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THE EXPECTATIONS - AUGMENTED PHILIPS CURVE

EVIDENCE FROM GHANA

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Abstract

The study estimated different forms of the Philips curve using Ordinary Least Squares (OLS). Data was taken from the World Bank Economic Indicators, International Monetary Fund (IMF), the Bank of Ghana and Ghana Statistical Service. The data series used covered the period from 1970 to 2012. The study showed non-existence of trade-off between inflation and unemployment in all estimated models of the Philips curve relationship. This implies that policy makers cannot exploit the inflation-unemployment relationship in the case of Ghana. The result revealed an inverse inflation-unemployment nexus in the traditional and adaptive expectations-augmented Philips curve relationship. However, the rational expectations Philips curve relationship showed both positive and negative inflation-unemployment nexus depending on inflation covariates. Also, it was revealed that there exists persistence in inflation. Thus, past inflationary experience feeds into current inflation. Moreover, the research revealed growth rates of real interest rate, real income, real exchange rate and past inflation as significant determinants of inflation in Ghana.

Keywords: Inflation, Unemployment, Filtering, Output Gap, Ghana

INTRODUCTION

Inflation-unemployment relationship is one of the most explored areas of macroeconomics. This relationship is enshrined in the Philips curve in one form or another. The traditional Philips curve and the expectations-augmented versions, has two main uses. In theory, the Philips curve explains how changes in nominal income are divided into price and quantity components. In policy formulation, the Philips curve explains the factors that leads to the effectiveness (or lack thereof) of expansionary and disinflationary policies. In expectations-augmented form, the Philips curve predicts that the power of expansionary measures to stimulate real activity

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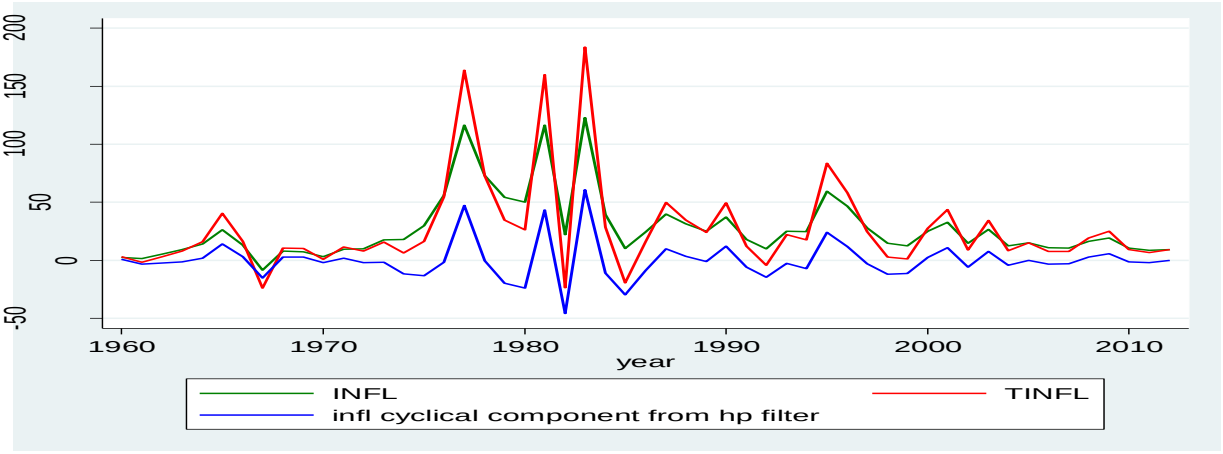
depends critically upon the role of price expectations. Similarly, Friedman (1968) and Phelps (1967, 1968) explained that, the Philips curve predicts that the effectiveness of disinflationary policy depends on the speed of adjustment of price expectations.

Since the inception of the Philips curve in 1958, it has hardly stood the test of time. It has evolved under the pressure of global economic events, changing from one economic epoch to another inculcating at each level new element. Thus, from the natural rate hypothesis, the adaptive expectations mechanism to the rational expectations hypothesis - each new element expanded its explanatory power. Each radically altered its policy implications. As a result, each stage radically altered policy implications. Whereas the Phillips curve was once seen as offering a stable enduring trade-off for the policymakers to exploit, it is now widely viewed as offering no trade-off at all. Friedman (1968) and Phelps (1967) warned that since economic agents will adapt to inflation expectations in a new policy environment, the apparent trade-off would prove illusory.

Historical Trends in Inflation in Ghana: 1960 - 2012

Figure 1 Trend Movements in Inflation in Ghana.



Key: INFL=Inflation rate TINFL= Long term trend in inflation from Hodrick Prescott

One major hindrance to the growth and development of the economy of Ghana since independence in 1957 has been inflation. In 1970, inflation in Ghana was as low as 3.03 percent. However, it kept on increasing at a steady rate until it skyrocketed to 116.45 percent in 1977. This rate was more than double the rate of 56.08 percent in the previous year. Average annual inflation rate for Ghana over the period 1960-2012 shows a general decelerating long-term trend since the mid-1980s. The erratic and volatile inflationary episodes mimic its cyclical component as shown in the filtered series of long term inflation and cyclical component.

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Inflation hit its all-time high of 122.8 percent in 1983, the highest since independence. This is could be as a result of the destruction of large quantities of food crops by the intensity of drought and bush fires in 1983 which culminated into serious food shortage in the country then. As pointed by Antwi-Bosiakoh (2009), the food shortage was further exacerbated by the return of approximately 1 million Ghanaians from Nigeria in the same period. Consequently, there was upward pressure on demand for goods and services and on general price levels.

The Economic Recovery Program (ERP) was then introduced in 1983 with the primary objective of taming increases in the general price level. Bayer and Grossman-Greene (2009) in their study concluded that the improved import supplies as a result of the cocoa boom in 1989 and 1990 was due to the introduction of the ERP. This led to drastic decline in all-time inflation of 122.8 percent in 1983 to 40.2 percent in 1984, and subsequently decreased to 10 percent in 1985. However, Inflation remained above targets in the ERP between 1986 and the end of 2000.

Ghana experienced a continuous decline in inflation between 1996 and 1999 falling from 46.6 percent in 1996 to 12.6 percent at the end of 1999. Unfortunately, the country's inability to sustain this decline in inflation led to a disappointing result in the year 2000. Adu and Marbuah (2011) attributed this result to unsustainable macroeconomic policies and currency depreciation as well asan increase in money supply for electoral campaigns because it was election year.

From 2007 to 2009, inflation increased again from 10.73 to 19.25 percent, before a decline in 2010 to 10.7 percent. The decline in 2010 can be attributed to the enactment of a legal framework for the sound management of the country's oil worth, which succeeded in maintaining macroeconomic stability (African Economic Outlook, 2012). In 2011, there was an economic growth peak due to the commencement of oil production in the last quarter of 2010 (CEPA 2012), causing inflation rate to fall to the much anticipated single digit of 8.70 percent, the lowest recorded since democracy in 1992. In 2012, there was a relatively low performance by cocoa and oil production and inflation rose to 9.10 percent (African Economic Outlook, 2012). This movements in inflation, according to the Philips curve, is associated with deviations in output from trend (unemployment). However, the exact relationship between inflation, output gap and employment is not clearly defined in the Philips curve in the case of Ghana. This research therefore seeks to explore the Philips curve relationship on the economy of Ghana by estimating the weights assigned to inflation and deviations in output from trend to steer a clear cut monetary policy. The main objective by the Central Bank in the inflation targeting as in the case of Ghana since 2002 is to minimize the loss function.Hence knowledge about the degree of weights assigned by the central bank to the fluctuations in output and inflation deviations is key to minimizing the loss function.

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The study estimated different forms of the Philips curve using OLS. Data was taken from the World Bank Economic Indicators, IMF, the Bank of Ghana and Ghana Statistical Service. The data series used covered the period from 1970 to 2012. The Philips curve was estimated in three stages; the Philips curve in its traditional form, adaptive expectations model and the rational expectations framework. OLS procedure was used to estimate the various forms of the Philips curve. However, all the estimates are short run phenomenon as an attempt to establish cointegration between inflation and its covariates failed.

The rest of the paper is organized as follows; the next section reviews the literature about inflation-unemployment relationship, followed by data and estimation strategy, discussions of empirical results and conclusions and recommendations drawn from the study.

LITERATURE REVIEW

The nexus between inflation-unemployment was a key component of the monetary doctrines of David Hume (1752) and Henry Thornton (1802). Irving Fisher in 1926 statistically identified the Philips curve, although he viewed a bidirectional causation from inflation to unemployment rather than vice versa. In furtherance, the Philips curve was stated in econometric equation form in 1936 by Jan Tinbergen and again by Lawrence Klein and Arthur Goldberger in 1955. It was finally graphed on a scatter plot chart by A. J. Brown in 1955 and by Paul Sultan in the form of a diagrammatic curve in 1957. Despite these early works, however, the analysis of modern Phillips curve can be traced back to 1958. Arthur W. Phillips (1958) in his seminal paper investigated the link between the change in nominal wages and the unemployment rate in the UK for the period 1862 – 1957.

Inflation targets are usually specified by policy makers in terms of rates of change of prices rather than wages. Philips curve became necessary to transform it from a wage-change relationship to a price-change relationship to make it more useful to policy makers. To achieve this transformation, as indicated by Solow and Samuelson (1960),it was assumed prices were set by applying constant mark-up to unit labour cost and so move in step with wages. Put differently, prices were set to move at a rate equal to the differential between the percentage rates of growth of wages and productivity. The result of this transformation is the price-change Phillips relation;

$\pi = ax(U)$ ……..[1]

π represents the rate of price inflation, whereas $x(U)$ is overall excess demand in labour and hence in product markets. This excess demand being an inverse function of the unemployment rate. The response of inflation to excess demand is represented by the price-reaction coefficient *a*. The implication of this equation is that, the authorities could determine the trade-off between

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inflation and unemployment. Thus, how much unemployment would be associated with any given target rate of inflation. However, the assessment of the comparative social cost of inflation vs. unemployment depends on the choice of policymakers and thus the assigned weights by policy makers to inflation and unemployment. As stated by Humphrey (1985), that policymakers would be constraint to choice of alternative combinations lying on the boundary of the Philips curve, unless they are prepared to alter the structure of the economy.

The original Phillips curve led to the formulation of the expectations-augmented version in the early 1970s.Three innovations ushered in this change as discussed by Humphrey(1985). First, the excess demand variable was re-specified. Thus, excess demand was redefined as the discrepancy or gap between the natural and actual rates of unemployment($U_N - U$). Originally, it was defined as an inverse function of the unemployment rate,$x(U)$. The natural (or full employment) rate of unemployment is the rate that prevails in steady-state equilibrium. That is, when expectations are fully realized and incorporated into all wages and prices and inflation is neither accelerating nor decelerating. It is called natural in the sense (1) that it represents equilibrium employment in the labour and commodity markets, (2) that, it is not influenced by the steady-state inflation rate, and (3) that, it is determined by real structural forces (job information and labour mobility costs, market frictions and imperfections, tax laws, subsidies, unemployment, etc and as such is not susceptible to manipulation by aggregate demand policies.

The introduction of price anticipations into the Phillips curve analysis constitutes the second innovation resulting in the expectations-augmented equation

$\pi = a(U_N - U) + \pi^e$ ……..[2]

In this scenario, excess demand is now defined as the gap between the natural and actual unemployment rates whereas$a$ is the price expectations variable representing the anticipated rate of inflation. Also, output gap $(Y_t - \overline{Y_t})$ is used as a proxy to measure unemployment rendering equation 2,

$\pi = a(Y_t - \overline{Y_t}) + \pi^e$ ……..[3]

The expectations variable enters the equation with a coefficient of unity. This reflects the assumption that price expectations are completely incorporated in actual price changes. Implicitly, the unit expectations coefficient implies the absence of money illusion. In other words, people are concerned with the expected real purchasing power of the prices they pay and receive (or, alternatively, that they wish to maintain their prices relative to the prices they expect others to be charging) and so take anticipated inflation into account.

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Notably, the expectations variable is the sole shift variable in the equation. The rest of the variables have been omitted, reflecting the view, prevalent in the early 1970s, that changing price expectations were the predominant cause of observed shifts in the Phillips curve.

Incorporation of an expectations-generating mechanism into Phillips curve analysis to explain how the price expectations variable is determined was the last innovation in deriving the expectations-augmented Philips curve. A simple *adaptive-expectations* or error-learning *mechanism* or rational expectations mechanism was used. These mechanisms posits that, economic agents form expectations by backward looking (adaptive mechanism) or forwarding looking mechanism (rational expectations). In symbols,

$\dot{\pi} = b(\pi - \pi e)$……..……[4]

The dot over the price expectations variable indicates time derivative of that variable, b is the adjustment fraction and $(\pi - \pi e)$ is the expectations or forecast. For adaptive expectations, analysts demonstrate that equation**4** is equivalent to the proposition that expected inflation is a geometrically declining weighted average of all past rates of inflation with the weights summing to one. Implicitly, any constant rate of inflation eventually will be fully anticipated, as can be seen by writing the error-learning mechanism as

$\pi^e = \Sigma v_i \pi_{-i}$……..……[5]

where $\boldsymbol{\Sigma}$ is the sum the past rates of inflation, the subscript i denotes past time periods, and v_i denotes the weights attached to past rates of inflation. With inflation rate stabilized and unchanging over time and a unit sum of weights, right hand side of the equation becomes, π, indicating that when expectations are formulated adaptively via the error-learning scheme, any constant rate of inflation will indeed eventually be fully anticipated. Both versions of the adaptive-expectations mechanism are combined with the expectations-augmented Phillips equation to explain the mutual interaction of actual inflation, expected inflation, and excess demand.

These three innovations; as engineered by Friedman and Phelps in their articles in the 1960s, the redefined excess demand variable, the expectations-augmented Phillips curve, and the error-learning mechanism-formed the basis of the celebrated *natural rate hypothesis* and *accelerationist* hypotheses. These changes radically altered how economists' and policymakers' views the Phillips curve in the late 1960s and early 1970s. Thus, neo-classical economist thinking and the natural rate hypothesis of non-existence of permanent trade-off between unemployment and inflation since real economic variables tend to be independent of nominal variables in steady-state equilibrium. Put differently by Friedman and Phelps (1968), tradeoffs may exist in the short run.

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Lucas (1972, 1973) and Sargent and Wallace (1975) added another dimension of the Philips curve: rational expectations. They explained that workers and firms use their knowledge of past history to work out the implications of an observed fall or rise in wages on the overall wage level. Rational expectations imply no errors in expectations in the long run. In early rational expectations models of Lucas (1972) and Sargent and Wallace (1975), the price level was a purely forward-looking which in these models implied that prices were flexible, and could ‘‘jump" in response to shocks.

Empirical inflation-unemployment relation

Though in the short run, Phillips (1958), Samuelson and Solow (1960) and others have shown that a rise in inflation due to a monetary expansion will lower unemployment at least in the short-run, the empirical estimates of the inflation-unemployment relation have varied across studies. For instance, Samuelson and Solow (1960), using U.S. data for the period 1934-1958, hand-drew a downward-sloping curve as a graphical illustration of the inflation-unemployment relation for the U.S. economy. Mitra (2012) showed that, for Samuelson and Solow’s hand drew Philips curve, a fall in unemployment rate from 5.5% to 4% will result in a 2.5%-3% rise in inflation. However, Hall and Hart (2012) estimated the Samuelson-Solow Phillips curve for the same period and obtained vastly different results. They concluded that a 1.5% fall in unemployment will result in a 0.50%-0.75% rise in inflation. This contradictory results is particularly striking, more so as both studies were carried out for exactly the same time period.

Philips (1958), Karanassou et al. (2003, 2005), Franz (2005), Karanassou and Sala (2008) and Karanassou and Sala (2010) found a negative inflation-unemployment relationship. However, Phelps (1967), Friedman (1968), Lucas (1976), Niskanen (2002), Taiwo et al (2013) and Sharif and Mitra (2013) found evidence of a positive relation between inflation and unemployment. Niskanen (2002) posited that, this positive relationship could be as a result of a number of factors. First, since the tax code is not fully indexed, inflation increases effective tax rates, especially on the income from capital, and thus reduces output and employment. Second, inflation may confuse the relative price and wage signals on which an efficient labor market is dependent. Third, after a year or so, a high rate of inflation may trigger monetary restraint that temporarily increases the unemployment rate. Also, (Shadman-Mehta, 1996) reexamined the work of A.W. Philips by using Johansen’s maximum likelihood method of testing for cointegration using UK data from 1860 to 1913. Indeed, a long-run inverse relationship was depicted between the rate of inflation and unemployment. However, it was revealed that the main impact of deviations from this long-run equilibrium is on the unemployment rate rather than the rate of inflation.

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RESEARCH METHODOLOGY

The model employed is Philips curve framework with output gap as a proxy for unemployment. The baseline model is estimated in three stages. The first stage involved estimation of the traditional Philips curve without any inflation expectations. The role of expectations is applied in formation of prices by employing the adaptive expectations and the rational expectations theories to estimate the second and third models respectively. The baseline model is algebraically expressed as;

$ln\pi_t = \alpha_0 + ln\pi^e + \delta ln(y_t - \bar{y}) + \varepsilon_t$.....[6]

where $ln\pi_t$ is the current rate of inflation and $ln\pi^e$ is the expected rate of inflation,$ln\ (y_t - \bar{y})$ is the output gap measured by the log difference between actual output and the potential output level of a country(Ghana). ε_t is a stochastic error term assumed to have a constant variance and a zero mean. The variable δ gives how inflation adapts to deviations in output from trend whereas α_0 is a constant term or the intercept of the Philips curve. All the estimates are done using OLS.

The main advantage of using the OLS technique is it underlying property of being best as compared to any other unbiased estimator. That is, it has the minimum variance within a class of unbiased estimators, easy to understand and analyze. In the scenario where all the time series variables are stationary, the OLS is a super-consistent estimator and has the minimum variance.

Model 1: The traditional Philips curve

Here it is assumed that economic agents do not form any expectation on prices. In this scenario, the coefficient of the expectation variable in the baseline model equals zero. The baseline model then simplifies to;

$ln\pi_t = \alpha_0 + \delta ln(y_t - \bar{y}) + \varepsilon_t$.....[7]

All variables are as previously defined.

Model 2: Adaptive Expectations

Here it is assumed that economic agents form expectations on prices based on past inflationary experience. In this scenario, $ln\pi^e = ln\pi_{t-1}$. Hence the baseline model becomes;

$ln\pi_t = \alpha_0 + \lambda ln\pi_{t-1} + \delta ln(y_t - \bar{y}) + \varepsilon_t$ ..... [8]

Where λ_t measures consumers' adaptive mechanism about future inflation levels. The rest of the variables are as previously defined.

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Model 3: Rational Expectations

Employing rational expectations, it is assumed that economic agents base their expectations on future prices not only on past inflationary experience but also on all other information available such as information on exchange rate, money growth, budget deficit, real income level, etc,

Algebraically, $ln\pi^e = f(Exr, MS, FD, \pi_{t-1}, Y, INT)$ ……. [9]

where Exr is the exchange rate at the time and is expected to be positively correlated with the rate of inflation. It is therefore expected that the coefficient on exchange rate be positive. Economic theory postulates a positive relationship between MS and interest rate on one hand and the rate of inflation on the other side. The paper attempted using three monetary aggregates (M1, M2 and M2+) to model the impact of money growth on inflation in Ghana. FD is the effect of deficit financing on inflation in Ghana and is expected to be positively correlated with the rate of inflation. π_{t-1} is the past rate of inflation and INT is the rate of interest with positive *a priori sign*. Real GDP is used as a proxy for real income represented by (Y). Economic theory postulates a negative relationship between inflation and real income. An increase in real income leads to an increase in real money demand which reduces monetary growth thereby reducing the impact of money growth.

Substituting for $ln\pi^e$ in the baseline model by assuming a log linear function gives the following operational model;

$$ln\pi_t = \alpha_0 + \alpha_1 lnExr + \alpha_2 lnMS + \alpha_3 FD + \alpha_4 lnINT_t + \alpha_5 lnY_t + \delta(y_t - \bar{y}) + \lambda\pi_{t-1} + \varepsilon_t \text{ …… [10]}$$

From equation 3.2, 3.4 and 3.5, ε_t is the disturbance term, which is assumed to have zero mean, constant variance and not correlated with the regressors. The *a priori* sign of unemployment $ln(y_t - \bar{y})$ is expected to be negative. That is, it is expected that, the relationship between inflation and unemployment would be inverse.

Measuring the Output Gap

There are different means of decomposing output into trend and cyclical components. From the baseline model, $ln(y_t - \bar{y})$ which is the output gap/unemployment needs to be estimated from the series of GDP data which is the business cycle component. The Hodrick Prescott filter, the Baxter-King filter, the Butterworth filter and the Christiano-Fitzgerald.

Only secondary data is used. World Bank site showing economic indicators including GDP and inflation from 1970 to 2012 is used. The inflation data used is computed from Consumer Price Index (CPI) of basket of goods in Ghana and GDP is computed from aggregate outputs Ghana has produced over the time range. The output gap is also computed from the

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GDP series by using the various filters. Interest rate, money supply, exchange rate and fiscal deficits are all real values. That is, they are adjusted by the consumer price index and they are all annual data. M1, M2 and M2+ are all different measure of monetary aggregate and used to model the effects of aggregate money supply on inflation. The exchange rate is the per Ghana cedi rate of the dollar adjusted by the CPI. All the variables are annual data.

Following the baseline model, all the variables are time series variables so unit root test is first conducted to test the presence of unit roots in the time series data in order to avoid the problem of spurious regression. In principle it is important to test the for unit root in a data series to establish whether it is non-stationary in order to determine the appropriate econometric strategy to apply in the estimation. Augmented Dicky Fuller (ADF) test is applied to test the null hypothesis that series does contain unit root (non-stationary) against the alternative of stationarity. However, in ADF test, there is loss of observation hence Phillips-Perron (1988) unit root test is applied to augment the ADF because of its use of non-parametric methods to adjust for serial correlation and endogeneity of regressors thereby preventing the loss of observations implied by the ADF test. It also allows for the possibility of heteroskedastic error terms Hamilton (1994) as cited in Adu and Marbuah, (2011).

To test the null hypothesis, the t-statistic is calculated and compare to the critical values to make a decision. If the Test Statistic is greater than the critical values, the null hypothesis of implied non- stationary series is rejected.

As a robust check of the results obtained from OLS estimation, Granger causality test is conducted on inflation and output gap to check if there is a causal relationship between inflation and output gap (unemployment) and the exact direction of causation if there is any.

EMPIRICAL RESULTS

Prior to detecting the presence or lack thereof of unit root in the data series, the output gap is measured using the Baxter-King filter, the Butterworth filter, the Christiano-Fitzgerald filter and the Hodrick-Prescott filter.

A comparative graph of the four filters and covariance matrix are shown in figure 2 and table 3 below for the purpose of comparing the various output gaps used as a proxy for unemployment for the estimation. The figure depicts a similar movement in the cyclical movements of the various filtered output gap series as depicted in low co-variances as shown in table 2. Trend movement of the filtered output gaps shows that unemployment was very high around 1974 and attained minimum range around 1983.

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Figure 2 Comparative series of cyclical components of real GDP using various filters

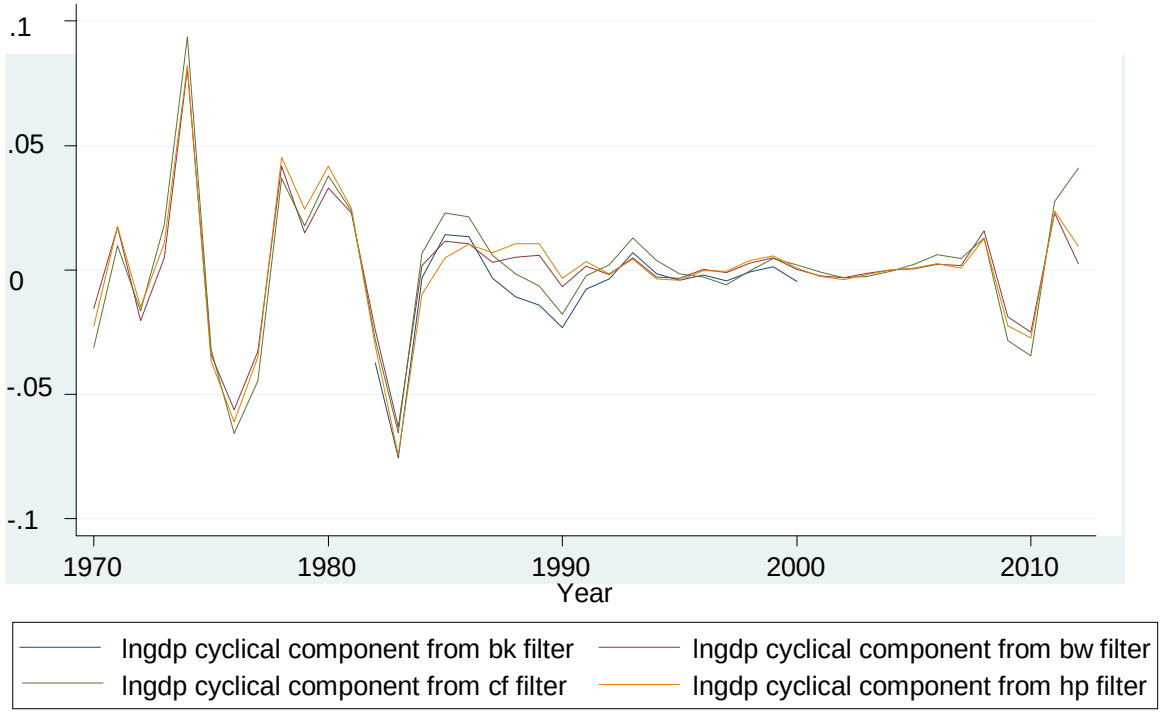

Table 1 Covariance matrix of coefficients of the various output gaps

VARIABLE	BK	BW	CF	HP	GDP
BK	0.000378				
BW	0.00294	0.000256			
CF	0.000357	0.000281	0.000348		
HP	0.000329	0.000297	0.000310	0.000360	
$lnGDP$	0.002008	0.001508	0.001332	0.002103	0.058092

Note: BK, BW, CF and HP are cyclical components of $lnGDP$ from filtered series from Baxter-King, Butterworth, Christiano-Fitzgerald and Hodrick-Prescott filters.

$lnGDP$= Gross Domestic Product.

However, deviations in output from trend (unemployment) were stable between 1985 and 2008 as seen in less deviation in their cyclical movement in the graph. However, measured output gap from Baxter-king filter was dropped because of its loss of observations which would limit the time frame in which the analysis spans.

Unit root test is then conducted on the measured output gap and the rest of the data series. The result from the unit test is shown in the table below. Table 2 clearly shows that all the variables were non-stationary stationary at the level at conventional levels of significance

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except measured output gap and inflation rate. However, after first differencing of the non-stationary variables (real income, interest rate, exchange rate and money supply at M1and M2+) as shown in table 2, stationarity is achieved at conventional level of significance.

Table 2 ADF AND PP Unit Root Test

ADF Unit Root Test Without Trend PP Unit Root Test Without Trend-Test statistic

Variable	Level	1st difference	Level	1st difference
$lnINFL$	-3.825***		-3.831***	
$ln(Y_t - \overline{Y}_t)bk$	-2.860*		-2.766*	
$ln(Y_t - \overline{Y}_t)bw$	-5.861***		-5.979***	
$ln(Y_t - \overline{Y}_t)cf$	-5.115***		-4.948***	
$ln(Y_t - \overline{Y}_t)hp$	-5.252***		-5.145***	
lnY	3.603	-4.143***	3.525	-4.142***
$lnM1$	0.980	-5.611***	0.645	-5.446***
$lnM2$	1.127	-4.429***	0.645	- 4.449***
$lnM2+$	1.364	-4.586***	0.746	-4.662***
$lnEXR$	-0.919	-3.764***	-1.314	-3.672***
$lnINT$	-0.933	-4.409***	-1.275	-4.274***
FD	- 3.795***		-3.799***	

*Note: ***, **, * are significance levels of 1%, 5% and 10% respectively at which the unit root test were evaluated.*

Since OLS estimation assumes that all the series are stationary, level stationary variables and generated first differenced stationary variables were used in the estimation in order to avoid spurious regression.

The tables 3 and 4 below respectively shows the result from the traditional Philips curve and the estimated adaptive expectations Philips curve.

Table 3 Estimated Traditional Philips curve

Variable	(1)	(1)	(1)
$ln(Y_t - \overline{Y})bw$	-4.477741		
	(-0.86)		
$ln(Y_t - \overline{Y})cf$		-4.653101	
		(-1.07)	
$ln(Y_t - \overline{Y})hp$			-3.624689
			(-0.77)
C	3.139722	3.142074	3.139722
	(25.99)***	(26.13)***	(25.94)***
$\overline{R^2}$	0.0177	0.0271	0.0098
N	43	43	43

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Note: $ln\pi_t = lnINFL$ *=Inflation (dependent variable). *,**,*** are significance levels at 10%, 5% and 1% respectively. Values in parenthesis are t-statistic.* $ln(Y_t - \bar{Y})bw$, $ln(Y_t - \bar{Y})cf$ *and* $ln(Y_t - \bar{Y})hp$ *are output gaps with regards to Butterworth, Christiano-Fitzgerald and Hodrick-Prescott filters respectively.*

Table 4 Estimated Adaptive Expectations-Augmented Philips Curve

variable	(2)	(2)	(2)
$\boldsymbol{ln(Y_t - \bar{Y})bw}$	-5.700981		
	(-1.45)		
$\boldsymbol{ln(Y_t - \bar{Y})cf}$		-5.411395	
		(-1.62)	
$\boldsymbol{ln(Y_t - \bar{Y})hp}$			-4.852607
			(-1.35)
$\boldsymbol{lnINFL(-1)}$	0.5393695	0.5224742	0.5363599
	(4.56)***	(4.43)***	(4.52)***
C	1.484849	1.542988	1.494862
	(3.86)***	(4.01)***	(3.87)***
$\boldsymbol{\overline{R^2}}$	0.3398	0.3482	0.3354
N	42	42	42

Note: $ln\pi_t = lnINFL$*Inflation (dependent variable). *,**,*** are significance levels at 10%, 5% and 1% respectively. Values in parenthesis are t-statistic.* $ln(Y_t - \bar{Y})bw$, $ln(Y_t - \bar{Y})cf$ *and* $ln(Y_t - \bar{Y})hp$ *are output gaps with regards to Butterworth, Christiano-Fitzgerald and Hodrick-Prescott filters respectively.*

The result shows an inverse relationship between inflation and unemployment in both the traditional and the adaptive expectations-augmented Philips curve. The coefficient of the output gap used as a proxy for unemployment is not statistically different from zero implying lack of causal relationship between inflation and unemployment and coincides with a low $\boldsymbol{\overline{R^2}}$ of 0.0177 and $\boldsymbol{\overline{R^2}}$of 0.3398 for the traditional and adaptive Philips curve respectively showing inability of output gap to explain trends in inflation in Ghana. Therefore, trade-off between inflation and unemployment of which output gap is used as a proxy cannot be exploited. This confirms neoclassical economic theory which teaches that real rather than nominal wages adjust to clear labour markets, however, it follows that the Phillips curve should have been stated in terms of real wage changes. In other words, real variables (output gap) are independent of nominal variables (inflation). The absence of trade of could also be attributed to the nature of aggregate supply curve of Ghana. That is, the aggregate supply curve could be very flat and therefore it is possible to expand output without significant increase in the cost of production. In other words, since there exist excess capacity in the economy, it is possible to implement a disinflationary policy with a little or no effect on output and employment. Ojapinwa

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and Esan (2013) attributed the insignificance of the output gap to high level of natural unemployment in developing countries.

However, this results differs from empirical conclusions made by Philips (1958), Franz (2005), Karanassou and Sala (2010) and other similar conclusions reviewed in the literature that there is significant trade-off between inflation and unemployment. Philips (1958) concluded that this trade-off exist because wages rose faster when unemployment was low and slower when unemployment was higher in the data investigated. If demand for labour is high then it is harder to replace employees, and hence their ability to negotiate wages increases; but when unemployment is high employees' ability to negotiate declines. The reverse could be applied to the economy of Ghana where there is frequent agitation for wage increase by labour unions whilst output gap (unemployment) is high. In other words, though unemployment may be high in Ghana, labour unions are still able to agitate for wage increase without corresponding productivity thereby leading to a breakdown of the Philips curve relationship. Thus, inflation does not inherit deviations in output from trend.

Inflation shows considerable persistence (inflation inertia), as indicated by the coefficient of lagged inflation. From table 3, in the adaptive expectations model, inflation inertia is estimated to be approximately 0.53%. The significant inflation inertia implies that past inflationary experience partly accounts for current inflationary experience and consequently feeds into trade-off between inflation and unemployment. Implicitly, inflation expectations are important in explaining trends in inflation in Ghana. To reduce this inertia in inflation, there is the need to lower expectations which is very important in explaining current and future inflation rates in Ghana. This is consistent with Gordon (2011), Knust (2011) who reported inflation inertia of 1.29 on US and Adu and Marbuah (2011) with inflation inertia ranging between 0.55 and 0.64 for Ghana.

The estimated rational expectations Philips curve is shown in table 6 above. The adjusted coefficient of determination ($\overline{R}^2$), used to measure the goodness-of-fit of the estimated model, is high enough to indicate that the model is reasonably accurate in making prediction. It suggests that approximately between 79% of the variations in inflation are explained by variations in the estimated determinants. Most of the variables (lagged inflation, real exchange rate, real interest rate and fiscal deficit) were significant, indicating that the problem of multicollinearity is minimized to produce efficient estimations. Log of M2 is dropped from the model to eliminate multicolinearity. Correlation matrix of the regressors as shown in table 5 below shows that M2 is highly correlated with log of growth rate of real GDP and log of growth rate of real exchange rate. It shows a high correlation coefficient of 0.604381 with log of real exchange rate and 0.850562 with log of growth rate of real GDP. The CUSUM squares as

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shown in the appendix shows that the estimated parameters of the Philips curve is consistent as all the estimates equations lies within the critical boundaries at 5% significance level.

Table 5 Correlation matrix of regressors in model (3) of the rational expectations framework

	BW	LNEXR	LNGDP	LNINFL	LNINTR	LNM2	FD
BW	1	0.076572	0.071027	-0.1332	0.036741	0.053122	0.07244
LNEXR	0.076572	1	0.692259	-0.59316	0.571851	0.604381	0.10077
LNGDP	0.071027	0.692259	1	-0.44802	-0.04914	0.850562	0.112933
LNINFL	-0.1332	-0.59316	-0.44802	1	-0.19495	-0.49858	-0.4314
LNINTR	0.036741	0.571851	-0.04914	-0.19495	1	-0.30796	0.049586
LNM2	0.053122	0.604381	0.850562	-0.49858	-0.30796	1	0.068712
FD	0.07244	0.10077	0.112933	-0.4314	0.049586	0.068712	1

The variables are in real units to reduce the degree of likelihood of multi-collinearity. The function is also expressed in log-linear form to bring the different units of variables to the same scale (percentage) to reduce heteroskedasticity.

Table 6 Estimated Rational Expectations Philips Curve

Variable	(3)	(3)	(3)	(4)	(4)	(4)	(5)	(5)	(5)
$ln(Y_t - \overline{Y})bw$	0.332870	-	-	1.015163	-	-	1.768623	-	-
	(0.11)	-	-	(0.37)	-	-	(0.67)	-	-
$ln(Y_t - \overline{Y})cf$	-	-0.311845	-	-	0.187321	-	-	0.668732	-
	-	(-0.13)	-	-	(0.80)	-	-	(0.31)	-
$ln(Y_t - \overline{Y})hp$	-	-	-0.284740	-	-	0.357236	-		0.994739
	-	-	(-0.11)	-	-	(0.15)	-		(0.42)
$lnINFL(-1)$	0.212617	0.215643	0.216187	0.204378	0.208867	0.207792	0.188831	0.196411	0.193544
	(2.57)**	(2.67)**	(2.65)**	(2.55)**	(2.63)**	(2.60)**	(2.42)**	(2.54)**	(2.49)**
$\Delta lnINT$	2.349296	2.246326	2.249389	2.885335	2.871365	2.873274	0.757751	0.814979	0.7893476
	(2.15)**	(2.14)**	(2.10)**	(7.87)***	(7.80)***	(7.84)***	(0.64)	(0.68)	(0.66)
$\Delta lnEXR$	-2.178185	-2.080218	-2.086411	-2.71284	-2.71095	-2.707681	-0.508135	-0.586573	-0.546558
	(-1.99)**	(-1.97)**	(-1.96)**	(-7.36)***	(-7.30)***	(-7.34)***	(-0.41)	(-0.48)	(-0.44)
$\Delta lnM1$	-0.508800	-0.595315	-0.594828	-	-	-	-	-	-
	(-0.52)	(-0.64)	(-0.62)	-	-	-	-	-	-
$\Delta lnM2 +$	-	-	-	-	-	-	-2.354649	-2.27442	-2.304383
	-	-	-	-	-	-	(-1.87)**	(-1.81)**	(-1.83)**
ΔlnY	-0.515921	-0.377715	-0.378606	-0.53341	-0.320849	-0.371600	-0.499707	-0.224509	-0.325379
	(-0.35)	(-0.26)	(-0.26)	(-0.36)	(-0.23)	(-0.25)	(-0.35)	(-0.16)	(-0.23)
FD	-0.057106	-0.057580	-0.057558	-0.054162	-0.053937	-0.053945	-0.056408	-0.055895	-0.055957
	(-2.79)***	(-2.81)***	(-2.80)***	(-2.78)***	(-2.76)***	(-2.76)***	(-2.99)***	(-2.95)***	(-2.96)***
C	2.32892	2.311227	2.309599	2.37592	2.355426	2.360592	2.434654	2.402719	2.415404
	(8.19)***	(8.46)***	(98.24)***	(8.90)***	(8.99)	(8.89)***	(9.38)***	(9.41)***	(9.33)***
$\overline{R^2}$	0.7731	0.7731	0.7731	0.7778	0.7770	0.7771	0.7927	0.7905	0.7910
N	42	42	42	42	42	42	42	42	42

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*Note :lnπ_t=lnINFL=Inflation (dependent variable). *,**,*** are significance levels at 10%, 5% and 1% respectively. Values in parenthesis are t-statistic. ln(Y_t-Y¯)bw, ln(Y_t-Y¯)cf and ln(Y_t-Y¯)hp are output gaps with regards to Butterworth, Christiano-Fitzgerald and Hodrick-Prescott filters respectively*

The result depicts an inverse relationship between inflation and unemployment in model (3) when Christiano-Fitzgerald and Hodrick Prescott measured output gap series were used in the estimation. However, models (4) and (5) show a rather positive relationship between inflation and unemployment. Also in model (3), there is a positive relationship between output gap (unemployment) and inflation when Butterworth filtered output gap is used as a proxy for unemployment and consistent with Lucas (1976), Niskanen (2002), Sharif and Mitra (2013) and Ojanpinwa and Esan (2013) who found evidence of a positive relation between inflation and unemployment implying stagflation which is characterized by falling output and employment, high unemployment and increasing prices, lack of consumer demand and business activity. Niskanen (2002), outlined three empirical reasons for positive inflation-unemployment nexus. First, a high inflation rate discourages capital investment as it increases the effective tax rate leading to a reduction in output and an increase in unemployment. Another empirical conclusion of the positive relationship from Niskenan (2002) that is peculiar to the Ghanaian economy is continuous high rate of inflation which may trigger monetary restraints that temporary increases unemployment rate.From the rational expectations model, there exist inflation persistence of approximately 0.20% showing an increasing trend in inflation in Ghana. Any attempt by monetary authorities to curb the persistence in inflation by reducing the growth rate of money supply would temporary increase unemployment rate. This inconsistent inflation-unemployment relationship is not expected since they are not in tandem with economic theory. Ojapinwa and Esan (2013) had similar result on the analysis of inflation-unemployment nexus on the Nigerian economy and attributed the inconsistent results to continuous changes in the composition of the labour force consequent upon the demographic changes and random economic shocks such as currency devaluation, unanticipated increase in crude oil prices and various other policy inconsistencies which are also applicable to the Ghanaian economy.

It is worth mentioning that relationship between inflation and unemployment is insignificant in all the estimated rational expectations models. In other words, there exist no trade-off between inflation and unemployment in the rational expectations model and reaffirms the reasons for no trade-off results from the traditional Philips curve and the adaptive expectations Philips curve.

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Inflation exhibits considerable persistence (inflation inertia) in the rational expectations framework as shown in the significant coefficient of lagged inflation. This result was expected as rational agents adjust their expectations on prices upwards in order to maintain their real incomes. From table 5 above, a significant inflation inertia of approximately 0.20% was revealed. The significant inflation inertia implies that past inflationary experience feeds into current inflation. This is consistent with Gordon (2011), Knust (2011) who reported inflation inertia of 1.29 on US and Adu and Marbuah (2011) with inflation inertia ranging between 0.55 and 0.64 for Ghana.

An increase in the growth rate of exchange rate (depreciation) of the Ghana cedi is expected to have a positive impact on inflation. The result rather suggests a rather negative impact of increase in the growth rate of real exchange rate on inflation. Implicitly, a unit increase in the growth rate of real exchange rate is expected to cause inflation to increase by approximately 2.5% with reference to models (3) and (4). However, the influence of changes in growth rate of exchange rate is not significant in explaining fluctuation in inflation in Ghana in model (5). This differing results could be as a result of inconsistent exchange rate policies pursued over the years. The result is consistent with negative relationship between inflation and exchange rate concluded by Adu and Marbuah (2011). They concluded a significant negative relationship between inflation and exchange rate of which they attributed to the exchange rate scarcity Ghana experienced at some point in time in the 1970s.

The expected sign of interest rate is positive. That is, an increase in growth rate of real interest rate is expected to cause price of non-tradable goods to increase and consequently cause inflation to increase. It is shown in table 5 that growth rate of real interest rate is significant in explaining fluctuation in inflation in Ghana. A unit increase in the growth rate of interest rate is expected to cause inflation to increase by approximately 2% with reference to models (3) and (4). Implicitly, interest rate policies could be used by the monetary authorities (the bank of Ghana) as a tool for reducing inflation as seen in the statistical significance and the magnitude of impact of the coefficient of its parameter. By so doing, the Bank of Ghana would have reduced inflation expectations considerably to suit the inflation targeting framework it operates. However, growth rate of real interest rate has no significant influence on inflation in model (5).

Economic theory postulates a positive relationship between inflation and growth rate of real money supply. That is, an increase in growth rate of real money supply is expected to cause inflation to rise. Inferring from table 5, the result differs from economic theory. That is, a unit increase in the growth rate of money supply is expected to cause inflation to significantly decrease by approximately 2.3% using model (5) as a point of reference. Implicitly, the impact

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of M2+ as aggregate measure of money supply for policy formulations by the Bank of Ghana is significant in explaining trends in inflation in Ghana. This implies that monetary policy can be relied on as policy instrument in influencing inflation in Ghana. This result contradicts Friedman (1968) assertion of monetary neutrality.

Growth rate of real income is expected to be negatively related to inflation. As individual's real income increases, demand for money for transactionary purpose increases thereby reducing the impact on inflation through a reduction in the excess money supply. As shown in the result, the realized sign is negative and confirms economic theory of negative relationship between inflation and the growth rate of real money supply. However, the growth rate of real money supply has no significant influence on inflation in Ghana in model (5). This implies that, using income policy instrument for influencing inflation in Ghana would prove futile inferring from model (5).

Fiscal deficit does exert significant influence on the level of inflation. Economic theory postulates a positive relationship between fiscal deficit and inflation. A unit change in the fiscal spending of the country (Ghana) is expected to cause inflation to significantly decrease by about 0.05% unit points. This result is surprisingly different from economic theory of positive relationship between inflation and fiscal deficit.

Table 7 Granger causality Wald test

Null Hypothesis	df	F-statistic	P-value	Decision
(1)$ln(Y_t - \bar{Y})bw$does not Granger cause$lnINFL$	2	1.92	0.1615	Accept
(2) $lnINFL$does not Granger-cause $ln(Y_t - \bar{Y})bw$	2	0.06	0.9412	Accept
(3) $ln(Y_t - \bar{Y})cf$ does not Granger-cause $lnINF$L	2	1.94	0.1593	Accept
(4) $lnINFL$ does not Granger-cause$ln(Y_t - \bar{Y})cf$	2	0.13	0.8820	Accept
(5) $ln(Y_t - \bar{Y})hp$does not Granger-cause $lnINFL$	2	1.95	0.1576	Accept
(6) $lnINFL$ does not Ganger-cause $ln(Y_t - \bar{Y})hp$	2	0.20	0.8214	Accept

Significance level at 5%. Note:$ln\pi_t = lnINFL = logged$ *Inflation.*$ln(Y_t - \bar{Y})bw$, $ln(Y_t - \bar{Y})cf$ *and* $ln(Y_t - \bar{Y})hp$ *are output gaps with regards to Butterworth, Christiano-Fitzgerald and Hodrick-Prescott filters respectively.*

Granger causality test is applied to find the presence or lack thereof of causal link between inflation and unemployment (output gap). Two different models were tested; first Granger causality was tested to determine if output gap (unemployment) could be used to accurately

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predict fluctuations in inflation (hypotheis1, Table 7). The second hypothesis was to test if Granger causality existed in the reverse direction, i.e. if inflation Granger causes output gap, (Hypothesis 2, Table 7). The results of both hypotheses depict no causal relationship between inflation and output gap (unemployment). That is neither unemployment nor inflation could be used to predict the other at 5% significance level hence we failed to reject the null hypothesis of no Granger causality. The results of the rest of the hypotheses do not differ from the first and second hypothesis. That is, irrespective of the measured output gap used, there is no causal relationship between inflation and unemployment and affirms the non-existence of inflation-unemployment trade-off on the economy of Ghana from the OLS estimation. Given that the test fails to reject the null hypothesis of no Granger-causality between the cyclical components of GDP and the inflation in either direction, it can be concluded that in Ghana the changes in inflation rate is independent of the fluctuations in the cyclical component of output and the vice versa.

CONCLUSIONS AND POLICY IMPLICATIONS

Employing the OLS approach to estimation, the results confirmed economic theory of non-existence of a trade-off between inflation and output gap. That is, neoclassical economic theory teaches that real variables are independent of nominal variables. This implies that the authorities cannot exploit the Philips curve relationship by either pegging unemployment or stabilize the rate of inflation. High natural rate of unemployment and excess capacity in Ghana could account for this insignificance of the output gap in explaining inflation in Ghana. Implicitly, output can be increased without generating any inflationary pressure on the economy.

The result also showed an inverse relationship between inflation and unemployment in all the models except the rational expectations model which showed a mixed results of both negative and positive inflation-unemployment nexus. These inconsistencies in the result could be accounted for by effect of random economic shocks like high crude oil prices, devaluation and inconsistent economic policies etc. on the economy of Ghana.

The result again suffices to show that, inflation inherits persistence in output. In other words, past inflationary experience influences current levels of inflation. In this regard, any high values of inflation would lead to a high inflationary experience in the future.

Moreover, growth rate of real exchange rate, real interest rate, real money supply (M2+), fiscal deficit and past inflationary experience have significant influence in explaining trends in inflation in Ghana. These results suggests that a sound interest rate, exchange rate and monetary policy is key to the success of the disinflation effort in Ghana and could be used by policy authorities. Given the close and highly significant relationship between inflation and growth rate

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of interest rate, any policy which increases the growth rate of interest rate is likely to have a damping effect on inflation. Thus, measures that reduce excessive increase in the rate of interest should be earnestly pursued. In other words, any lowering of interest rates which leads to increased growth is likely to lead to a decline in the rate of inflation. Taming inflation within a reasonable rate of unemployment demands careful interest rate policy.

Given the significance nature of fiscal deficit and money supply as determinants of inflation in Ghana, enhanced coordination between fiscal and monetary authorities in designing an effective stabilization package would help meet future inflation targets.

In concluding the study on inflation determinants, the results provides justification for the Bank of Ghana's use of M2+ as a target variable for implementation of monetary policy as a result of its significance as a determinant of inflation in Ghana.

Since this study estimated the output gap by statistical approach, future studies should consider estimating the output gap used as a proxy for unemployment by theoretical approach such as using the Cobb Douglass production function.

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APPENDICES

Figure A1: Plot of CUSUM of Squares of recursive residuals for estimated traditional Philips curve

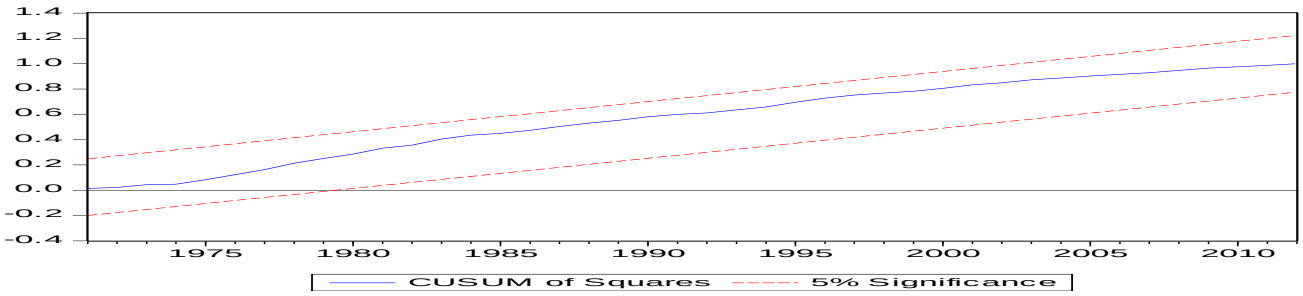


Figure A2: Plot of CUSUM of Squares of recursive residuals for estimated adaptive expectations Philips curve

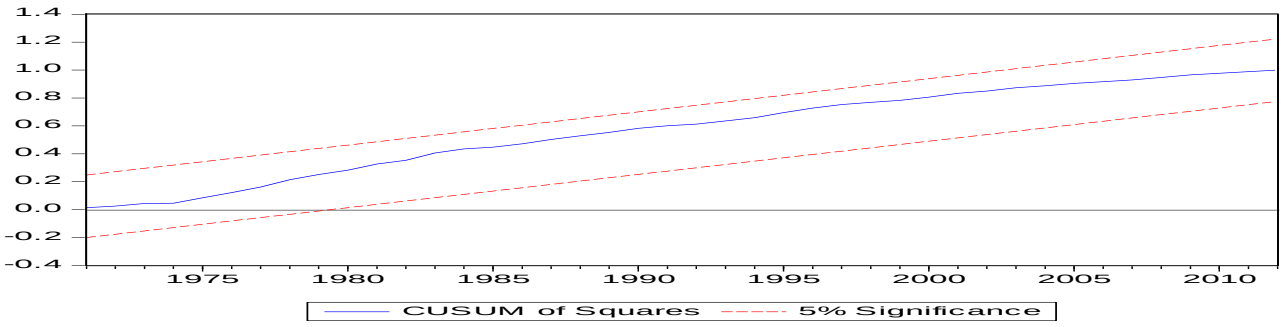
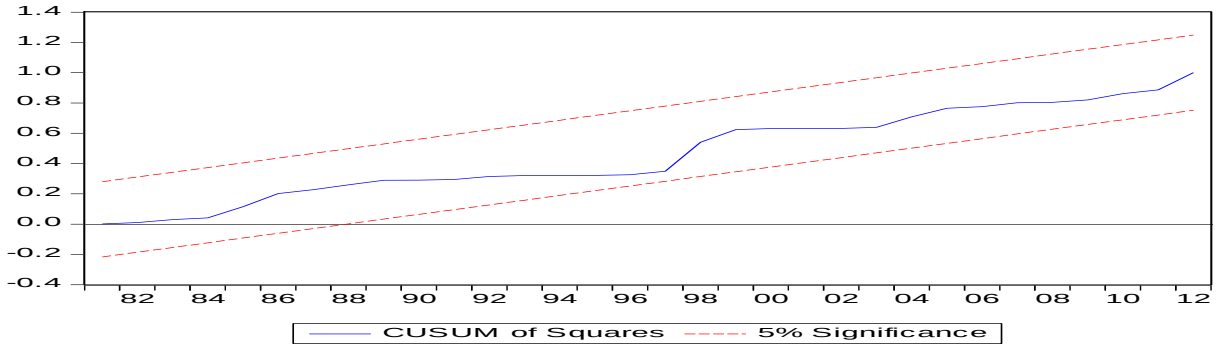


Figure A3: Plot of CUSUM of Squares of recursive residuals for estimated rational expectations Philips curve



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