(DRAFT)

NAIRU: Is it Useful for Monetary Policy in Jamaica?

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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 Kalman and HP filters, the study finds support for the hypothesis that the unemployment gap explains in part, the dynamics of inflation in Jamaica. However, 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 has a consistent negative trend, which implies that wage aspirations tend to exceed productivity, with a positive impact on inflation.

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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 posits that the unemployment rate plays a role in the transmission from unanticipated changes in aggregate demand to inflation. 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 leading 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 paper estimates a time variant NAIRU for Jamaica between 1994 and 2007 using unobserved components models. State space models are used as sincethe NAIRU is unobserved but is assumed to be persistent. The analysis explicitly accounts for changes in labour productivity in the economy. The implications of the NAIRU in the assessment of inflationary pressures are also examined. This is motivated 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). Given that monetary policy should be pre-emptive to control for inflation and that the effects of monetary policy have long lags (Estrella and Mishkin, 1998), the estimation of the Jamaican NAIRU is an attempt to include 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 NAIRU. Section 3 sets 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 implies that inflation will stabilize at the permanently higher level. Tight labour markets induce employees to bid for higher wages, which given that labour is generally 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 on econometric models that allow for variation in the NAIRU overtime. The NAIRU in the short run is therefore more volatile and often affected by structural changes as well as supply shocks (Staiger, Stock, & Watson, 1995). The determinants of the NAIRU are assumed to be influenced by inter alia demographics and technological changes which give merit for the variable to be modelled as persistent (Laubach, 2001). 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 use has to be seen within the context of the uncertainty as identified by Stagier,

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Stock and Watson (1997). This uncertainty relates to the specification of a "proper model", the smoothness parameter and the margin of error associated with the estimated parameters. The empirical literature generally finds large standard error bands around the Kalman filter estimates (Greenslade (2003), Slacelak (2005), Stagier et al., (1997)). 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. 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. However, they warn against the improper use of the NAIRU as a potential target given its short run construct.

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.

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 long run concept of the NAIRU which controls for shocks 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

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

shortcomings include dependence on the assumptions of the underlying behaviour of economic agents for which there is no general consensus. Further, the intricacy 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, so that on average, the unemployment rate will be close to 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, its variance as well as the relationship between the trend and 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.

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. 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 over the period 1980 to 1999. The shocks used in the study are real import and oil prices. The results found support for the statistical significance of the NAIRU in explaining movements in the inflation. 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 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 in predicting changes in infaltion, 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) but uses a 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 purely 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.

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[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.

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 NAIRU is inferred from a Phillips curve-type regression of the following form:

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

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 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.

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:

$$\Delta\pi_t = \beta(L)\Delta\pi_{t-1} + \gamma(L)(U_{t-1} - U_{t-1}^*) + \delta(L)X_{t-1} + \varepsilon_t \qquad \varepsilon_t \sim N(0,\sigma_\varepsilon^2) \quad (2)$$

$$U_t^* = \eta U_{t-1}^* + v_t \qquad\qquad v_t \sim N(0,\sigma_v^2)$$

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

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 NAIRU.

The univariate NAIRU is modelled as an unobserved stochastic component, 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 used with the assumption that the unemployment gap has a tendency to revert to a zero mean over time thereby imposing some structure on the unemployment gap. i.e.,

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

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.

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

The Kalman filter estimates the reduced-form Phillips curve jointly with the NAIRU[5]. 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 paper draws on both Laubach (2001) and Ball and Moffitt (2001) who considers a specification of the NAIRU without drift.

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).

4.2   Incorporating Productivity

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. Assuming mark-ups are constant price setting in this model is given by

$$\pi_t = \omega_t - \theta_t + \upsilon_t \qquad\qquad (4)$$

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[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.

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.

The wage-setting process assumes that in the steady state, where there is flexibility, the equilibrium 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:

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

(5a)

where β is the discount factor which is the weight placed on past levels of real wage growth. Rewriting equation 5a recursively gives:

$$A_t = \beta A_{t-1} + (1-\beta)\left(\omega_{t-1} - \pi_{t-1} \right)$$

(5b)

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] 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.

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

Combining equations (4) and (5a), 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:

$$\left(\omega_t - E_{t-1}\pi_t\right) = \alpha - \gamma U_t + \delta\theta_t + (1-\delta)A_t + \eta_t \qquad (6)$$

where E_{t-1} is the expectations operator. 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 (6) into the price setting equation (4), assuming adaptive expectations (i.e. $E\pi_t = \pi_{t-1}$) and allowing supply shocks, S_t, the productivity-augmented Phillips curve is:

$$\pi_t = b(L)\pi_{t-1} + c_1\left(U_{t-1} - U^*_{t-1}\right) + \delta(L)X_{t-1} - f_1\left(\theta_{t-1} - A_{t-1}\right) + \varepsilon_t \qquad (7)$$

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

Equation (7) 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 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 (2)).

2. Univariate NAIRU model including productivity (Equation (7) and (9)).

3. Bivariate NAIRU model (equations (3) and (2)).

4. Bivariate NAIRU model including productivity (Equation (3), (7) and (9)).

4.3 Estimation issues

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.

4.4 Data

The study uses quarterly data over the period 1994:1 to 2007:4. The measure of inflation used in the study is the change in the Consumer Price Index (CPI). Jamaica's official unemployment rate is defined as those persons of *working age* (14 years and older) who were (a) without work during the reference period; (b) currently available for work; (c) seeking work, and also includes persons who are not seeking work[7]. The unemployment

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[7] This relaxed definition follows the international standards on the basis that in many developing countries the labour market is largely unorganised, most workers are self-employed or informally employed and that

rate was not entered contemporaneously so 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 variable, which is expected to revert to zero after a year, is import prices measured by an index of imported raw materials and food prices. Laubach (2001) in their study found the coefficients for the univariate model ranging between 0.09 and 0.26. 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.

Figure 1 shows that both the unemployment rate and the inflation series were relative stable 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 volatile 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).

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there may be situations in which persons do not actively seek work because they believe that there will be no demand for their skill.
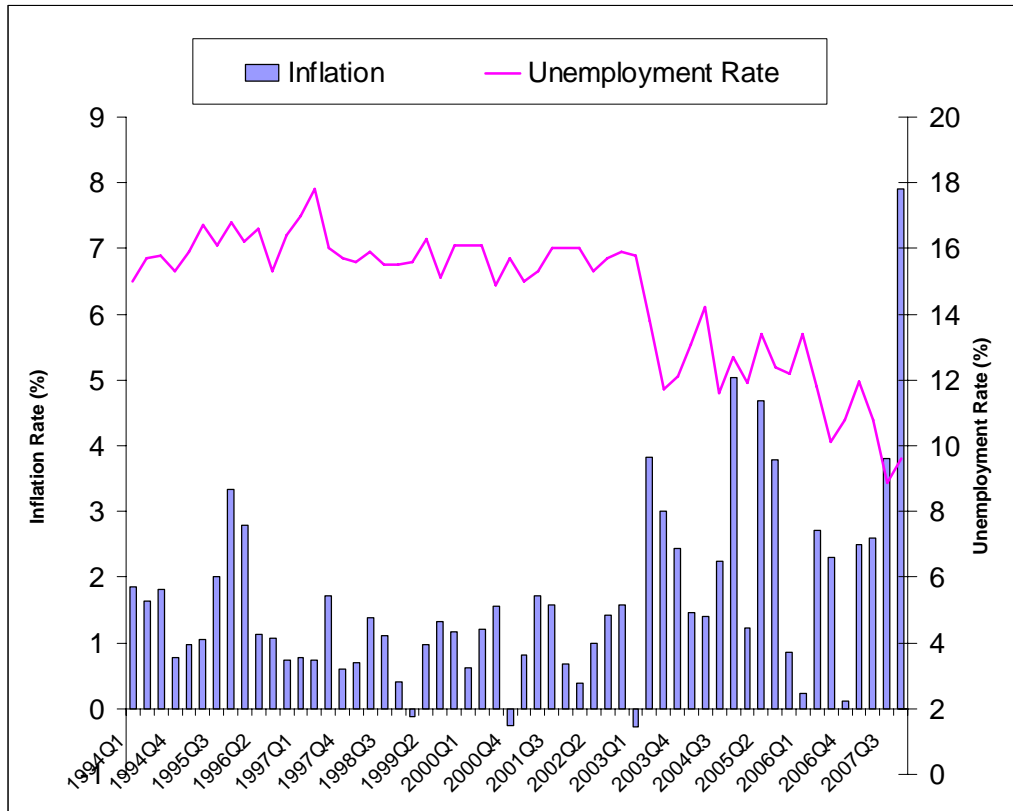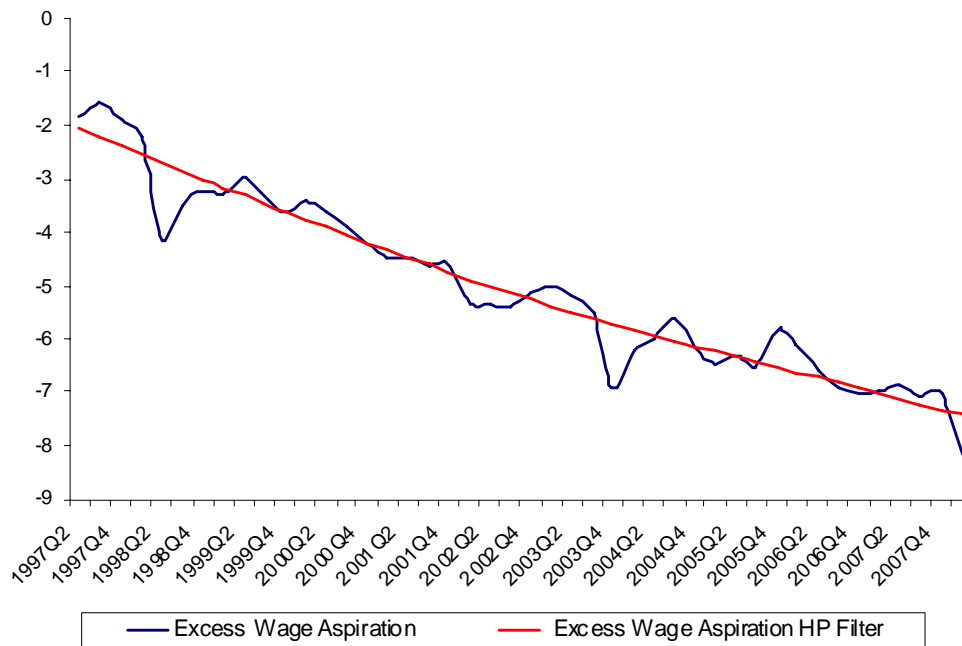
Figure 1: Jamaica Unemployment rate and Inflation

Figure 2: Jamaica Labour Productivity minus Wage Aspirations

5.0   Results

The difference between θ_t and A_t is graphed with its HP-filtered trend, 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 and 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.   They demonstrate a fairly strong negative relationship between the unemployment gap and inflation with the coefficient being significantly different from zero at the 5% level. The estimates of the coefficient 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 Tables1, 2, 3, and 4). 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 size 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 Kalman smoother was used to obtain the point estimates of each specification (see figure 3, 4 and 5 in the appendix).

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 the unemployment gap of the bivariate specification does not Granger cause wages. The hypothesis that changes in wages does not Granger cause changes in inflation was rejected at the 10 percent level which maybe indicative of feedback.

6.0 Conclusion

The concept of the NAIRU can play 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 for 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 negative relationship between the unemployment gap and inflation. The productivity-augmented NAIRU has 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.

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[8] This result was found for all models with the exception of the univariate model without productivity.

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Appendix
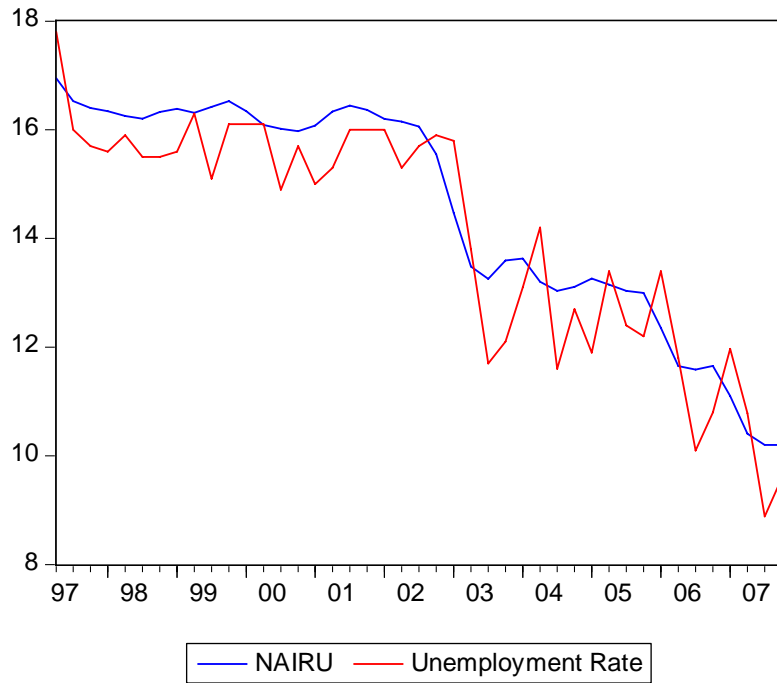
Figure 3: Univariate NAIRU Model

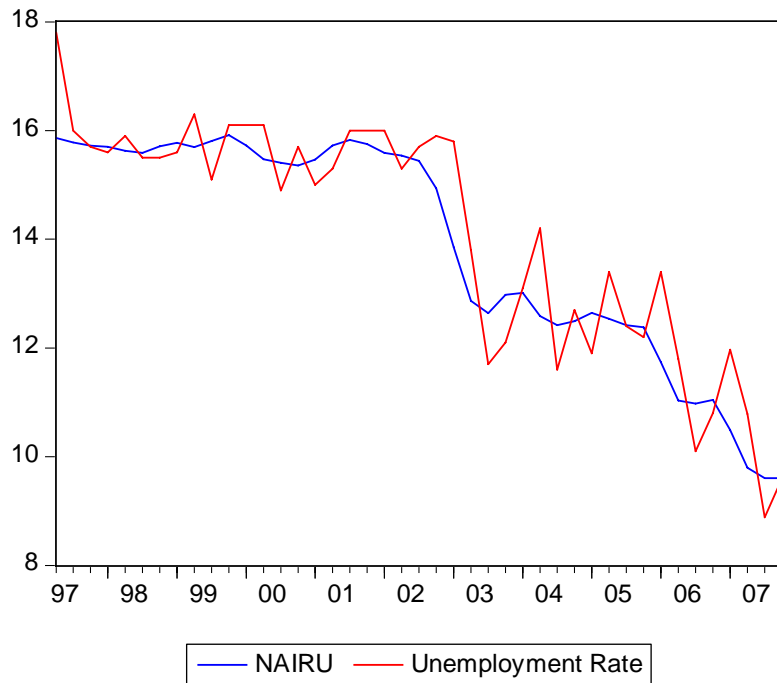**Figure 4: Univariate NAIRU Model Including Productivity**

Figure 5: Bivariate NAIRU Mmodel

NAIRU — Unemployment Rate

Figure 6: Bivariate NAIRU Model Including Productivity

Unemployment Rate — NAIRU

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