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NAIRU: Is it Useful for Monetary Policy?

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Abstract

This paper estimates the non-accelerating inflation rate of unemployment (NAIRU) for Jamaica and examines its usefulness in the conduct of monetary policy. Using a Kalman and HP filter framework, the study finds support for the hypothesis that the unemployment gap explains in part, the dynamics of inflation. Notably, given the small coefficient derived from the model, the use of the NAIRU in policy decisions should be analyzed jointly with other indicators. The productivity-augmented NAIRU illustrate a consistent negative trend, which implies that wage aspirations tend to exceed productivity, with a positive impact on inflation. The inclusion of the productivity indicator in the bivariate specification of the Phillips curve improves the NAIRU estimates of the univariate expectations-augmented model.

Keywords: NAIRU; Unemployment; Kalman filter; Phillips curve
JEL Classification: C22, E31, C13

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1.0 Introduction

The non-accelerating inflation rate of unemployment (NAIRU), better known as the natural rate of unemployment, is the rate of unemployment that is consistent with the steady state rate of inflation in the absence of supply shocks (Staiger et al, 1997). In the short run, the Phillips curve analysis posits that the unemployment rate plays a role in the transmission process from unanticipated changes in aggregate demand to inflation. The Phillips curve relationship states that changes in aggregate demand push inflation and unemployment in opposite directions in the short run, hence allowing for the NAIRU to vary over time (Ball and Mankiw, 2002)[1]. More specifically, models that incorporate Philips curve analysis show that increases in demand enhance real Gross Domestic Product (GDP) relative to its potential level, thereby increasing the demand for labour and hence lowering the unemployment rate relative to the NAIRU. Empirical evidence has shown that the NAIRU can be a good indicator of future inflation when the economy undergoes demand shocks. However, the NAIRU may give misleading policy signals when there is a supply shock, such as an increase in productivity. An unexpected increase in productivity causes downward price pressures (as aggregate supply exceeds aggregate demand) as well as a reduction in the unemployment rate (attributed to the increase in real GDP and its associated increase in demand for labour). In this context, policy makers may misinterpret the reduction in the unemployment level relative to the NAIRU as a reason to tighten policy in fear of higher inflation

This study seeks to estimate a time variant NAIRU for Jamaica between 1994 and 2007 using unobserved components models. State space models are used as the paper assumes that the determinants of the NAIRU are unknown but persistent. The implications of the NAIRU in the assessment of inflationary pressures are also examined. The assessment explicitly accounts for changes in labour productivity in the economy. The inclusion of the latter arises from the hypothesis that increased productivity growth in conjunction with inertia in real wage aspiration on the part of workers allows unemployment to decline below the non- accelerating inflation level without generating inflationary pressures (Ball & Moffitt, 2001 and Gruber, 2003). The study therefore answers as well:

[1] The time variant NAIRU is a possible consequence of changes in demographics, technology, government policies as well as other factors which may perpetuate fluctuations in productivity.

what role, if any, does productivity have in explaining the dynamics of the trade-off between inflation and unemployment. Given that monetary policy should be pre-emptive to control for inflation given that the effects of monetary policy have long lags (Estrella and Mishkin, 1998), the estimation of the Jamaican NAIRU is an attempt to improve the use of the NAIRU as an additional tool in making more informed policy decisions.

The paper is developed as follows: Section 2 will review the theoretical underpinnings of the concept being examined. Section 3 lays out the modelling issues described in the literature and the data properties. Section 4 presents formulation of the econometric model. Finally, section 5 gives the results of the estimations and section 6 concludes with a discussion of the implication of the results.

2.0 Conceptual Issues

2.1 NAIRU

In theory whenever the unemployment rate persists below the NAIRU (refers to a tight labour market), the rate of inflation tends to rise and vice versa. The Phillips curve relationship states that inflation will stabilize at the permanently higher level. Tight labour markets induce employees to bid for high wages while high unemployment encourages workers to accept low wages. The former, along with labour being the largest single component of production, implies that persistent increases in wages should eventually result in increased prices by firms and hence "economy-wide" price inflation through the cost-push inflation mechanism. (Espinosa-Vega and Russell, 1997).

Given the large and sustained changes in unemployment, most of the literature has focused attention on econometric models that allow for variation over time in the NAIRU. The NAIRU in the short run is therefore more volatile and often affected by structural changes as well as supply shocks. The determinants of the NAIRU, although unknown, are assumed to be inter alia influenced by demographics and technological changes which give merit for the variable to be modelled as persistent. Uncertainty about the NAIRU does not render the Phillips curve useless for the conduct of monetary policy as posited by King and Watson (1994) who found that unemployment rate Granger-causes inflation.

2.2 Limitations of the use of the NAIRU for Monetary Policy

While the application of the NAIRU is deemed important for the conduct of monetary policy its importance is blurred by uncertainty as identified by Stagier, Stock and Watson (1997). The uncertainty relates to the specification of a “proper model”, the smoothness parameter and uncertainty regarding the estimated parameters. The literature on the NAIRU has indicated large standard error bands around the Kalman filter estimates (Greenslade (2003), Slacelak (2005), Stagier et al., (1997)). Given that the NAIRU cannot be estimated with much precision, it could provide misleading signals for monetary policy. In addition, the short-run trade-off between unemployment and inflation may be unstable over time and is sensitive to the way inflation expectations are formed. Hence any trade-off would tend to disappear if policy makers attempted to exploit it systematically.

Nevertheless, Estrella and Mishkin (1998) conclude that the above-mentioned issues do not negate the use of the NAIRU but rather reduce the magnitude of the policy response to the indicator. Furthermore, they warn against the improper use of the NAIRU as a potential target given its short run construct. Estrella and Mishkin (1998) also note that the divergence of inflation from its target is of equal importance as the NAIRU gap in developing a policy stance. Moreover, a common consensus in the literature is that generally the NAIRU should not be used in a vacuum and that monetary policy should be informed by a wide range of variables.

3.0 Modelling the NAIRU

The techniques used in the existing literature to estimate the NAIRU can be broadly classified into three categories: structural, statistical and reduced-form methods. This section will examine the three methods and illustrate the superiority of the reduced-form technique as well as highlight its application in recent studies.

3.1 Structural Method

The structural method involves modelling aggregate wage and price setting behaviour in a system of equations. The estimation of the NAIRU is made under the assumption that markets are in full or sometimes partial equilibrium (Richardson, 2000)[2]. The model presupposes full adjustment of firms and workers to all shocks. As such, the derived unemployment corresponds to the natural rate of unemployment rather than the short run NAIRU which commonly appears in the reduced-form Phillips curve specification.

Structural models are useful as they present more information on the determinants of the NAIRU given the theoretical relationship between macroeconomic shocks, policy instruments and the long run equilibrium rate of unemployment. However, their shortcomings include dependence on the assumptions of the underlying behaviour of economic agents for which there is no general consensus. Further, the complexity of the estimation prevents the timely calculation of the estimates and there exists a number of econometric and measurement issues associated with the method.

3.2 Purely Statistical Method

Purely statistical methods dichotomize the unemployment rate into its trend and cyclical components, without accounting for the relationship between the unemployment rate and inflation. These models are intended to be predictive and rely on the assumption that equilibrating forces are swift and sufficient in bringing the unemployment rate to its trend position, so that on average, the unemployment rate will fluctuate around the NAIRU. While purely statistical methods can be estimated in a timely and consistent way, they are often dependent on arbitrary assumptions. These assumptions relate to the modeling of the estimated trend, particular to its variance and relationship with the cyclical components. This is the case of the HP filter which identifies unemployment as a weighted average of actual unemployment. However, given that filters work as moving averages they often respond slowly to apparent changes in unemployment.

[2] The equilibrium level of unemployment is obtained as a set of values for which inflation is stable (Szeto and Guy, 2004).

3.3 Reduced Form Methods

The reduced form method of estimation of the NAIRU is grounded in the theoretical underpinnings of the expectation-augmented Phillips curve, which allows for additional factors other than the inflation/unemployment relationship. This method is therefore likely to be more robust than the corresponding structural approach, as it has both greater explanatory power as well as greater flexibility of the functional form. Consequently, the reduced form approach has become the most popular technique in recent studies. Nonetheless, the reduced form approach is by no means perfect and has a number of disadvantages. These disadvantages include the heavy dependence of the NAIRU estimates on the estimation of inflation expectations as well as the method's atheoretical approach of estimating the NAIRU via the reduced form method, which does not identify the underlying structural inflation/unemployment relationship (Richardson et al, 2000). Also, the filters lack precision for end of sample estimates, while the results are liable to be sensitive to arbitrary choices of variance parameters such as the signal to noise ratio. Stock and Watson's (1998) procedure is propose in order to obtain median-unbiased estimates of the ratio of the variance parameters (i.e. signal to noise ratio). This paper follows the approach of Laubach (2001) in fixing the variance parameters.

3.4 Recent Empirical Studies

Richardson et al (2000) using the Kalman filter procedure, jointly estimate the Phillips curve and Time-Varying NAIRU for the 21 OECD member countries for the period 1980 to 1999. The supply shocks used in the study are real import prices and oil prices. The results found support for the statistical significance of the NAIRU. Laubach (2001) using a similar framework as Richardson et al (2000) includes a drift in the specification of the NAIRU and models the NAIRU as a persistent stochastic process. The supply shock variables used in this paper are the nominal exchange rate, commodity prices and two measures of price changes; the CPI and the GDP deflator. Laubach (2001) examines the NAIRU between 1971 and 1998 for the G7 member countries excluding Japan and Australia. The results show support for the significance of the NAIRU for the United States, however, for most European countries the NAIRU specification does not explain the joint progression of unemployment and inflation.

Slacalek (2005) uses a similar framework to that of Laubach (2001) and Richardson et al (2000) and creates the productivity-augmented Phillips curve. The approach adds to the augmented Phillips curve by modelling the NAIRU with information contained in the trend of productivity as opposed to modelling NAIRU as a persistent stochastic process. The main assumption is that productivity has two components, namely, the capitalization effect and the creative destruction effect[3]. Using quarterly data between 1960 and 2002 for the United States, Slacalek (2005) found the net impact of the two effects to have a negative correlation between productivity growth trend and the NAIRU.

Greenslade et al (2003) applies a reduced form framework of the Philip's curve to estimate the NAIRU for the United Kingdom from 1973 to 2000. The supply shock variables used are similar to Richardson et al (2000), real import prices and oil prices. In addition to examining the impact of the unemployment gap to price inflation, he also estimates the relationship between the unemployment gap and wage inflation. The results found support for the use of the NAIRU (albeit with some level of uncertainty) as well as the importance of the supply shocks in analyzing inflationary pressure.

4.0 Econometric Model

4.1 The Model

The model of the expectations-augmented Phillips curve is:

$$\pi_t - \pi_t^e = \beta(L)(\pi_{t-1} - \pi_{t-1}^e) + \gamma(L)(U_{t-1} - U_{t-1}^*) + \delta(L)X_{t-1} + \varepsilon_t \qquad (1)$$

where $\beta(L)$, $\gamma(L)$ and $\delta(L)$ are the polynomial in the lag operators, π_t and π_t^e denote realized and expected inflation, respectively. U_t^* denotes the NAIRU at time t, X is a

[3] The capitalization effect represents the creation of jobs due to increased labour productivity. This effect states that labour productivity is negatively related to unemployment. The creative destruction effect represents the structural change where increases in productivity shortens employment duration and raises the NAIRU. The correlation between the productivity growth and the NAIRU therefore depends on the relative size of these two effects.

vector of variables capturing supply shocks and the random exogenous event, ε_t. Intuitively, the unemployment gap is defined as $(U_{t-1} - U^*_{t-1})$ and is negatively related to inflation.

Assuming, initially, that the NAIRU is constant, the NAIRU is estimated using Ordinary Least Squares (OLS) (Slacalek, 2005). Rewriting the above equation to an equivalent expression that can be estimated by OLS is as follows:

$$\Delta\pi_t = \gamma_0 + \beta(L)\Delta\pi_{t-1} + \gamma(L)U_{t-1} + \delta(L)X_{t-1} + \varepsilon_t \qquad \text{(1a)}$$

Given least squares estimates of the constant term, γ_0, the estimate of the constant NAIRU is $u^*_t = -\gamma_0/\gamma(1)$ where $\gamma(1)$ is the sum of unemployment coefficients (Slacalek, 2005).

Given the aforementioned restrictiveness of the constant NAIRU assumption as well as the paucity of empirical evidence to substantiate the assumption, a time varying parameter model (Kalman filter) is used to capture the structural changes of the labour and commodity markets. Specifically the model becomes:

$$\pi_t - \pi^e_t = \beta(L)(\pi_{t-1} - \pi^e_{t-1}) + \gamma(L)(U_{t-1} - U^*_{t-1}) + \delta(L)X_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim N(0, \sigma^2_\varepsilon) \qquad (2)$$

$$U^*_t = \eta U^*_{t-1} + v_t \qquad v_t \sim N(0, \sigma^2_v)$$

Here the random exogenous events ε_t and v_t are assumed to be *i.i.d.* normal with mean zero and variance σ^2_ε and σ^2_v, respectively, and $\text{cov}(\varepsilon_t, v_t) = 0$.

Intuitively, the system represents an expectation-augmented Phillips curve consisting of the Phillips curve (the first equation of (2)), which models the unexpected inflation as a function of past deviations from expected inflation, the unemployment gap and shocks.

Expectations are assumed to be adaptive and exhibit inertia represented by lags of inflation, i.e. $\pi_t^e = \pi_{t-1}$. The second equation of (2) represents the time variant modeling of the NAIRU.

The univariate NAIRU is modelled as an unobserved stochastic component and assumed to follow a random walk. Given the absence of an upward trend in Jamaica's unemployment data it is plausible to assume that the NAIRU can be specified as a random walk without drift (Laubach, 2001)[4]. The assumption of the size of the standard error of v_t determines how the NAIRU will move from quarter to quarter. Given the steady state concept of the NAIRU, Gordon (1997) postulates a "smoothness" prerequisite that allows the NAIRU to move around without sharp quarter to quarter volatility. Intuitively, the variation of v_t is usually small. Similar to Laubach (2001), a bivariate specification is developed with the assumption that the unemployment gap has a tendency to revert to a zero mean over time thereby imposing structure on the unemployment gap. Algebraically,

$$U_{t-1} - U_{t-1}^* = \phi(L)(U_{t-1} - U_{t-1}^*) + k_t \quad \text{where } \phi(1) < 1 \qquad (3)$$

The assumption that the unemployment gap follows a stationary process yields additional information about the NAIRU (Laubach, 2001). This imposition is in line with Friedman's 1968 natural-rate hypothesis that the unemployment rate can be kept away from its natural rate only by ever accelerating inflation or deflation.

The Kalman filter estimates the Phillips curve jointly with the NAIRU. In the estimation of the Kalman filter an iterative procedure is used to identify the NAIRU series and the coefficient on the unemployment gap until convergence is achieved. The methodology

[4] Laubach (2001) modelled the U.S. the NAIRU as a random walk without drift given the mean reversion nature of its unemployment data.

uses the reduced-form Phillips curve, in collaboration with the Kalman filter[5]. The paper's model draws from both Laubach (2001) and Ball and Moffitt (2001) who considers a specification of the NAIRU without drift.

Decomposing the shock variable, $\delta(L)X_t$, from equation (2) we rewrite the model as

$$\Delta\pi_t = \beta(L)\Delta\pi_{t-1} + \gamma(L)(U_{t-1} - U^*_{t-1}) + \delta(L)X_{t-1} + \varepsilon_t \qquad i = 1...n \qquad (4)$$

$$u^*_t = \eta U^*_{t-1} + v_t$$

The reported NAIRUs are calculated such that the entire Phillips curve error is assigned to the variation of the NAIRU (i.e. in each year the time varying NAIRU is the value of the NAIRU that would set the predicted value of inflation equal to the actual value of inflation.

The methodology of incorporating productivity in the Phillips curve emanates from Ball and Moffitt (2001), amongst others, who sought to explain the low unemployment and low inflation environment in the United Sates in the 1990s. Ball and Moffitt (2001) found that the increased growth rate in productivity that occurred around the same time was responsible for the change in the levels of the unemployment and inflation trade-off. The argument proposed by the authors is entrenched in the idea that workers' wage aspiration adjust slowly to shifts in productivity. The model assumes initially that wage adjustments are largely based on past wage increases and less on productivity. Secondly, the model assumes that wage inflation depends negatively on unemployment.

The productivity augmented Phillips curve is a combination of a price-setting and wage-setting equations. The model starts by looking at the price setting equation, which is the labour cost characterization of inflation.

[5] The reduced form approach was also the framework of choice in the recent studies of Laubach (2001), Szeto et al (2004) and Gordon (1997) as opposed to the structural models. The main reason for the selection of the reduced form was that the structural model framework assumes full adjustment to all shocks.

$$\pi_t = \omega_t - \theta_t + \upsilon_t \qquad (5)$$

where inflation, π_t, is determined by the difference between nominal wage growth, ω_t, and the growth rate of productivity, θ_t, and an error term, υ_t. Mark-ups are assumed to be constant. Increases in wages above productivity will translate into upward movements in prices. Equation (5) can be rewritten to show that growth in real wages is equal to productivity growth, plus error:

$$\omega_t - \pi_t = \theta_t + \upsilon_t \qquad (6)$$

The wage-setting process assumes that in the steady state, where there is flexibility, workers prefer nominal wage growth equal to the rate of inflation plus the rate of productivity growth. However, Ball and Moffitt (2001) introduce inertia into the real wage adjustment process and suggest that workers, in addition to examining contemporaneous inflation and productivity when setting their wages, also look at past levels of real wage growth which is captured in a "wage aspirations" term. These wage aspirations, A_t, depend on past wage increases and are defined as:

$$A_t = \frac{1-\beta}{\beta}\sum_{i=1}^{\infty}\beta^i\left(\omega_{t-i} - \pi_{t-i}\right) \qquad (7a)$$

where β is the discount factor which is the weight placed on past levels of real wage growth. Rewriting equation 7a recursively gives:

$$A_t = \beta A_{t-1} + (1-\beta)(\omega_{t-1} - \pi_{t-1}) \qquad (7b)$$

For the aspiration term, the initial value of A is set equal to the starting value of the HP-filtered real wage growth series. The discount parameter is set equal to 0.95.[6]

Combining equations (6) and (7a), A_t is the discounted sum of past levels of productivity growth and is a weighted average of past increases with exponentially declining weights. The workers' target level of real wage growth becomes:

$$(\omega_t - E\pi_t) = \alpha - \gamma U_t + \delta\theta_t + (1-\delta)A_t + \eta_t \qquad (8)$$

where E is the expectations operator and U_t denotes the rate of unemployment. Theoretically, workers' real wage aspirations depend on a weighted average of current productivity growth and current and past productivity wages encompassed in, A_t, as well as unemployment, U_t. Unemployment is negatively related to the workers' real wage growth target, since as the number of job seekers increase, workers tend to revise downwards their wage expectations.

By substituting the wage-setting equation (8) into the price setting equation (5), assuming adaptive expectations (i.e. $E\pi_t = \pi_{t-1}$) and allowing supply shocks, S_t, the productivity-augmented Phillips curve is derived as follows:

$$\pi_t = b(L)\pi_{t-1} + c_1(U_{t-1} - U^*_{t-1}) + \delta(L)X_{t-1} + f_1(\theta_{t-1} - A_{t-1}) + \varepsilon_t \qquad (9)$$

Intuitively, equation (9) implies that inflation is negatively associated with the excess productivity growth over aspirations of real wage growth. In the steady state changes in productivity are directly proportionate to changes in wage aspiration ($\theta = A$). In the short run, however, movement in productivity θ is not matched immediately by a shift in A

[6] Taken from Ball and Moffitt (2001) and Gruber (2003).

which results in downward pressures on inflation. In effect, movements in $\theta - A$ are treated as persistent supply shocks that shift the Phillips curve for a given NAIRU.

In summary the specifications estimated in the paper are as follows:

1. Univariate NAIRU model (equation (4)).
2. Univariate NAIRU model including productivity (Equation (4) and (9)).
3. Bivariate NAIRU model (equations (3) and (4)).
4. Bivariate NAIRU model including productivity (Equation (3), (4) and (9)).

4.2 Estimation issues

Laubach (2001) identifies the issues concerning the treatment of the variance parameters, the choice of the initial value of the state, and the computation of standard errors. Firstly, the estimation of the unobserved components models, faces a "pile up problem" when there are non stationary state variable. The Maximum Likelihood Estimates of the signal to noise ratio (σ_v / σ_τ) has a point mass of zero even if the true value is greater than zero (Stock, 1994). This paper adopts the approach of Laubach (2001) in fixing the parameters σ_ε and σ_v by using a diffuse prior. Secondly, two alternative methods were used in this paper to choose the initial value for the state, U_0^*. The first approach chooses $U_0^* = U$ in computing the initial state and its covariance matrix for the bivariate specifications. For the univariate specifications the paper follows Laubach (2001) in defining a variable $Z_t \equiv U_t^* - U_0^*$ and re-writing equation (4) as

$$\Delta\pi_t = c + \beta(L)\Delta\pi_{t-1} + \gamma(L)(u_{t-1} - z_{t-1}) + \delta(L)X_{t-1} + \varepsilon_t \qquad i = 1...n \qquad (10)$$

$$z_t = z_{t-1} + v_t$$

The initial value (u_0^*) is given by $-c/\gamma(L)$. In the specification the initial value of z_0 is zero by definition.

4.3 Data properties

The study uses quarterly data over the period 1994:1 to 2007:4. The measure of inflation used in the study is the Consumer Price Index (CPI). Following Laubach (2001) the unemployment rate was not entered contemporaneously as to avoid the simultaneity issues. Expectations are assumed to be adaptive and exhibit inertia represented by lags of inflation. Productivity growth is the change in the log of output per worker. The short term shock selected, which is expected to revert to zero after a year, is a selected import price index of raw materials and food. The shock series was taken as deviations from its mean, to ensure that in the steady state it does not impact the rate of inflation. Wage aspirations are measured as a weighted sum of discounted past levels of real wage growth.

5.0 Results

Figure 1 shows that both the unemployment rate and the inflation series were relative stability between 1995 and 2002. Inflation ranged between 0.0 and 4.0 per cent while unemployment ranged between 16.1 to 17.4 per cent. Unemployment declined sharply in 2003 with a similar movement in inflation. The decline in the unemployment rate could be attributed to the construction boom that started during the early 2000's. The construction boom involved significant construction of highways, roads and hotels, which increased employment in the respective as well as support industries. The remainder of the period under study was characterised by a declining unemployment rate ranging between 13.1 and 9.6 per cent while inflation was more volatility and ranged between -0.3 and 7.9 per cent. For the sample period, the unemployment gap can be assumed to have averaged close to zero as the inflation data does not exhibit explosive behaviour (Laubach, 2001).

Figure 1: Jamaica Unemployment rate and Inflation

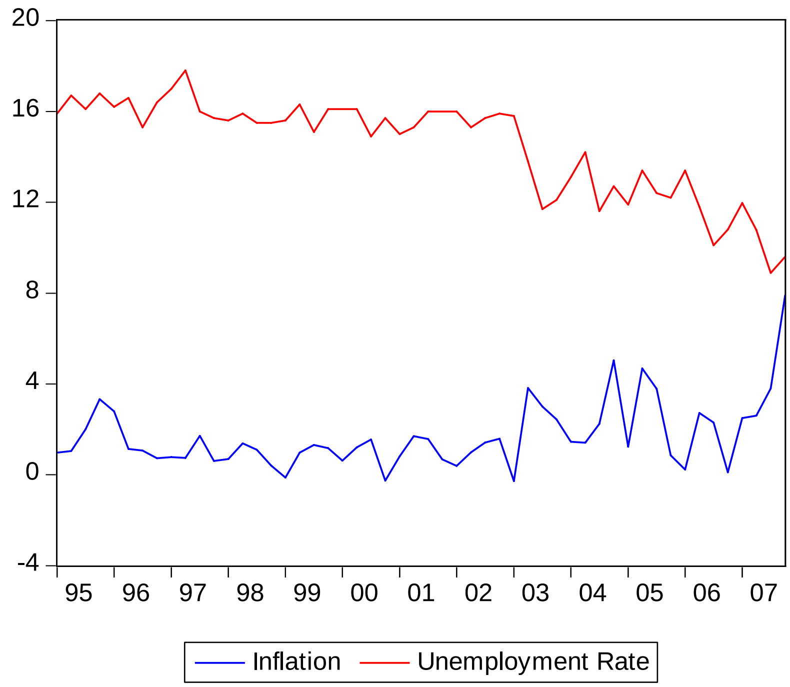
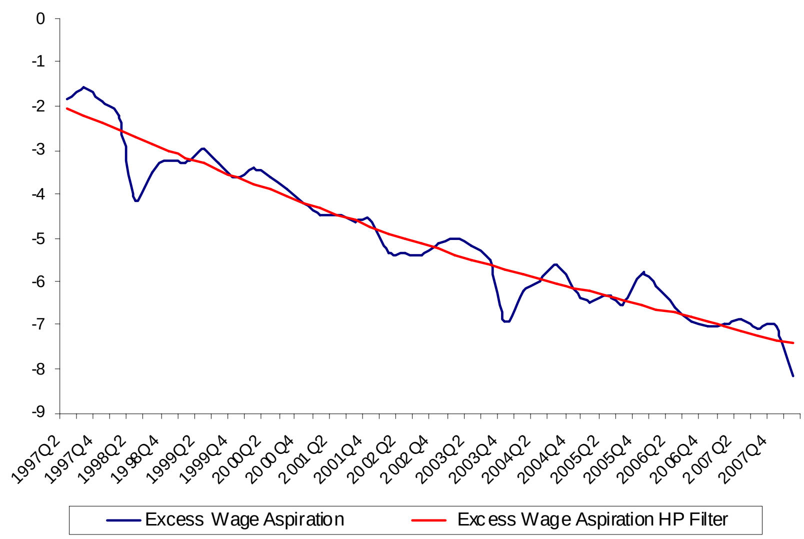


Figure 2: Jamaica Labour Productivity minus Wage Aspirations



The difference between θ_t and A_t is graphed with its HP-filter values, in figure 2. The consistent negative trend implies that wage aspirations of real wage growth exceed productivity, with a consequent positive impact on inflation. The results illustrate that the coefficient of the productivity term is negative and significant. The results also display that the supply shock is positively correlated with inflation.

The results from the estimation of each of the specification are presented in tables 1 through 4. The results demonstrate a fairly strong negative relationship between the unemployment gap and inflation thereby rejecting the hypothesis that the unemployment gap is not significantly different from zero at the 5% level. The estimates of the sum of the coefficients on the unemployment gap ranges between -0.05 and -0.15, and implies that increases in employment, above full employment level, will lead to increased inflation.

Table 1: Univariate NAIRU Model

Method: Maximum likelihood (Marquardt)
Sample: 1994Q1 2008Q1
Included observations: 55

	Coefficient	Std. Error	Prob.
C	0.041490	0.003111	0.0000
$(u_{t-1} - u^*_{t-1})$	-0.100000	0.000113	0.0000
$\Delta\pi_{t-1}$	0.834070	0.000320	0.0000
X_{t-1}	0.400000	0.078034	0.0000
Log likelihood	-18766.18		
NAIRU Average SE	0.030324		
Diffuse priors	5		

Table 2: Bivariate NAIRU Model

Method: Maximum likelihood (Marquardt)
Sample: 1994Q1 2008Q1
Included observations: 55

	Coefficient	Std. Error	Prob.
$(u_{t-1} - u^*_{t-1})$	-0.055000	1.53E-06	0.0000
$\Delta\pi_{t-1}$	0.500000	6.18E-08	0.0000
X_{t-1}	0.200000	0.036521	0.0000
Log likelihood	-28658.77		
NAIRU Average SE	0.034446		

Table 3: Univariate NAIRU Model with Productivity

Method: Maximum likelihood (Marquardt)
Sample: 1994Q1 2008Q1
Included observations: 44

	Coefficient	Std. Error	Prob.
C	1.388846	0.000411	0.0000
$(u_{t-1} - u^*_{t-1})$	-0.099754	1.11E-10	0.0000
$\Delta\pi_{t-1}$	0.399999	1.79E-05	0.0000
X_{t-1}	0.186552	0.002596	0.0000
$(\theta_t - A_t)$	-0.028494	8.95E-05	0.0000
Log likelihood	-93848.30		
NAIRU Average SE	0.030616		
Diffuse priors	5		

Table 4: Bivariate NAIRU Model with Productivity

Method: Maximum likelihood (Marquardt)
Included observations: 44

	Coefficient	Std. Error	Prob.
$(u_{t-1} - u^*_{t-1})$	-0.150000	1.34E-09	0.0000
$\Delta\pi_{t-1}$	0.900000	1.71E-06	0.0000
X_{t-1}	0.210000	0.024468	0.0000
$(\theta_t - A_t)$	-0.040000	0.000412	0.0000
Log likelihood	-1067.60		
NAIRU Average SE	0.03293		

Examining the log likelihood statistics of the smoothed NAIRU estimates, the results indicate that the bivariate specifications (tables 2 and 4) outperform the univariate specification (tables 1 and 3). The results indicate that the significance of the unemployment gap increases when the productivity term is added to both the univariate and bivariate NAIRU specifications (see figure 3, 4 and 5). The bivariate model with productivity is therefore the preferred model.

A comparison of the results reported in tables 3 and 4 shows that by adding an autoregressive structure of the unemployment gap to the Phillips equation lead to an increase in magnitude of the unemployment gap. The Kalman filter NAIRU is estimated as an autoregressive process that mirrors the random walk specification, as seen in other studies. Intuitively, the auto-regressive form is consistent with the NAIRU adjusting only slowly to enduring supply shocks. Furthermore, the autoregressive structure is important in a short term forecasting context as "changes in the estimated NAIRU over the recent past may provide information relevant to its likely future profile" (Richardson, 2000). The inclusion of the auto regressive structure of the unemployment gap results in a greater amount of information. The Kalman smoother was used to obtain the point estimates and standard errors[7]. The maximum likelihood estimation of the model produce results in accordance with *a priori* expectations from theory.

Results from the granger causality tests reject the hypothesis that changes in the unemployment gap does not Granger cause changes in inflation for the bivariate model with productivity (table 5)[8]. Additionally, granger causality tests reject the hypothesis that changes in wages does not Granger cause changes in inflation as well as the hypothesis that the unemployment gap of the bivariate specification does not Granger cause wages.

6.0 Conclusion

The concept of the NAIRU plays an important role in the conduct of monetary policy. This paper estimates and assesses several specification of the time varying NAIRU for Jamaica and examines its usefulness in the conduct of monetary policy. Using a Kalman filter framework, the paper finds that the NAIRU estimates are considerably improved when productivity is accounted for.

The results demonstrate a fairly strong negative relationship between the unemployment gap and inflation. The productivity-augmented NAIRU illustrate a consistent negative trend, which implies that wage aspirations of real wage growth tend to exceed productivity, which have a positive impact on inflation. Using the log likelihood test the bivariate specification with productivity produces more precise estimates of the NAIRU. Granger causality test reject the hypothesis that the unemployment gap does not granger cause changes in inflation. The downward sloping excess wages shows that continuous wage increases above the productivity is significant and causes increased inflation.

There are further extensions and avenues to enhance the use of the NAIRU in policy decisions. Among these extensions is an exploration of whether the unemployment rate adjusts in a linear or nonlinear fashion (Szeto and Guy, 2004). Additionally,

[7] Intuitively this implies full information.
[8] This result was found for all models with the exception of the univariate model without productivity.

investigations should be made to determine whether forecasts of inflation are heavily dependent on the value of the NAIRU gap in comparison to other leading indicators of inflation such as capacity utilization, interest rates or other labour market variables (Stagier et al, 1997).

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Appendix

Figure 3: Univariate NAIRU Model

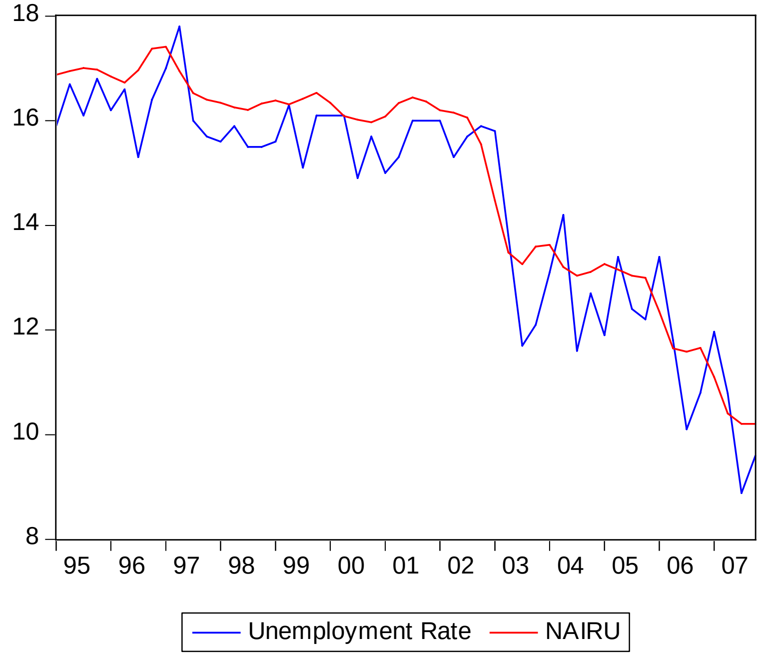

Figure 4: Univariate NAIRU Model Including Productivity

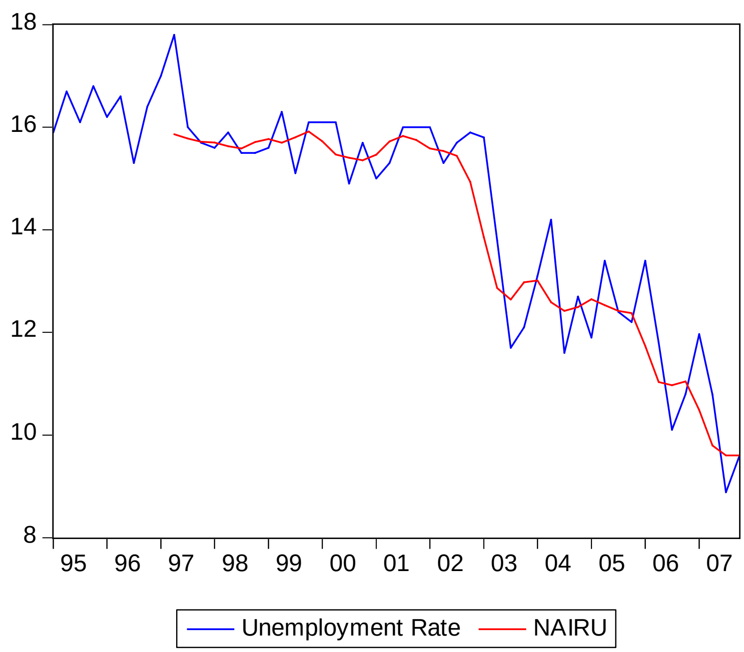

Figure 5: Bivariate NAIRU Mmodel

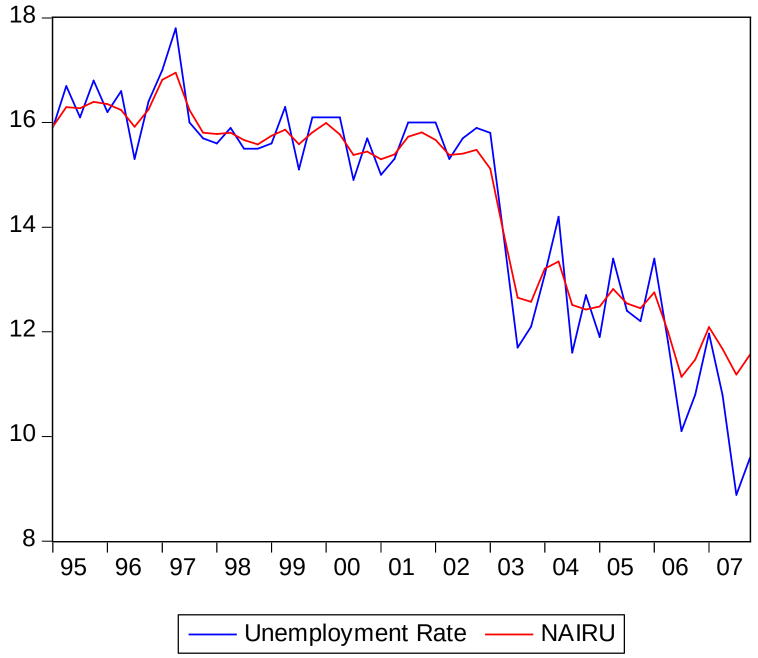

Figure 6: Bivariate NAIRU Model Including Productivity

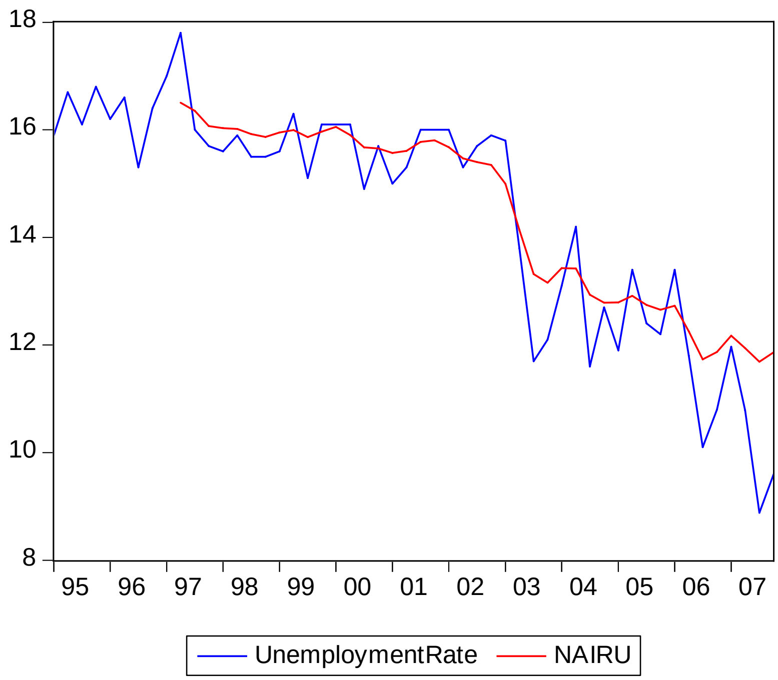

Table 5: Granger Causality of the Bivariate NAIRU Model with Productivity

Pairwise Granger Causality Tests
Sample: 1996Q1 2007Q4
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Probability
Unemployment Gap does not Granger Cause WAGES	42	7.55156	0.00903
WAGES does not Granger Cause Unemployment Gap		0.06062	0.80681
Inflation changes does not Granger Cause WAGES	47	1.31168	0.25828
WAGES does not Granger Cause Inflation changes		2.90654	0.09527
Inflation changes does not Granger Cause Unemployment Gap	42	5.47033	0.02456
Unemployment Gap does not Granger Cause Inflation changes		8.89869	0.00490