stochastic process (X_t, Y_t)} \quad \text{Stationarity}
- E(k_t, G_t) = 0 \quad \text{Regressors predetermined}

Identification: If we have multiple endogenous regressors \( X_1, \ldots, X_K \) and multiple instruments \( Z_1, \ldots, Z_K \) and the coefficients on the endogenous variables \( \beta_1, \ldots, \beta_K \), i.e. M and K are number of IV and endogeneous variables used respectively.

Based on the above model and assumptions, the estimator for OLS can be expressed as:

\[ \hat{\beta}_{OLS} = (X'_t X_t)^{-1} X'_t Y_t \]

and the instrumental variable estimator can be stated as:

\[ \hat{\beta}_{IV} = (Z'_t X_t)^{-1} Z'_t Y_t \]

supposed \( x \) is the \( T \times M \) matrix of the explanatory variable and \( z \) is \( T \times M \) matrix of the instrument.

Now, if there are more instruments than there are covariates in the regression equation of interest (over identification when M>K) and homoskedasticity (E(\epsilon \epsilon') = \sigma^2 I_n) then GIVE can be used. For example, the NKPC and the hybrid NKPC model shown in equation (3.9) and (3.8) respectively are over-identified according to the studies of review of literature above.

Further to calculate GIVE, let’s assume \( \hat{W} = (Z' \hat{y}_t) \) and \( \hat{y}_t = P_w y_1 \) is the best linear predictors of endogeneous variables, we use this to obtain the estimator: \( \hat{W}(y_t - \beta X_t) = 0 \)

We can then obtain the estimator of the form: \( \hat{\beta}_{GIV} = (\hat{W}' x_t)^{-1} \hat{W}' y_t \)
Similarities between IV, GIVE, Two-stage least squares (2-SLS) and GMM

One method, which can be used to calculate IV estimates, is two-stage least squares. In the case of exact identification the 2-SLS estimator equals the IV estimator, $\hat{\beta}_{2SLS} = (Z_t'X_t)^{-1} = \hat{\beta}_{IV}$ as well as the GIV. But when, there is more than one instrument, we get

$$\hat{\beta}_{2SLS} = (X_t'P_ZX_t)^{-1}X_t'P_ZY_t \equiv (W'x_t)^{-1}W'y_t = \hat{\beta}_{GIV}$$

In addition, the GMM is an extension of the GIVE that accounts for heteroscedasticity or autocorrelation (i.e. $E(\varepsilon_t\varepsilon_t') = \Omega$) The GMM is equal to GIVE when $\Omega = I\sigma^2$

In conclusion, the 2-SLS is equivalent to GIVE. The 2-SLS is asymptotically efficient among the class of IV estimators in which the instruments are linear combination of the exogeneous variables as in the NKPC and hybrid NKPC shown in equation (3.9) and (3.8) respectively. Therefore, the use of GIVE to estimates the NKPC and the Hybrid NKPC will give significant results.
4 Methodology

This chapter describes the data variables and the pre-estimations strategies employed to estimates the hybrid NKPC.

4.1 Data

The analysis is based on secondary data available from Macrobond and Ghana Statistical Service (GSS). The Macrobond database provides up to date global financial and economics time series data of countries all over the world. In addition, the GSS is an official governmental office in charge conducting and compiling both financial, economic, social, health data and environmental data in Ghana. For the above reasons, both Macrobond and GSS give credible data. The data are in quarterly time series from 1993 to 2015. The main variables of focus are actual inflation rate, broad money growth, global crude oil prices, the Ghana cedi to the US dollar exchange rate and output gap (difference between potential GDP and actual GDP/ growth of GDP). Although, other macroeconomics variables like interest rate, currency devaluation, tax policies, both foreign and local investment, immigration, global food prices, governments spending’s are potential endogenous variables the choice of variables were based on availability and its relative importance to the study model. See appendix 2 for the data.

4.1.1 Broad money supply

As intimated earlier in section 3.1.2, broad money supply is an important determinant of inflation. Ghana experienced a tremendous growth and development immediately after independence in the year, 1957. Nevertheless, the growth and development was financed by borrowing and printing of new currency in an attempt to boost the economy. Section 2.1.1 mentioned that although, the increased in money supply by the government led to growth and development for a short period, it also had an adverse effects on inflation. Therefore, the data on broad money supply may contribute to inflationary pressures in Ghana for the period under consideration.
4.1.2 Global crude oil prices

The choice of the global crude oil price is because Ghana imports large quantity of crude oil each year for its transport systems, factories for their production of goods and service as well as crude oil being the main raw material for the production of electricity of the country. For these reasons, changes in crude oil price level affect the country’s general prices of commodities. For example, as stated in section 2.1.4 that in 1983, a cut in crude oil supplies to Ghana created a shortage that resulted in an increased in domestic prices. This means that including global oil price is a good endogenous variable and it is an important addition when measuring inflation in Ghana.

4.1.3 The potential GDP and actual GDP (The output gap)

I used the output gap as a proxy to calculate marginal cost as suggested by the model. The literature on Ghana in section 2.1.2 depicts that between 1970 and 2011, the Ghanaian economy had a growth in real domestic product per capita and this may help explain Ghana’s inflationary pressures. The output gap will be estimated using the Hodrick- Prescott Filter.

4.1.4 The exchange rate

The data on exchange rate, measured as Ghana cedi per US dollar is chosen as an additional endogeneous variable. The reason is that the medium of transaction in importing goods and services into Ghana is mostly US dollars. A recall from section 2.2.4 mentioned that in 1983, there was a devaluation of the Ghana cedi from 991% to 1 US dollar in an attempt to reduce the high inflation recorded in that year. This means that exchange rate of Ghana cedi per the US dollars is mostly considered by the bank of Ghana when taking monetary policies or inflationary policies. Moreover, study on economic growth and inflation by (Adu, 2012) showed that exchange rate Ghana cedi per US dollar have a statistical negative on inflation in the long run. If indeed Adu’s finding is true, then what happens in the short run? In theory, we expect currency depreciation to fuel inflation but this is not the case of Ghana. Therefore, including the Ghana cedi to the US dollar exchange rate into the estimates can add more information to the estimates of this thesis.
4.1.5 Future inflation expectations and inertia inflation

Expected future inflation and lagged inflation plays an important role in inflation determination as discussed in the model review and section 3.1.3 of the thesis. Hitherto, inflation expectation and lagged inflation that are also significance in determining inflation has not been applied in Ghana. Using data period from 1993q1 to 2015q4, we will investigate the role of expected inflation and lagged inflation plays in explaining inflation persistence in Ghana.

4.2 Estimation strategies and findings

This section gives details on the estimation procedures and findings for unit root test using Augmented Dickey Fuller (ADF) test and Hodrick-Prescott filter see details in Doornik et al. (2007) employed in the study.

4.2.1 Output gap estimation using Hodrick-Prescott (HP) filter

There are several smoothing filter, which are used to smooth variables. For example, Hodrick-Prescott (HP) filter and Kernel & Spline smoothing approach. In macroeconomics, HP filter uses valid observations when there are missing values in the data series (French, 2001). For this reason, it gives valid estimates and easy to interpret. Therefore, HP filter is often used when estimating the output gap. The HP filter for data is:

\[ \text{HpOutput} = \text{smooth}_\text{hp}(\text{output}, \lambda, \text{GAP}) \]

where lambda (\(\lambda\)) is the smoothing parameter. It is noted that the sample used in HP filter has a bandwidth parameter of 100 (freq) \(^2\) see details in Doornik and Hendry (2007)

In the study, the estimation of the output gap followed the four steps below using the econometrics software OxMetrics:

1) Take the log of real GDP so that ‘gap’ measured is an approximate relative deviation from the trend GDP.

2) Calculate seasonally adjusted log of real GDP by moving average calculation. This step was necessary because there was no seasonality early in the sample, but strong seasonality in the most recent years of the data.
3) Further, find the trend of seasonal adjusted log of real GDP by the using Hodrick-Prescott filter (1997) with a smoothing parameter (so called “lambda”) of 400,000.

4) The output gap calculated as the difference between trend of seasonal adjusted log of real GDP and seasonally adjusted log of real GDP.

Figure 5. Output gap

The graph of output gap in figure 5 depicts a recession in Ghana’s economy from 1993 to 2005, a boom in the economy from 2006 to 2012 and right after 2012, the Ghanaian economy began to recess to 2015. This negative output gap for the period 1993 to 2005 seems reasonable with reference in chapter 2.1.4 IMF and World Bank Recovery Programme. During this period, the economy of Ghana faced a severe drought, crude oil shortages and devaluation of the Ghana cedi to the US dollar; all these were expected to contribute towards negative growth in GDP. Ocran, (2007). In 2004, Ghana joined the HIPC, which led to many debts cancellation and many development grants and projects from foreign countries. In addition, Ghana attracted many foreign investments upon the discovery of oil in 2004 and in 2009; Ghana made first commercial supply of crude oil to the world market. All these, can explain the growth in the economy from 2005 to the year 2012 and then started to decline. As noted in chapter 2.1.5,
Democratic Era, the shock of global financial crisis and high food prices in 2009, resulted in a deficit of 13.9% of GDP, Adu and Marbuah (2011). This may explain the negative gap from 2013 to 2015. Therefore, estimating the output gap using the Hodrick-Prescott filter gave a clear picture of real economic issues that aroused under the period considered in this study.

4.2.2 The Unit root testing (ADF-test) of the variables.

Estimating the GIVE requires all variables to be stationary since non-stationarity in the parameters will produce biased results. For this reason, stationarity is an important benchmark when using the GIVE in estimating of hybrid NKPC model. Therefore, I use ADF test on the all data variables except the output-gap. The output gap is better derived by the HP filter test.

Take log of all the variables in order to remove any exponential growth in the time series. Further test for the unit root individually using ADF-test and found out that only the logarithm of inflation rate is stationary. All the other variables have unit root. I used a lag of three because ADF statistics recommends that using more lag because it gives a better broader scope than fewer lag, Stock and Watson (2015). The ADF-tests are below:

Table 1. ADF test

<table>
<thead>
<tr>
<th>D-lag</th>
<th>LINF</th>
<th>LEX</th>
<th>LOIL</th>
<th>LM2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>-4.536**</td>
<td>-2.470</td>
<td>-1.366</td>
<td>-1.834</td>
</tr>
<tr>
<td>2</td>
<td>-5.171**</td>
<td>-2.458</td>
<td>-1.179</td>
<td>-1.710</td>
</tr>
<tr>
<td>1</td>
<td>-5.013**</td>
<td>-2.467</td>
<td>-1.583</td>
<td>-1.131</td>
</tr>
<tr>
<td>0</td>
<td>-2.998*</td>
<td>-2.478</td>
<td>-1.241</td>
<td>-1.076</td>
</tr>
</tbody>
</table>

Note: The ADF test on logarithms of inflation rate, crude oil price, money supply and inflation rate. The model is with a constant, the critical values are 5%=2.88 1%=3.48 for T=140, see (Doornik and Hendry (2007), pp. 31-40)

In table 1 of column 2, at row 3, the ADF test, is the t-statistic testing the hypothesis that the coefficient on LINF is zero; this is t=-4.536. Using the 5%, critical value of -2.88 above, shows that the ADF statistic of -4.536 is more negative than -2.88, therefore the test rejects the null hypothesis at 5% significance level. This implies that the null hypothesis that the logarithm of inflation rate has a unit autoregressive root or LINF has a stochastic trend – against the alternative that it is stationary around a linear trend is rejected (at 5% significance level). There is therefore stationarity in the logarithm of inflation rate.
On the other hand, column 3, 4, and 5 of table 1, shows that the ADF t-statistic coefficient on LEX, LM2 and LOIL estimates are -2.470, -1.366 and -1.834 respectively. Comparing, the 5% critical value of -2.88, the ADF statistics of -2.470, -1.366 and -1.834 is less negative than -2.88, which means the test does not reject the null hypothesis at 5% significance level. This depicts that the logarithm of money supply, exchange rate and oil price have unit autoregressive root or stochastic trend. Thus, non-stationarity in these parameters.

Table 2. ADF test

<table>
<thead>
<tr>
<th>D-lag</th>
<th>DLEX</th>
<th>DLOIL</th>
<th>DLM2</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>-4.527**</td>
<td>-4.397**</td>
<td>-2.986*</td>
</tr>
<tr>
<td>2</td>
<td>-3.784**</td>
<td>-5.116**</td>
<td>-8.477**</td>
</tr>
<tr>
<td>1</td>
<td>-4.708**</td>
<td>-7.157**</td>
<td>-10.85**</td>
</tr>
<tr>
<td>0</td>
<td>-5.762**</td>
<td>-7.301**</td>
<td>-10.52**</td>
</tr>
</tbody>
</table>

Note: The ADF test on the first difference of logarithm of EX, OIL and M2. The model is with a constant, the critical values are 5%=2.88 1%=3.48 for T=140, see (Doornik and Hendry (2007), pp. 31-40)

I further took the first difference on the logarithm of exchange rate, oil price and money supply and then re-run the ADF test on them again. This is because, stationarity of these variables are important for the validity of the thesis. Thus, usage of table 1 results (with stochastic trend) to run the model will lead to biased estimates, spurious regression and other problems.

Table 2 shows the ADF test on the first difference of the logarithms of exchange rate, oil price and money supply. Analyzing from third row (three lags), the column 2 shows that ADF statistics on DLEX is -4.527 is more negative than the critical value of -2.88 or taking the absolute form, 4.527 is more than 2.88 and therefore, we reject the null hypothesis that the coefficient on DLEX has a stochastic trend. Similar results are seen in column 3 and column 4 for DLOIL and DLM2 respectively.

In conclusion, there is stationarity on the coefficient of the logarithm of the inflation rate and first difference of the logarithm of oil price, money supply and exchange rate. See appendix 1 for ADF test calculations.
4.2.3 Estimating for the expected future inflation rate ($\pi_{t+1}$)

Test of the relevance of the instrumental variable (IV)

Table 3. Ordinary Least Squared (OLS) Estimate

The dependent variable: quarterly expected future inflation rate ($\pi_{t+1}$)

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Coefficient</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>15.6961</td>
<td>5.85</td>
<td>0.0000</td>
</tr>
<tr>
<td>DLEX</td>
<td>59.3463</td>
<td>2.85</td>
<td>0.0055</td>
</tr>
<tr>
<td>DLM2</td>
<td>39.5730</td>
<td>1.38</td>
<td>0.1711</td>
</tr>
<tr>
<td>DLOIL</td>
<td>-4.93873</td>
<td>-0.530</td>
<td>0.5973</td>
</tr>
<tr>
<td>Sigma</td>
<td>12.7002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced-form sigma</td>
<td>4.8094</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F(3, 87)</td>
<td>3.303 [0.024]*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In table 3, we estimated the expected future inflation rate ($\pi_{t+1}$) term using DLEX, DLM2 and DLOIL. We further investigated the "strength" or relevance of the instrumental variable using the OLS estimator. We regress expected future variable on the DLM2, DLEX and DLOIL and found that coefficients of DLM2 and DLEX are significantly different from zero but DLOIL gave an insignificant coefficient. The insignificant of DLOIL may be due to multicollinearity between the repressors. With this, basing on joint hypothesis, by conducting the F-statistics: F (3, 87), the result shows that their joint hypothesis is significant. In other words, a simple OLS conducted shows that F-test: F (3.87) = 3.03 (0.024)*. This implies that the insignificant of the instrumental variable DLOIL will not affect the analysis of the thesis. In addition, endogeneity issue can occur when the estimated expected future inflation is from the actual inflation variable. For instrumental exogeneity, the variables; DLEX, DLM2 and DLOIL do not affect.
the dependent variable (inflation rate today/actual inflation variable) directly but help explain the expected inflation rate. See table 3, which depicts that these variables are jointly significant at 10% significant level.

4.2.4 Estimating for the lagged inflation rate term ($\pi_{t-1}$)

The quarterly lagged inflation data was obtained from the quarterly actual inflation data. We took the actual inflation rate at time $t$ as inflation rate for time $t-1$. 


5 Empirical results and discussions

This section shows the estimation results for the hybrid NKPC and the NKPC. I further discuss the findings of these estimates.

5.1 The estimated NKPC for Ghana

Table 4. Estimate for the NKPC using GIVE

Dependent variable: inflation rate ($\pi_t$)

<table>
<thead>
<tr>
<th>Regressors</th>
<th>Coefficient</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi_{t+1}$</td>
<td>0.805927**</td>
<td>6.25</td>
<td>0.0000</td>
</tr>
<tr>
<td>GAP</td>
<td>2.06424</td>
<td>0.121</td>
<td>0.9039</td>
</tr>
<tr>
<td>CONS</td>
<td>4.32165</td>
<td>1.52</td>
<td>0.1328</td>
</tr>
</tbody>
</table>

Sigma

5.24318

Reduced-form sigma

13.651

RSS

2116.80281

Sargan specification test: Chi^2(2) 2.5123 [0.2848]

Testing beta = 0: Chi^2(2) 50.068 [0.0000]**

Note: Individual coefficients are statistically significant at the *5% level or **1% level

Table 4 shows the estimates for the NKPC. Based on the estimates in column 2, the coefficient on the forward- looking term is significant while the output gap is insignificant. This means that output gap does not help in explaining inflation rate changes using data from Ghana.
5.2 The estimated hybrid NKPC for Ghana

Table 5. Estimate for the hybrid NKPC by GIVE

Dependent variable: inflation rate ($\pi_t$)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Coefficient</th>
<th>t-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi_{t+1}$</td>
<td>0.461228**</td>
<td>5.35</td>
<td>0.0000</td>
</tr>
<tr>
<td>$\pi_{t-1}$</td>
<td>0.572199**</td>
<td>8.16</td>
<td>0.0000</td>
</tr>
<tr>
<td>GAP</td>
<td>-0.420592</td>
<td>-0.0644</td>
<td>0.9488</td>
</tr>
<tr>
<td>CONS</td>
<td>-0.743429</td>
<td>-1.29</td>
<td>0.1998</td>
</tr>
<tr>
<td>Sigma</td>
<td>2.08287</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced-form sigma</td>
<td>4.8094</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RSS</td>
<td>329.713934</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specification test: Chi^2(2)</td>
<td>0.71986 [0.6977]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Testing beta = 0: Chi^2(3)</td>
<td>3158.8 [0.0000]**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Individual coefficients are statistically significant at the *5% level or **1% level

From table 5, we see that the t-values for lagged and expected inflation rate are statistically significant whilst the t-value of output gap is not significant. In addition, from column 2 of table 5, the estimated model shows that the Sargan specification Chi^2 test for the independence of the instruments and errors is insignificant. However, the reported beta = 0 is significant and therefore corresponds to the findings of the F-test. See (Doornik and Hendry 2007 p 177 and chapter 17.3.3). The test of instrument validity is the sargan test, and is the same type of test as the J-test.

The hybrid NKPC estimation in the case of Ghana finds that the expectation of future inflation variable is crucial in the changes of inflationary behavior. Observing, the column 2 of table 5, with a one percent increase in lagged inflation ($\pi_{t-1}$), the inflation rate this year will rise by
0.57%, which implies a very high persistence rate in Ghana’s inflation. Similarly, one percentage point rise in the next period inflation ($\pi_{t+1}$) expectation increases this year’s inflation rate by 0.46%. This implies that both inflation expectations and lagged inflation plays an important role in explaining the high inflationary trend in Ghana. In the case of output gap, the t-value shows that the output gap is not significantly different from zero. This means output gap of the economy of Ghana does not help in explaining the high inflationary persistent for the period under consideration in this thesis.
6 Conclusion and recommendations

This study examined empirically the ability of the hybrid NKPC to explain inflation dynamics in Ghana for the period.

The estimated hybrid NKPC by the GIVE based on lagged inflation term, expected inflation term, output gap, broad money supply, Ghanaian cedi per the US dollar exchange rate and crude oil price fits the hybrid NKPC. Quarterly data for all the variables over the period 1993q1 - 2015q1 were used. The study finds both the lagged inflation and expected future inflation coefficients as having a significant impact on inflationary pressures on the economy of Ghana. It was also found; broad money supply, Ghanaian cedi per the US dollar exchange rate and crude oil price used as explanatory variables for determining the expected future inflation term, all have a significant impact on expected future inflation rate in Ghana when jointly used. The estimated coefficients of 0.6 for lagged inflation term and 0.5 for the expected future inflation for period under consideration showed that the former dominates. This implies that the Ghana inflation pressures are more of a backward-looking than a forward-looking. Thus, the Ghanaians uses past level inflation rates to form expectations of inflation today.

Further it was realized that, the coefficient of the output gap or GDP growth was insignificant. Therefore, positive or negative output gap cannot explain the trend of inflation rate in the Ghanaian economy. The possible explanation is, Ghanaian governments sometimes uses inflation targeting policies, for example the use of broad money supply to reduce inflation. In such cases, GDP growth may not influence inflation since inflation targeting policy is in effect. Also, in the traditional Philips curve, inflation depends on the rate of unemployment if available or the output gap and a cost-push term that reflects the influence of expected inflation where it assumed lagged and future expected inflation are equal then inflation rate will depend on a discounted series of future output gaps. In this case, the traditional Philips curve cannot explain the inflation rates in Ghana for the period 1993q1- 2015q4.

Therefore, the hybrid NKPC can be a useful tool in explaining inflationary dynamics in Ghana despites the disinflationary pressure of the output gap.
The findings of this study recommends that to maintain low and steady inflation, the central bank of Ghana (BoG) policies should gear towards controlling lagged and expected inflation first.

Furthermore, the study is a first primary estimation of the hybrid NKPC in the case of Ghana and therefore the results may be affected due to limitations in the model specifications and the data accuracy, which can be investigated in the case of further research. Further research can test the robustness of the study results, weak identification of parameters and instrumental variables. This is because the GIVE estimation results may be affected due to weak instruments and therefore further research can be done on the validity and the relevance of the instruments used in the study. In addition, in further studies, global food prices, wage rate and the price of cocoa can be included in the estimation of the hybrid NKPC to see how vulnerable inflation rate in Ghana changes of these prices. The reason being that Ghana as a small – open economy can be affected by trading internationally. Thus, prices in the international market for commodities that Ghana trade can have effects on its inflation.
References


Appendix

Appendix 1: Testing for a unit AR root

The unit root test can be used to investigate whether the time series variable possesses a unit root, the null hypothesis. The alternative hypothesis is stationarity (which can mean trend stationarity). Augmented Dickey-Fuller (ADF) test is a unit root tests that generalize the unit root test to different higher order dynamics. Hence, I will use the ADF test on all explanatory variables in the hybrid model of equation (4.1) to examine the stationarity of the parameters.

Using the derivation of the ADF test by Stock and Watson (2015, p. 608), Introduction to Econometrics.

We begin with a time series variables $Y_t$ without a constant stated:

$$ Y_t = \beta_1 Y_{t-1} + \mu_t \quad (1) $$

In testing, $Y_t$ has a stochastic trend, we set up the hypothesis testing of the form:

$$ H_0: \beta_1 = 1 \ , \ H_1: \beta_1 > 1 \quad \text{for the model} \quad Y_t = \beta_1 Y_{t-1} + \mu_t \quad (2) $$

If, $\beta_1 = 1$ we do not reject the null hypothesis and which means that the auto regression has a unit root of one (non-stationarity of $Y_t$) and the alternative is that $Y_t$ is stationary, OLS t-statistic can be non-normal. Therefore, we modified equation (1) by subtracting from both sides of the equation to obtain.

$$ Y_t - Y_{t-1} = \beta_1 Y_{t-1} - Y_{t-1} + \mu_t \quad (3) $$

$$ \Delta Y_t = \delta Y_{t-1} + \mu_t \quad (4) $$

Becomes: $H_0: \delta = 0 \ , \ H_1: \delta < 0$ in $\Delta Y_t = \delta Y_{t-1} + \mu_t$ where $\beta_1 - 1 = 0$

Using the OLS t-statistic testing $\delta = 0$ also called the Dickey-Fuller statistic. When $\delta < 0$ or $\beta_1 < 1$ then $Y_t$ is stationary and therefore the regression model will provide valid estimates.

The three forms of estimated DF test which allows for variations in data under the null hypothesis $\delta = 0$ and $\Delta Y_t$ is a stationary AR (P); Where P denotes number of lags $\Delta Y_t$. 
\( Y_t \) follows a random walk

\[
\Delta Y_t = \delta Y_{t-1} + \mu_t
\]  
(5)

\( Y_t \) as a random walk with drift

\[
\Delta Y_t = \beta_0 + \delta Y_{t-1} + \mu_t
\]  
(6)

\( Y_t \) is a random walk with drift around a deterministic linear trend?

\[
\Delta Y_t = \beta_0 + \alpha t + \delta Y_{t-1} + \mu_t
\]  
(7)

When there is a time trend, treat it as an additional regressor in equation (7).

The three forms of the Dickey-Fuller test stated above applies only to an AR (1), Thus, autoregression with one Lag (P=1). The AR (1) does not include serial correlation in but in practice, the higher order autoregression is more preferred. This led to an extension of Dickey-Fuller test of AR(1) to AR(P) which includes many lags is called the augmented Dickey-Fuller (ADF) statistic.

The augmented Dickey-Fuller (ADF) for autoregression test where has a:

I. stochastic trend

\[
\Delta Y_t = \beta_0 + \delta Y_{t-1} + \varphi_1 \Delta Y_{t-1} + \ldots + \varphi_p \Delta Y_{t-p} + \mu_t
\]  
(8)

II. \( Y_t \) is stationary around a deterministic trend

\[
\Delta Y_t = \beta_0 + \alpha t + \delta Y_{t-1} + \varphi_1 \Delta Y_{t-1} + \ldots + \varphi_p \Delta Y_{t-p} + \mu_t
\]  
(9)
Appendix 2: Data

Table 6. The study data

Time- quarterly data, INF- inflation rate (%), OIL – Crude Oil price (USD per barrel), EX- Exchange rate (GHC per USD), M2- Broad money supply (Millions of GH cedi) and GDP- Real gross domestic product (Millions of GH cedi)

<table>
<thead>
<tr>
<th>TIME</th>
<th>INF</th>
<th>OIL</th>
<th>EX</th>
<th>M2</th>
<th>GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993(1)</td>
<td>12.6</td>
<td>18.27879</td>
<td>0.05844</td>
<td>53.2</td>
<td>2586.83</td>
</tr>
<tr>
<td>1993(2)</td>
<td>24.3</td>
<td>18.47066</td>
<td>0.060241</td>
<td>53.03333</td>
<td>2586.83</td>
</tr>
<tr>
<td>1993(3)</td>
<td>25.8</td>
<td>16.69274</td>
<td>0.068363</td>
<td>55.53333</td>
<td>2586.83</td>
</tr>
<tr>
<td>1993(4)</td>
<td>26.9</td>
<td>15.33948</td>
<td>0.077118</td>
<td>60.53333</td>
<td>2586.83</td>
</tr>
<tr>
<td>1994(1)</td>
<td>22.1</td>
<td>13.74672</td>
<td>0.092608</td>
<td>64.66667</td>
<td>2671.4</td>
</tr>
<tr>
<td>1994(2)</td>
<td>21</td>
<td>15.99598</td>
<td>0.093752</td>
<td>68.43333</td>
<td>2671.4</td>
</tr>
<tr>
<td>1994(3)</td>
<td>24</td>
<td>17.0445</td>
<td>0.097404</td>
<td>75.73333</td>
<td>2671.4</td>
</tr>
<tr>
<td>1994(4)</td>
<td>31.8</td>
<td>16.609</td>
<td>0.102926</td>
<td>89.73333</td>
<td>2671.4</td>
</tr>
<tr>
<td>1995(1)</td>
<td>39.2</td>
<td>16.82402</td>
<td>0.105567</td>
<td>98.3</td>
<td>2778.88</td>
</tr>
<tr>
<td>1995(2)</td>
<td>56</td>
<td>18.00312</td>
<td>0.114767</td>
<td>101.2</td>
<td>2778.88</td>
</tr>
<tr>
<td>1995(3)</td>
<td>69</td>
<td>16.21279</td>
<td>0.1226</td>
<td>105.4</td>
<td>2778.88</td>
</tr>
<tr>
<td>1995(4)</td>
<td>70.1</td>
<td>16.86244</td>
<td>0.1394</td>
<td>122.6</td>
<td>2778.88</td>
</tr>
<tr>
<td>1996(1)</td>
<td>67.3</td>
<td>17.90063</td>
<td>0.1526</td>
<td>135.7667</td>
<td>2906.49</td>
</tr>
<tr>
<td>1996(2)</td>
<td>54.3</td>
<td>19.05237</td>
<td>0.160833</td>
<td>146.6333</td>
<td>2906.49</td>
</tr>
<tr>
<td>1996(3)</td>
<td>39.5</td>
<td>20.7512</td>
<td>0.168033</td>
<td>157.3667</td>
<td>2906.49</td>
</tr>
<tr>
<td>1996(4)</td>
<td>33.4</td>
<td>23.5147</td>
<td>0.171767</td>
<td>176.7</td>
<td>2906.49</td>
</tr>
<tr>
<td>1997(1)</td>
<td>30.4</td>
<td>21.20245</td>
<td>0.178467</td>
<td>191.7333</td>
<td>3028.6</td>
</tr>
<tr>
<td>Year(1)</td>
<td>Value1</td>
<td>Value2</td>
<td>Value3</td>
<td>Value4</td>
<td>Value5</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>1997(2)</td>
<td>29.2</td>
<td>18.50129</td>
<td>0.2022</td>
<td>201.6</td>
<td>3028.6</td>
</tr>
<tr>
<td>1997(3)</td>
<td>28.4</td>
<td>18.62109</td>
<td>0.2195</td>
<td>213</td>
<td>3028.6</td>
</tr>
<tr>
<td>1997(4)</td>
<td>24.1</td>
<td>18.98871</td>
<td>0.224733</td>
<td>242.5667</td>
<td>3028.6</td>
</tr>
<tr>
<td>1998(1)</td>
<td>19.9</td>
<td>14.69162</td>
<td>0.230133</td>
<td>261.4667</td>
<td>3170.74</td>
</tr>
<tr>
<td>1998(2)</td>
<td>22.6</td>
<td>13.99921</td>
<td>0.232833</td>
<td>269.9333</td>
<td>3170.74</td>
</tr>
<tr>
<td>1998(3)</td>
<td>18.2</td>
<td>12.97459</td>
<td>0.2325</td>
<td>281.2</td>
<td>3170.74</td>
</tr>
<tr>
<td>1998(4)</td>
<td>16.3</td>
<td>11.73051</td>
<td>0.234</td>
<td>307.7333</td>
<td>3170.74</td>
</tr>
<tr>
<td>1999(1)</td>
<td>14.7</td>
<td>11.52957</td>
<td>0.238267</td>
<td>323.2</td>
<td>3311.02</td>
</tr>
<tr>
<td>1999(2)</td>
<td>10</td>
<td>15.83539</td>
<td>0.248767</td>
<td>328.5</td>
<td>3311.02</td>
</tr>
<tr>
<td>1999(3)</td>
<td>12.2</td>
<td>20.66256</td>
<td>0.263467</td>
<td>342.9667</td>
<td>3311.02</td>
</tr>
<tr>
<td>1999(4)</td>
<td>13.2</td>
<td>23.87573</td>
<td>0.3263</td>
<td>372.9333</td>
<td>3311.02</td>
</tr>
<tr>
<td>2000(1)</td>
<td>14.9</td>
<td>26.49596</td>
<td>0.382367</td>
<td>398.2667</td>
<td>3434.73</td>
</tr>
<tr>
<td>2000(2)</td>
<td>18.7</td>
<td>26.79972</td>
<td>0.494167</td>
<td>418.9333</td>
<td>3434.73</td>
</tr>
<tr>
<td>2000(3)</td>
<td>27</td>
<td>30.3865</td>
<td>0.677167</td>
<td>437.2333</td>
<td>3434.73</td>
</tr>
<tr>
<td>2000(4)</td>
<td>39.2</td>
<td>29.88589</td>
<td>0.7204</td>
<td>495.6</td>
<td>3434.73</td>
</tr>
<tr>
<td>2001(1)</td>
<td>41</td>
<td>26.26317</td>
<td>0.731167</td>
<td>554.1333</td>
<td>3578.48</td>
</tr>
<tr>
<td>2001(2)</td>
<td>38.1</td>
<td>27.62497</td>
<td>0.7471</td>
<td>567.3</td>
<td>3578.48</td>
</tr>
<tr>
<td>2001(3)</td>
<td>31.7</td>
<td>25.69748</td>
<td>0.7205</td>
<td>619.7333</td>
<td>3578.48</td>
</tr>
<tr>
<td>2001(4)</td>
<td>23.5</td>
<td>19.92199</td>
<td>0.731633</td>
<td>725.5667</td>
<td>3578.48</td>
</tr>
<tr>
<td>2002(1)</td>
<td>18.1</td>
<td>21.53835</td>
<td>0.758733</td>
<td>792</td>
<td>3741.19</td>
</tr>
<tr>
<td>2002(2)</td>
<td>14.3</td>
<td>25.42981</td>
<td>0.791067</td>
<td>813.5</td>
<td>3741.19</td>
</tr>
<tr>
<td>2002(3)</td>
<td>13.2</td>
<td>26.75893</td>
<td>0.817767</td>
<td>874.8667</td>
<td>3741.19</td>
</tr>
<tr>
<td>Year</td>
<td>Week</td>
<td>Value 1</td>
<td>Value 2</td>
<td>Value 3</td>
<td>Value 4</td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
<td>---------</td>
<td>----------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>2002(4)</td>
<td>14.1</td>
<td>26.39006</td>
<td>0.833167</td>
<td>1080.3</td>
<td>3741.19</td>
</tr>
<tr>
<td>2003(1)</td>
<td>22.9</td>
<td>30.64286</td>
<td>0.8306</td>
<td>1158.133</td>
<td>3937.58</td>
</tr>
<tr>
<td>2003(2)</td>
<td>31.3</td>
<td>25.82822</td>
<td>0.8402</td>
<td>1169.533</td>
<td>3937.58</td>
</tr>
<tr>
<td>2003(3)</td>
<td>32.1</td>
<td>28.22006</td>
<td>0.841833</td>
<td>1243</td>
<td>3937.58</td>
</tr>
<tr>
<td>2003(4)</td>
<td>32.7</td>
<td>29.13503</td>
<td>0.856733</td>
<td>1503.267</td>
<td>3937.58</td>
</tr>
<tr>
<td>2004(1)</td>
<td>21.1</td>
<td>31.26587</td>
<td>0.877333</td>
<td>1653.8</td>
<td>4157.21</td>
</tr>
<tr>
<td>2004(2)</td>
<td>17.6</td>
<td>35.25008</td>
<td>0.897333</td>
<td>1662</td>
<td>4157.21</td>
</tr>
<tr>
<td>2004(3)</td>
<td>17.4</td>
<td>40.7359</td>
<td>0.901967</td>
<td>1731.867</td>
<td>4157.21</td>
</tr>
<tr>
<td>2004(4)</td>
<td>16.6</td>
<td>44.74243</td>
<td>0.904867</td>
<td>2012.933</td>
<td>4157.21</td>
</tr>
<tr>
<td>2005(1)</td>
<td>17.2</td>
<td>47.93992</td>
<td>0.903533</td>
<td>2021.233</td>
<td>4401.15</td>
</tr>
<tr>
<td>2005(2)</td>
<td>15.2</td>
<td>52.78148</td>
<td>0.9112</td>
<td>2064.933</td>
<td>4401.15</td>
</tr>
<tr>
<td>2005(3)</td>
<td>15</td>
<td>61.82753</td>
<td>0.908133</td>
<td>2124.467</td>
<td>4401.15</td>
</tr>
<tr>
<td>2005(4)</td>
<td>14.5</td>
<td>57.80226</td>
<td>0.9126</td>
<td>2297.533</td>
<td>4401.15</td>
</tr>
<tr>
<td>2006(1)</td>
<td>12.1</td>
<td>62.72724</td>
<td>0.919867</td>
<td>2437.6</td>
<td>4088</td>
</tr>
<tr>
<td>2006(2)</td>
<td>11.5</td>
<td>70.4398</td>
<td>0.924233</td>
<td>2620.667</td>
<td>4068</td>
</tr>
<tr>
<td>2006(3)</td>
<td>12.4</td>
<td>70.67623</td>
<td>0.930567</td>
<td>2800.633</td>
<td>5073</td>
</tr>
<tr>
<td>2006(4)</td>
<td>10.8</td>
<td>60.67087</td>
<td>0.9311</td>
<td>3106.3</td>
<td>5477</td>
</tr>
<tr>
<td>2007(1)</td>
<td>10.5</td>
<td>58.62182</td>
<td>0.935833</td>
<td>3384.067</td>
<td>4544</td>
</tr>
<tr>
<td>2007(2)</td>
<td>10.7</td>
<td>68.65698</td>
<td>0.9358</td>
<td>3588.1</td>
<td>4361</td>
</tr>
<tr>
<td>2007(3)</td>
<td>10.2</td>
<td>74.64986</td>
<td>0.9378</td>
<td>3749.633</td>
<td>5363</td>
</tr>
<tr>
<td>2007(4)</td>
<td>11.4</td>
<td>88.66943</td>
<td>0.970567</td>
<td>4428.567</td>
<td>5645</td>
</tr>
<tr>
<td>2008(1)</td>
<td>13.3</td>
<td>96.52187</td>
<td>0.974167</td>
<td>4636.4</td>
<td>4944</td>
</tr>
<tr>
<td>Year (Cycle)</td>
<td>Year</td>
<td>Value</td>
<td>Unit</td>
<td>Value</td>
<td>Unit</td>
</tr>
<tr>
<td>-------------</td>
<td>------</td>
<td>-------</td>
<td>------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>2008(2)</td>
<td>16.9</td>
<td>122.97</td>
<td>4859.26</td>
<td>4616</td>
<td></td>
</tr>
<tr>
<td>2008(3)</td>
<td>18.1</td>
<td>117.04</td>
<td>5089.13</td>
<td>5984</td>
<td></td>
</tr>
<tr>
<td>2008(4)</td>
<td>17.6</td>
<td>57.19</td>
<td>5761.63</td>
<td>6048</td>
<td></td>
</tr>
<tr>
<td>2009(1)</td>
<td>20.2</td>
<td>45.73</td>
<td>6002.13</td>
<td>4948.5</td>
<td></td>
</tr>
<tr>
<td>2009(2)</td>
<td>20.5</td>
<td>59.74</td>
<td>6165.36</td>
<td>4745.3</td>
<td></td>
</tr>
<tr>
<td>2009(3)</td>
<td>19.5</td>
<td>68.99</td>
<td>6305.06</td>
<td>6096.7</td>
<td></td>
</tr>
<tr>
<td>2009(4)</td>
<td>17</td>
<td>75.55</td>
<td>7279.09</td>
<td>6545.9</td>
<td></td>
</tr>
<tr>
<td>2010(1)</td>
<td>14.1</td>
<td>77.33</td>
<td>7879.37</td>
<td>5410.9</td>
<td></td>
</tr>
<tr>
<td>2010(2)</td>
<td>10.6</td>
<td>79.44</td>
<td>8205.81</td>
<td>5098.6</td>
<td></td>
</tr>
<tr>
<td>2010(3)</td>
<td>9.4</td>
<td>76.95</td>
<td>8424.11</td>
<td>6771.6</td>
<td></td>
</tr>
<tr>
<td>2010(4)</td>
<td>9</td>
<td>87.33</td>
<td>10272.3</td>
<td>6819</td>
<td></td>
</tr>
<tr>
<td>2011(1)</td>
<td>9.1</td>
<td>105.24</td>
<td>10763.7</td>
<td>6088.7</td>
<td></td>
</tr>
<tr>
<td>2011(2)</td>
<td>8.8</td>
<td>117.14</td>
<td>11407.8</td>
<td>5989.2</td>
<td></td>
</tr>
<tr>
<td>2011(3)</td>
<td>8.4</td>
<td>112.22</td>
<td>11778.3</td>
<td>7605.1</td>
<td></td>
</tr>
<tr>
<td>2011(4)</td>
<td>8.6</td>
<td>108.98</td>
<td>13555.9</td>
<td>7802.8</td>
<td></td>
</tr>
<tr>
<td>2012(1)</td>
<td>8.7</td>
<td>118.34</td>
<td>13757.7</td>
<td>7611.5</td>
<td></td>
</tr>
<tr>
<td>2012(2)</td>
<td>9.3</td>
<td>108.91</td>
<td>14601.5</td>
<td>6804.2</td>
<td></td>
</tr>
<tr>
<td>2012(3)</td>
<td>9.5</td>
<td>109.44</td>
<td>14951.3</td>
<td>7620.3</td>
<td></td>
</tr>
<tr>
<td>2012(4)</td>
<td>9.1</td>
<td>110.09</td>
<td>16672</td>
<td>8004.2</td>
<td></td>
</tr>
<tr>
<td>2013(1)</td>
<td>10.4</td>
<td>112.54</td>
<td>17227.8</td>
<td>7678.3</td>
<td></td>
</tr>
<tr>
<td>2013(2)</td>
<td>11.2</td>
<td>103.35</td>
<td>17797.8</td>
<td>7708</td>
<td></td>
</tr>
<tr>
<td>2013(3)</td>
<td>11.7</td>
<td>109.69</td>
<td>18061.9</td>
<td>8060.8</td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>Code</td>
<td>Gsp</td>
<td>X</td>
<td>Y</td>
<td>Z</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>-----</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>2013</td>
<td>4</td>
<td>13.3</td>
<td>109.3828</td>
<td>2.270833</td>
<td>20087.96</td>
</tr>
<tr>
<td>2014</td>
<td>1</td>
<td>16.8</td>
<td>107.9228</td>
<td>2.538433</td>
<td>21424.37</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>21.5</td>
<td>109.7812</td>
<td>2.939333</td>
<td>22534.6</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>23.8</td>
<td>103.436</td>
<td>3.454267</td>
<td>23041.3</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>17</td>
<td>76.90854</td>
<td>3.2057</td>
<td>26044.31</td>
</tr>
<tr>
<td>2015</td>
<td>1</td>
<td>16.5</td>
<td>55.16142</td>
<td>3.532467</td>
<td>27547.26</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>16.9</td>
<td>63.42954</td>
<td>4.0793</td>
<td>28061.54</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>17.5</td>
<td>51.19846</td>
<td>3.824</td>
<td>27911.71</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>17.6</td>
<td>44.68159</td>
<td>3.876767</td>
<td>32897.9</td>
</tr>
</tbody>
</table>