Estimating the Natural Rate of Interest for Jamaica

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PRELIMINARY DRAFT

Abstract

Economic theory reveals that the natural rate of interest plays an important role in the conduct of monetary policy. In this study we jointly estimate the natural rate of interestand potential output in an effort to identify the importance of the natural rate of interest in Jamaica. In the analyses, the Kalman filter technique is applied to a state space model of the economy to estimate these unobserved variables for the period 1990:1 to 2011:1.It was found that there exists a negative relationship between the natural rate of interest and inflation. The impact of the interest rate gap on inflation was found to be weak and the interest rate gap affects inflation with a lag. Additionally, estimates generated revealed that actual interest rates are currently below the natural rate of interest a phenomenon that may exert inflationary pressures on the economy in the future.

JEL Classification: C3, E43, E52, O40

Keywords: Kalman Filter, state space models, natural rate of interest, interest rate gap, potential output, output gap, credit channel

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[♣] The views expressed in this paper are those of the author and do not necessarily represent those of the Bank of Jamaica.

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1. Introduction

For the greater part of the last two decades, Jamaica has been caught in a vicious cycle of low growth and unsustainable fiscal and debt dynamics. The 2008 global financial crisis worsened the economic conditions and with the severe demand pressures in the foreign exchange market, the central bank raised interest rates in late 2008. During this period the economy experienced unstable domestic financial markets, increasing inflation and a condition of low domestic output (BOJ Annual Report, 2009). Subsequent to the settling of the domestic financial markets and in an effort to spur economic growth, the central bank commenced an easing of its monetary policy stance by lowering interest rates in 2009[1]. The rise in economic confidence resulting from the engagement of an IMF Stand-By Arrangement, stability of the exchange rates and low inflation expectations facilitated the further lowering of interest rates in 2010.

Like other central banks, the Bank of Jamaica is charged with the responsibility of undertaking the country's monetary policy to achieve stable prices. This is achieved primarily by making appropriate changes to its short-term nominal interest rate. In light of this approach monetary policymakers commonly need a benchmark to assess whether the level of interest will stimulate or contract the economy. This benchmark is generally called the 'natural rate of interest' (Archibald and Hunter, 2001).The natural rate of interest broadly put, is the real interest rate consistent with an output gap of zero and inflation rate stable at its target.

In light of its ability to assist in the stabilizationof prices the natural rate of interest which dates back to the seminal work of Wicksell (1898)has received increasing attention in recent years. Wicksell stated that there exists a negative relationship between inflation and the real interest rate gap (that is, real interest rate – natural rate of interest). Jonsson (2002) explains Wicksell'sframework that if the natural rate of interest exceeds actual interest rate the price level will increase as follows:

An increase in interest rate implies that firms' profits increase due to an increase in returns on their capital. This leads to an increased demand for labour and thus increased wages. The

[1] Additional measures taken to improve the economic and financial welfare included the introduction of the Jamaica Debt Exchange (JDX) and the signing of the Stand-By Arrangement with the International Monetary Fund (IMF) in February 2010.

higher wages increases households' demand for consumer goods and services which increase prices.

Similarly, Brzoza-Brzezina (2003) posits that real interest rate above (below) the natural rate of interest for a period of time would contract (stimulate) economic growth through lowered consumption and investment, and inflation would eventually fall (rise) in the absence of any shocks to the economy. Thus it is important to identify the natural rate of interest for any economy who seeks to maintain stable prices.

Although the natural rate of interest is a useful guide to policymakers, it is an unobservable variable and so must be estimated. Therefore this study seeks to generate estimates of the natural rate of interest for Jamaica, in an attempt to create a benchmark that policy rates can be measured against in the policymakers' effort to maintain stable price. Price stability is desirable because it creates a predictable environment that encourages investment and growth, and by extension increases the financial and economic welfare of the economy. Given the steady decline in the real interest rate in Jamaica, this study seeks also to provide clarity to the following questions: Can the real rate of interest be lowered further or have we passed the natural rate of interest?

The remainder of the paper is organized as follows. Section 2 examines the linkage between the natural rate of interest and inflation targeting. Section 3summarizes the relevant literatures. Section 4 outlines the models used andpresents a brief description of the data set. Section 5 presents the empirical results and discussion of these findings. Section 6 concludes the paper.

2. The Natural Rate of Interest and Inflation Targeting

This section identifies the importanceof the natural rate of interest in attaining stable prices. It outlines how countries use the natural rate as a policy instrument and how the manipulation of interest rate in response to the natural rate helps monetary policymakers.

Monetary policy is taken as the main macroeconomic policy. It is viewed as a flexible instrument, as it can adjust quickly in response to macroeconomic developments. The ultimate purpose of monetary policy is to maximize social welfare by attaining low and stable prices in the long run which according to Sarel (1996) is supportive of high and stable long term growth.

In recent years, several countries such as New Zealand and Canada have adopted inflation targeting (IT) as their main monetary policy objective. Arestis and Sawyer (2003) posit that inflation targeting mainly includes the setting of a numerical target range for the rate of inflation by the government or central bank, and the subsequent use of monetary policy as the key policy instrument to achieve the target, with monetary policy taking the form of interest rate adjustments. Given that (short-term) interest rate is the policy instrument that is directly controlled by the central bank, it is not surprising that inflation targeting countries use interest rate as their operating targeting guide.

Inflation targeting regimes set short-term interest above or below the natural rate of interest in order to keep inflation stable at its target. If actual output is greater than potential output, (a positive output gap) supply constraints tend to increase inflation above target. In response to this positive output gap, monetary policymakers set interest rate above its natural rate which places downward pressure on demand. This alleviates capacity constraints reducing the inflationary pressures that may arise. On the other hand, if actual output is below potential output (a negative output gap) policymakers are inclined to set interest rate below the natural rate increasing demand in an attempt to prevent inflation falling below target (Archibald and Hunter, 2001).

The Bank of Jamaica, in its conduct of monetary policy, focuses on maintaining low and stable inflation rates.In particular, since 2000 an inflation target has been announced at the beginning of each fiscal year. In a recent International Monetary Fund (IMF) report, Carare and Stone (2003)[2]categorized Jamaica as an Inflation Targeting Lite (ITL) based on its low credibility in inflation targeting (not being able to maintain its inflation target). The natural rate of interest is crucial for the conduct of monetary policy supportive of an inflation target, since it provides monetary policymakers with an indicative benchmark, by telling them whether a given interest rate is likely to contract or stimulate demand. Consequently, obtaining estimates of the natural rate of interest for Jamaica may facilitate the appropriate monetary policy stance; adjusting short-term interest rate above or below the natural rate, in response to demand shocks, in order to maintain an inflation target. The maintenance of the inflation target may increase the credibility of the Jamaican economy thereby promoting growth and development.

3.Literature Review

Economic literature reveals that a key variable in the conduct of monetary policy is the natural rate of interest. The natural rate of interest may be defined as the real interest rate consistent with an output gap of zero and inflation rate at its target. In the literature, various expressions are used for the natural rate of interest including the neutral real interest rate and equilibrium real interest rate. Additionally, the concept has also been differentiated based on time horizons; namely the short-term and long-term natural rate of interest. Archibald and Hunter (2001) consider the long-term equilibrium real interest rate as being the most stable, as it is a feature of the economy in the long run or when all markets are in equilibrium and there is no pressure for any resources to be redistributed or the growth rates for any variables to change. Given that it is often difficult to capture a state of equilibrium in all markets, the natural rate of interest for this study is defined as the real short-term interest rate consistent with output equaling potential and stable inflation[3].

Brzoza- Brzezina (2003) asserts that many countries have adopted the natural rate of interest given its applicability to a monetary policy regime of direct inflation targeting. Given that the natural rate of interest can be used to attain price stability, he estimates the natural rate of interest

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[2] Categorized inflation targeting countries into three groups: *Full-Fledged Inflation Targeting* (FFIT), the best known form of inflation targeting, *Eclectic Inflation Targeting* (EIT) and *Inflation Targeting Lite* (ITL).
[3]This definition is cited in the literature; see Laubach and Williams (2003), Garnier and Wihelmsen(2005).

in the United States for the period 1960 to 2002 using a Structural Vector Autoregressive (SVAR) model. His analysis reveals that the natural rate of interest varies over time and is correlated with the economic cycle. He posits that it is a pro-cyclical variable – increasing in times of boom and decreasing in recessionary times.

Ophanides and Williams (2002) estimate the natural rate of interest in their attempt to answer the question of how the central bank should conduct monetary policy in practice, given their objective to attain low and stable rates of inflation and full employment. Focusing on the United States over the period 1969:1 to 2002:2, they define the natural rate of interest as the rate consistent with unemployment being at its natural rate and therefore stable inflation. In their analysis they assume that the natural rate of interest follows a random walk. To estimate the natural rate of interest they use univariate filters such as Hodrick-Prescott (HP) and Band-pass filters to obtain one-sided[4] (real time) estimates as well as multivariate filters such as the Kalman filter to obtain two-sided (retrospective) estimates. The Kalman filter estimate was used as the baseline estimate. They conclude that the natural rate varies over time because it is likely to be influenced by variables such as trend income growth, fiscal policy and household preferences.

Using quarterly data Laubach and Williams (2003) seek to jointly estimate the short-term natural rate of interest, potential output and trend growth in the United States for the period 1961:1 to 2004:4. They allow for an explicit relationship between the natural rate of interest and trend growth rate of potential output. After estimating several variants of the IS and Phillips curve by maximum likelihood using the Kalman filter they conclude that the natural rate of interest varies over time, and document that the variation in trend growth rate is an important determinant of the variation in the natural rate of interest. They report that this result is robust to changes in model specification[5].

[4] A technique is one-sided if it only uses the information available up to time t to compute estimates of an unobserved variable. While a two-sided estimate uses all the available information in the sample (past and future information)to estimate a variable at time t.

[5] In addition to using the IS and Phillips curve as measurement equations in the state space model they use an equation that relates detrended private nonfarm employee hours to the output gap as in Roberts (2001).

Garnier and Wihelmsen (2005) apply the estimation technique put forward by Laubach and Williams (2003)[6] to estimate and compare the natural rate of interest in the US, Germany and the Euro Area. Using quarterly data for the period 1961:1 to 2004:1, they conclude that the estimated interest rate gap is negatively related to the output gap and inflation. Garnier and Wihelmsen (2005) like Laubach and Williams (2003) asserts that the natural rate of interest varies and associates the variation in the natural rate of interest with trend growth as well as household preferences.

After conducting one of the many studies to estimate the natural rate of interest in the United States, Clarke and Kozicki (2004) conclude that statistical estimates of the natural rate of interest is difficult to use reliably in practical policy as estimates may be distorted by different data sources and one-sided data filtering. In an attempt to mitigate such distortion, data for this study use the Kalman filter which is a multivariate two-sided approach in estimating the natural rate. Like Laubach and Williams (2003), Clarke and Kozicki (2004) argue that the real rate of interest can be linked to trend growth rate. They also model the natural rate of interest as a random walk which was put forward by Orphanides and Williams (2002). In this study both functional forms of the natural rate are investigated and a comparison conducted to assess possible differences in the estimates.

3.1 Problems Associated With the Estimation of the Natural Rate of Interest

Brzoza- Brzezina (2003) affirms that the main precondition for the gap between the real interest rate and the natural rate of interest to give helpful information about monetary policy stance is our ability to calculate and predict the future behavior of the natural rate of interest. There is however, uncertainty regarding the natural rate of interest and ambiguity about how best to estimate it. Laubach and Williams (2003), for example, state that there is a great degree of uncertainty regarding the estimation of the natural rate. Additionally, after assessing the impact of changes in the natural rate of interest they discover that large stabilization losses are associated with its misspecification. This point is also supported by Orphanides and Williams

[6] Maximum likelihood using the Kalman filter is applied to a small scale macroeconomic model, which encompasses an IS and a Phillips curve.

(2002) as they argue that the errors associated with the misspecification of the natural rate of interest can cause undesirable fluctuations in the economy, worsening stabilization performance.

Garnier and Wihelmsen (2005) argue that the estimation of the natural rate of interest is not straight forward and is associated with a very high degree of uncertainty. They warn that much work is still needed in the estimation of the natural rate of interest as estimates have relatively high variation when compared to real interest rates.

De-Juan (2007) on the other hand, concludes that a natural rate of interest does not exist as there is no gravity center for interest rates. Instead, he endorses a conventional rate of interest on which economic agents base their investment in real and financial assets. This conventional rate he asserts would be close to a natural rate variable if there was *only one interest rate compatible with price stability*. On the other hand, Archibald and Hunter (2001) postulate that the uncertainties[7] surrounding the determination of the natural rate of interest are very good reasons for not regarding the natural rate as being stable over time.

Though difficulties are encountered in the estimation of the natural rate of interest, its potential worth continues to encourage economists to improve their strategies. In light of this, several estimation techniques[8] have been used to estimate the natural rate of interest. In this present paper, however, maximum likelihood using the Kalman filter is adopted to estimate potential output and the natural rate of interest. In practice multivariate unobserved component models such as the Kalman filter are widely preferred to estimate the natural rate of interest because they exhibit distinctive advantages. They have the ability to provide economic interpretation for both unobserved variables and model parameters. They enable large changes in unobservable variables and can therefore manage and account for large shocks and many structural changes (Mesonnier and Renne, 2004). Since multivariate unobserved component models are able to give an explanation for changes in structural variables they may perform better in emerging economies that are exposed to large shocks such as Jamaica. It must also be noted that when used

[7] One of the uncertainties regarding unobservable variables, the natural rate of interest in particular is that different estimation techniques and data may yield different, though equally valid results.
[8] The Structural Vector Autoregressive (SVAR) models, Dynamic Stochastic General Equilibrium (DSGE) models, Hodrick-Prescott (HP) filter, the Band-pass (BP) filter are some of the techniques used to estimate the natural rate of interest.

with other techniques the Kalman filter has been the baseline estimate indicating that it has the least specification problem[9].

4. Empirical Framework

4.1 The Kalman Filter

This section seeks to give an overview of the estimation technique used in the analyses. The overview outlines the advantages of the Kalman filter in an attempt to provide reasons for why it one of the most popular techniques for modeling the natural rate of interest. Possible problems that may be encountered in the execution of the procedure are also noted.

The Kalman filter is a multivariate method used to estimate unobservable variables by specifying them as a function of observed variables in a state space form. The estimation utilizes a recursive procedure, which is combined with maximum likelihood techniques. The Kalman filter technique has proven more useful thantheunivariate HP filter(a popular but purely statistical method) because it combines economic theory with the time series techniques, hence it has the ability to provide economic interpretation for the unobserved variable.

A state space consists of two essential components, a signal or measurement equation which relates an unobserved variable (x_t) to an observable variable (y_t), and some state equations, which governs the theoretical behaviour of the unobserved variables. A state space model may be of the form:

$$y_t = \alpha x_t + \varepsilon_t \qquad \text{(Signal equation)}$$
$$x_t = x_{t-1} + \mu_t \qquad \text{(State equation)}$$

where y is some observed variable and x the unobserved variable. The ε and μ are white noise processes and α measures the association between $y$and$x$.

[9]Orphanides and Williams (2002) argue that the magnitude of the misperception associated with the Hodrick-Prescott (HP) and the Band-pass (BP) filters are twice that implied by the Kalman filter.

It is important to note that the estimates of the natural rate of interest and potential may be imprecise given the pitfalls associated with the Kalman filter technique. The estimation results are sensitive to initial specifications of the model and the selection of starting values for the parameter. In spite of these potential problems the kalman filter is still the more useful alternative when compared with univariate techniques.

4.2 The Model

In estimating the natural rate of interest we adopted the empirical framework put forward by Laubach and Williams (2003) and Garnier and Wihelmsen (2005). They proposed a model of neo-Keynesian inspiration which defines the behavior of the interest rate gap, inflation and the output gap through variants of the IS and Phillips curves. Equations 1 and 2 specifies the IS and Phillips curve, respectively:

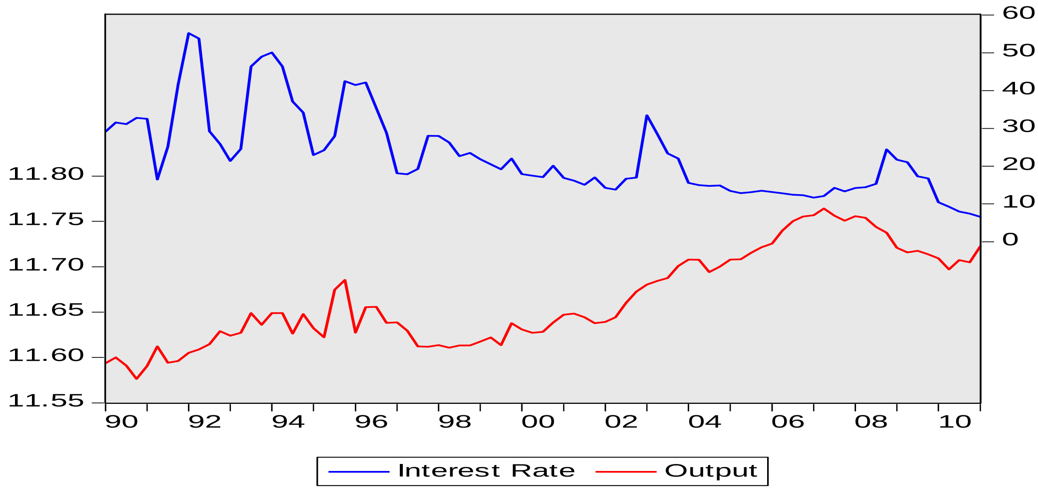
$$\tilde{Y}_t = \alpha_y(L)\tilde{Y}_{t-1} + \alpha_r(L)(r_{t-1} - r^*_{t-1}) + \varepsilon_{\tilde{Y}t} \tag{1}$$

$$\pi_t = \beta_\pi(L)\pi_{t-1} + \beta_{\tilde{Y}}(L)\tilde{Y}_{t-1} + \beta_x(\mathrm{L})x_{t-1} + \varepsilon_{\pi t} \tag{2}$$

where$\tilde{Y}_t = Y - Y^*_t$ denotes the output gap, Y is the logarithm of the seasonally adjusted real gross domestic product (real GDP)and Y^* represents potential output. The interest rate is denoted by r while r^*represents the natural rate of interest. The t notation indicates time and ε is the serially uncorrelated error term, α_y measures persistency of the output gap and α_r captures the association between the output gap and the interest rate gap $(\tilde{r_t} = r_t - r^*_t)$. The symbol π represents the inflation rate, with the lag of inflation, π_{t-1}, being used as a proxy for expected inflation. The variable$x$captures all other determinants of inflation such as imported inflation.

Equation 1 is a reduced form aggregate demand equation or the IS equation which relates the output gap to lags of itself and the interest rate gap. Essentially, the IS curve is a macroeconomic tool that demonstrates a negative relationship between interest rates and real output (i.e. $\alpha_r < 0$) in the goods and services market. Figure 1 is a graphical representation of the trend in real GDP and interest rate for Jamaica and it reveals that the relationship between output and interest rate in the Jamaican economy is not exclusively negative. Instead a negative relationship seems to exist for the period 1990:1 to 2008:2 after which the variables exhibit a positive relationship. This contradicts theory and may prompt unexpected results. It must be noted however, that output in Jamaica is largely affected by external factors (adverse weather and increases in oil prices for example). In light of this, the global financial crisis of 2008 had a significant impact on the economy and so the subsequent fall in output may have resulted from the global crisis and not due to changes in the interest rates[10].

Figure 1: Jamaica's Real GDP and Interest Rate



The second equation is an aggregate supply equation or a standard Phillips curve where inflation is defined by its lags, the output gap and imported inflation. This equation identifies how shocks to the output gap affect inflation in the Jamaica.

Economic theory reveals that real interest rate can be decomposed into a trend (the natural rate of interest) and a cyclical (the interest rate gap) component (see for e.g. Garnier and Wihelmsen 2005; Cour-Thimann et al 2004; Woodford 2003; Neiss and Nelson 2003). This approach is used in this study and so real interest rate is specified as:

$$r_t = \tilde{r}_t + r_t^* \tag{3}$$

[10] It has been found in previous studies that the impact of the interest rate on output is weak in Jamaica.

Output is also decomposed into its permanent and cyclical components; potential output is identified as the permanent component while the cyclical component represents the output gap. Output is therefore defined as:

$$Y_t = \tilde{Y}_t + Y^* \quad (4)$$

Equations 1 to 4 constitute the signal equations of the state space models.

Based on the theoretical link between the natural rate of interest and the growth rate of potential output put forward by economists such as Laubach and Williams (2003) the natural rate of interest is specified as:

$$r_t^* = cg_t + z_t \quad (5)$$

Where$g$ represents the growth rate of potential output and z captures all other determinants of the natural rate of interest, both $g$and$z$are unobserved variables. Laubach and Williams (2001) considered z as both a stationary AR process and a random walk. According to Garnier and Wihelmsen (2005) the estimation of z is associated with problems[11] when it is specified as a random walk and to evade these problems they define $z$as a stationary AR process. In addition, Laubach and Williams (2003) posit that in cases where $z$is nonstationary, any inferences regarding c are invalid, for this reason they do not report statistics for the estimates of c when z is defined as a random walk. Consequently, z is assumed to be a stationary AR(2) process.

$$z_t = \Phi_1 z_{t-1} + \Phi_2 z_{t-2} + \varepsilon_{z_t} \qquad \text{where} \Phi_1 < 1 \quad (6)$$

Potential output[12] is defined as a random walk with drift and is therefore specified as:

[11]In applying the Kalman filter to the model, maximum likelihood estimates of the standard deviation of the innovations of z,σ_z, are likely to be biased towards 0, owing to the *so-called pile-up problem* (Laubach and Williams, 2003).
[12]Potential output refers to the highest level of real GDP output that can be sustained over the long term. The existence of a limit on output is due to natural and institutional constraints

$$y_t^* = \; c + y_{t-1}^* + \; \varepsilon_{y_t^*} \qquad (7)$$

The output gap is defined as a stationary autoregressive (AR) process consistent with studies using unobserved component models (see for e.g. Watson (1986); Roberts (2001); Kuttner (1994)).

$$\tilde{Y}_t = \; \partial(L)\tilde{Y}_{t-1} + \; \varepsilon_{\tilde{Y}_t} \qquad \text{where} \;\; \partial < 1 \qquad (8)$$

Equations 5 to 8 are used as state equations in the state space models.

4.3 Data

The sample consists of quarterly observations from 1990:1 to 2011:1 and the set of variables includes interest rates, inflation, real GDP and imported inflation.

The 180-day Treasury Bill rate (irate) was used as a proxy for the interest rate. The 180-day Treasury Bill rate was used because it is the most popular market derived rate and most responsive to changes in the economy, and often used as a reference point for the risk-free rate[13].

Real GDPwas used as a measure of output. Quarterly data for real GDP as well as data for the 180-day Treasury Bill rate were collected from the Bank of Jamaica.

Core inflation (dcore), a less volatile measure of price changes was used as a proxy for inflation rate. The change in the Consumer Price Index (CPI) was used asan alternative estimate of inflation.Both measures are included in the analysis to assess whether the relationship between inflation and the interest rate gap varies based on the definition of inflation. Core inflation was defined as CPI net food and fuel.

Given Jamaica's openness and dependence on imported commodities, imported inflation is an important determinant of inflation in Jamaica. Imported inflation was defined as a combination

[13]The 180-day Treasury Bill rate is the interest rate that investors can seek returns on their funds without any risk.

of the Jamaica's exchange rate and US CPI. The choice of the US variables is due to the high level of trade that is carried out with that country[14].

5. The Estimation Methodology

In order to reduce problems associated with the misspecification of variables each time series was reviewed individually and the appropriate transformation performed. To ensure comparability we take the log of CPI, core inflation and real GDP. To control for seasonal differences the log of CPI (lcpi) and the log of real GDP (lrgdp) were seasonally adjusted using the US Census Bureau's X12 seasonal adjustment methodology included in the Eviews package. The seasonally adjusted CPI series as well as the log of core inflation were then differenced to capture a change in prices. All series were then checked for stationarity using both the Augmented Dickey-Fuller and the Phillips-Perron unit root tests. The result of each test is presented in Table 1.

Table 1: Unit Root Tests

1990:1 - 2010:4	ADF		PP		Degree of Integration
	Levels	**Difference**	**Levels**	**Difference**	
Null Hypothesis	There is a unit root		There is a unit root		
Variables					
dlcpi_sa	-5.287**		-3.905**		I(0)
impinf	-3.865**		-3.590**		I(0)
irate	-1.257	-6.741**	-2.114	-9.434**	I(1)
lrgdp_sa	-1.571	-5.492**	-1.571	-8.763**	I(1)
dlcore	-3.151*		-4.903**		I(0)

ADF represents the Augmented Dickey-Fuller unit root test, PP represents the Phillips-Perron unit root test. Asterisk,* represents 5% level of significance and ** represents 1% level of significance. I(0) indicates that the variable is stationary in levels while I(1) indicates that the variable is stationary after first difference.

Additional diagnostic testswere conducted to identify and correct for structural breaks in the series. The Chow Breakpoint test was used to assess the statistical significance of each structural break and dummy variables were created to capture significant breakpoints in the series.

[14]The US is Jamaica's main trading partner; trade with the US accounts for approximately 40% of total trade.

The estimation procedure follows two main steps. In the first step we generated estimates for potential output[15],its growth rate and the output gap. In the second stage we estimated the natural rate of interest and the interest rate gap.

In estimating potential output using the Kalman filter, initial values were derived from using Ordinary Least Squares (OLS) estimation technique. Firstly, output was decomposed into its permanent and transitory components as outlined in equation 4. The permanent component of actual output (aproxyforpotential output) was specified as AR process with dummies controlling for structural breaks. OLSestimation technique was used to estimate coefficients of this equation. The cyclical component (a proxy for the output gap) was regressed on lags of itself in order to identify its functional form and to obtain the corresponding coefficients values. Due care was taken to ensure that residuals obtained from each regression was normally distributed. Preliminary estimates from both OLS regressions were used as starting coefficients values for the maximum likelihood estimation of the coefficients, in line with the approach taken by Garnier and Wihelmsen (2005). Equations2 and4were the signal equations, and equations 9 and 10 specify the respective state variables for the state space model used to generate estimates for potential output and the output gap. The lag lengths in all equations were determined by the data. Specifically, we include one lag of the output gap in equation 2, two lags of inflation and impose the restriction not rejected by the data that the coefficients sum to unity[16]. The output gap was defined as a stationary AR(3) process.

In the second stage of the estimation equations 1 and 3 were used as signal equations and equations 5 and 6 used as state equations. A similar approach to that outlined above was taken to obtain starting coefficients values for the state space model. Specially, interest rate was decomposed into its cyclical and permanent components as outlined in Equation 3, and OLS used to generate starting coefficients values. The interest rate gap was defined as a stationaryAR(2) process. The IS curve included one lag of the output gap and two lags of the interest rate gap. At the end of each stage correlation coefficients were calculated to assess the linear relationship between the variables estimated and both measures inflation.

[15] In the estimation of potential output, it growth rate g is treated as a constant.
[16]Laubach and Williams (2001) also restricted the coefficients on the lags of inflation to sum to unity.

The univariate HP filter is often used to estimate the potential output, as a result, HP filter estimates of potential output and the natural rate of interest are generated and compared with the Kalman filter estimates (see Figures 5 and 6 in the Appendices). Additionally, correlation coefficients are generated (see Table 6 and 7 in the Appendices) in order to assess whether the association between the HP filter estimates of the output gap and inflation as well as the association between the interest rate gap and inflation are in line with theory.

5.1 Estimation Results

Table 2below outlines the results of the state space models used to obtain estimates of potential output and the output gap.

Table 2:State Space Model: Kalman Filter Output Estimates

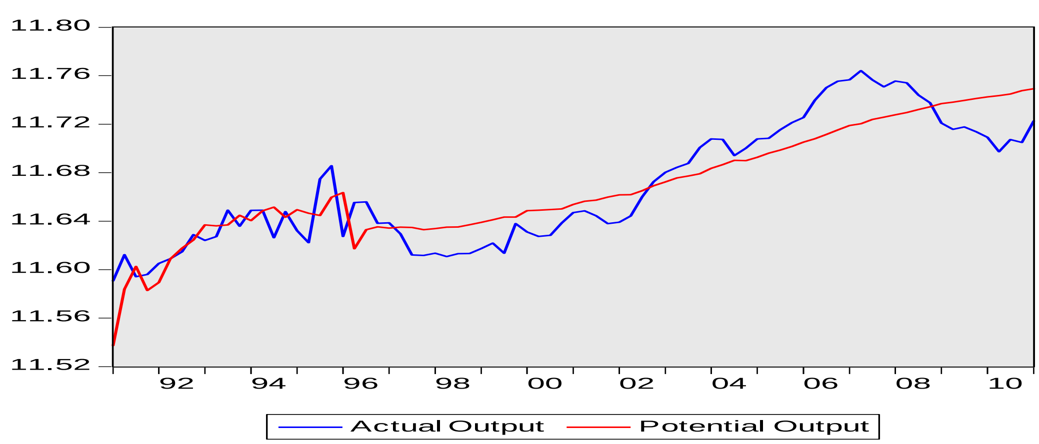
	Estimates	
constant	0.002**	
	(0.001)	
Parameters		
β_π	0.483***	
	(0.102)	
$\sum\alpha_y$	0.860	
$\beta_{\tilde{Y}}$	0.041	
	(0.058)	
β_x	0.071***	
	(0.017)	
Error variance		
σ_{Y^*}	0.0000	
σ_π	0.0001***	
$\sigma_{\tilde{Y}}$	0.0002***	
State variables		Root MSE
Y^*	11.752***	0.009
$\tilde{Y}_t$	-0.024**	0.016
Sample: 1990:1 2011:1		
Included observations: 85		
Convergence achieved after 42 iterations		

Notes: Estimates for potential output and the output gap were obtained by Maximum Likelihood using the Kalman filter. For each state space model (each column) the first value represents the estimated coefficient and the value in parentheses(), the standard errors. In Column 1core inflation is used as the proxy for inflation while headline inflation is used in Column 2.Asterisk, * represents 10% level of significance, ** represents 5% level of significance and***indicates significance at the 1% level. MSE represents Mean squared error

The root mean squared error is a good measure of precision as it captures the differences between values predicted by the model and the actual values. The root mean squared error for both potential output and the output gap are small which suggests that estimates of these variables are close to their actual values.

Inflationary pressures can come from a number of sources. Archibald and Hunter (2001) postulate that capacity constraint in the economy is a source of inflation as it may give rise to increased pressures on factor prices, such as labour and capital costs. If actual output rises and stays above potential output inflation may increase (in the absence of controls) as demand exceeds supply.The graphical representation of potential output against actual output, Figure 2, reveals that in 1991, 1995, 1996 as well as in the period 2002 to 2008, actual output was greater than potential output, an indication of high levels of inflation. These periods were indeed inflationary, suggesting that the positive output gap contributed to some of the inflation that was experienced. These periods were also characterized by the economic liberalization, financial crisis as well as high commodity prices which also contributed to the high inflation experienced.

Figure 2: Actual Output and Potential Output



There was a negative output gap during the period 1996:3 to 2002:4 which suggests that there was low inflation; this coincides with the time period in which Jamaica recorded low levels of inflation (see Figure 4 in the Appendices). Our findings therefore indicate that the negative output gap may have contributed to the low level of inflation thatpersisted during the above mentioned time period. Since the first quarter of 2009, there has been a negative gap and the economy has also been experiencing relatively low levels of inflation.

To further assess the accuracy of the estimates obtained correlation coefficients were calculated to determine whether the anticipated positive correlation between the output gap and inflation was achieved. Table 5in the Appendices, shows that both headline inflation and core inflation are both positively related to the output gap which is consistent with theory. It must be noted that in Jamaica, of the three main contributors to inflation, expectation, the output gap and imported inflation, the output gap has the least impact. Consequently, the relatively low correlation coefficients were anticipated.The correlation between core inflation and the output gap however, is twice that of headline inflation and the output gap. The stronger association with core inflation as oppose to headline inflation may exist because core inflationcan be considered as a more precise estimate of underlying demand.Given that our expectations were met, the output gap and the growth rate of potential output were used to generate estimates of the natural rate of interest using the Kalmanfilter.Estimates from this state space model are outlined in Table 3 below.

Based on the findings presented in Table 3 below only the second lag of interest rate gap is statistically significant in the IS equation. This suggests that in Jamaica changes in the interest rate gap affect the output gap with a lag.

Figure 3 reveals that the natural rate of interest in Jamaica varies over time, a result that is consistent with the theory put forward by Laubach and Williams (2003). They attributed the variation in the natural of interest in the US to trend growth. Specifically they found that the natural rate of interest varies one-to-one with trend growth. For Jamaica, we found that though negative and consistent with theory, the coefficient on the growth rate is moderate and statistically insignificant. This seems to suggest that in Jamaica the natural rate of interest is dependent on factor outside of the growth rate of potential output such as household preferences and fiscal policy captured by z. This is not surprising as theory puts forward a weak association between the interest rate and output in Jamaica.

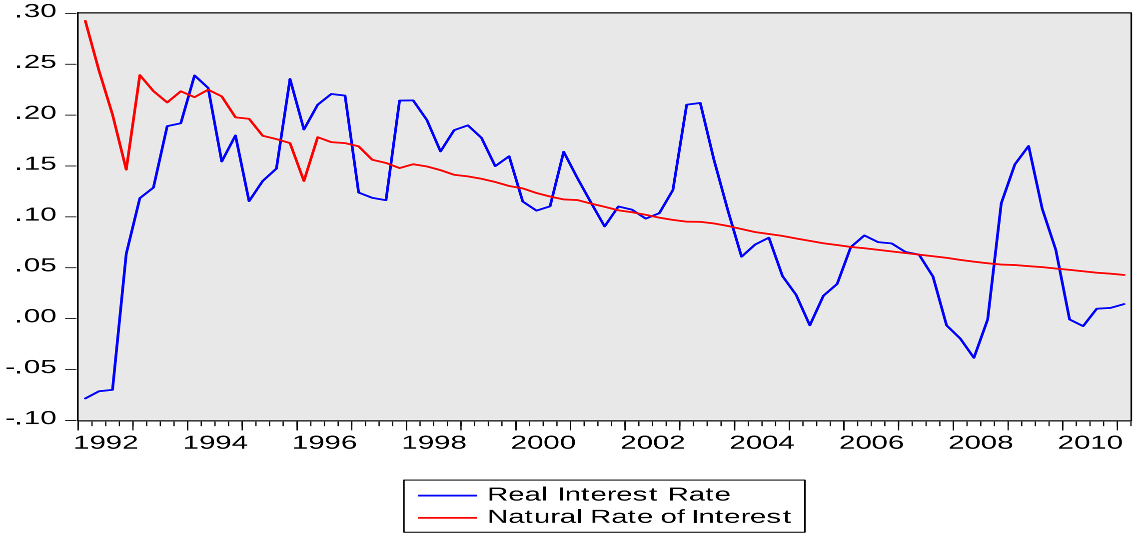
Table 3: State Space Model: Kalman Filter Interest Rate Estimates

	Estimates	
c	-0.448	
	(0.627)	
Parameters		
$\delta_{\tilde{r}_1}$	0.774***	
	(0.115)	
$\delta_{\tilde{r}_2}$	-0.010	
	(0.034)	
α_y	0.860***	
	(0.095)	
Φ_1	0.975***	
	(0.014)	
Φ_2	0.0001	
	(0.008)	
α_{r1}	0.017	
	(0.018)	
α_{r2}	-0.0136*	
	(0.008)	
Error Variance		
$\sigma_{\tilde{r}_t}$	0.003***	
$\sigma_{\tilde{Y}_t}$	0.000***	
σ_{z_t}	0.000	
State variables		Root MSE
r_t^*	0.042***	0.005
$\tilde{r}_t$	-0.022	0.036
z_t	0.041***	0.005

Sample: 1991:1 2011:1
Included observations: 81
Convergence achieved after 35 iterations

Notes: Estimates for the natural rate of interest and the interest rate gap were obtained by maximum Likelihood using the Kalman filter. For each state space model (each column) the first value represents the estimated coefficient and the value in parentheses (), the standard errors. In Column 1core inflation is used as the proxy for inflation while headline inflation is used in Column 2. Asterisk, * represents 10% level of significance, ** represents 5% level of significance and *** indicates significance at the 1% level.$\delta_{\tilde{r}_1}$and $\delta_{\tilde{r}_2}$are the coefficients on the lags of interest rate gap. State variables are in decimal.

Figure 3: Interest Rate and the Natural Rate of Interest



Though Garnier and Wihelmsen(2005) argue that interest rates above the natural rateare expected to lower inflation andinterest rates below the natural rate are expected to raise inflationcaution must be taken when assessing changes in the interest rate gap and its impact on inflation in Jamaica. Allen and Robinson (2004) seem to give reason why caution should be taken when they posited that there are two main channels of monetary policy in Jamaica; the *exchange rate channel* and the *credit channel*and inflation stabilization is achieved mainly through the exchange rate channel. The output gap which is affected by monetary policy through the credit channel plays a *minor* role in terms of a direct impact on inflation.They also found that the exchange rate responds most quickly, within the first quarter, to a monetary policy innovation. The impact of interest rate on the output gap and its impact on inflation, the credit channel, are seen over longer horizons.

In 2009:2 the central bank reduced interest rates; a phenomenon that continued for the remaining sample periods given the favourable economic atmosphere[17] that persisted. Based on estimates generated, the reduction was theoretically feasible as interest rates were above the natural rate of interest in 2009 (see Figure 3). In 2010:1 however, the interest rates fell below the

[17] Increase economic confidence resulting from the IMF Stand-By Arrangement, the stability of the exchange rates and a positive inflation outlook

estimated natural rate; a situation that would facilitate inflation given the negative relationship between the interest rate gap and inflation outlined in theory.

The HP filter, a purely statistical method, was also used to estimate potential output and the natural rate of interest. Estimates generated from both the Kalman filter and the HP filter (see Figures 4 and 6) suggest that as of the first quarter of 2010 actual interest rate fell below the natural rate of interest. Though it is expected that such a phenomenon should exert inflationary pressures on the economy, the country has been experiencing relatively low and stable inflation. The credit channel used in this analysis has a minor impact on inflation; this is a potential reason for the low and stable level of inflation in spite of the negative interest rate gap (see Allen and Robinson, 2004). Additionally, the exchange rate which has a stronger impact on inflation has been relatively stable and so could explain the relatively low inflation rates.

5.2 Statistical Properties of the Interest Rate Gap

We examine the statistical properties of the state space model by focusing on simple statistics that describe the relationship between the interest rate gap and both measures of inflation. The correlation between both measures of inflation and the interest rate gap is negative and weak (see Table 6 in the Appendices). This indicates that only a small fraction of the developments in Jamaica's inflation for the period 1990:1 to 2011:1 is related to the innovations in the interest rate gap.Additionally, the correlation between the interest rate gap and the output gap is weak and negative (-0.081).

We also investigate the leading indicator properties of the interest rate gap for inflation. Following the approach of Neiss and Nelson (2003) and Garnier and Wilhelmsen (2005) we estimate the following equation:

$$\boldsymbol{\pi_t = \alpha + \rho_1 \pi_{t-1} + \rho_2 \tilde{r}_t + \sum_{i=1}^{5} \beta_i \tilde{r}_{t-i} + \varepsilon_t} \qquad (11)$$

where inflation (π_t) is regressed on a lag of itself, the contemporaneous value of the interest rate gap as well as lags of the real interest rate gap. Table 4 shows the result of the OLS regressions.

Table 4: Parameter Estimates

Variables	Estimates	Standard Error
$\boldsymbol{\alpha}$	0.01263***	0.00366
$\boldsymbol{\rho_1}$	0.57477***	0.09743
$\boldsymbol{\rho_2}$	0.05361	0.09524
β_1	-0.04824	0.12790
β_2	-0.08833	0.08180
β_3	-0.00030	0.00018
β_4	-0.00039***	0.00014
β_5	-0.00034***	0.00013

Notes: Dependent variable in the regression is Headline inflation. The estimates were obtained from an OLS regression. Asterisk, * represents10% level of significance and *** indicates significance at the 1% level

The results indicate that the interest rate gap is negatively related to inflation. However, the association is weak and the negative impact is at a lag. The interest rate gap yields statistically significant parameter estimates when added to the autoregressive model for inflation however, the estimates are only significant after four lags. This suggests that changes in the interest rate gap have a statistical significant impact on inflation only after four quarters. A similar result was found by Garnier and Wilhelmsem (2005) in their analysis of the interest rate gap and inflation in the Euro Area. The regression results also seem to be consistent with the common view that monetary policy affects inflation after a delay.

6. Conclusion

In this paper we have jointly estimated the natural rate of interest and potential output for Jamaica for the period 1990:1 to 2011:1using the Kalman and HP filters.

The natural rate of interest is an important benchmark for monetary policy as actual interest rates maybe manipulated relative to the natural rate in order to keep inflation low and stable. The analysis reveals that the natural rate of interest is not constant as specified by De-Juan (2007) but varies over time. There exists a weak negative relationship between the interest rate gap and inflation in Jamaica. The relationship between the interest rate gap and the output gap is also weak and negative. Consequently, monetary policy innovations through the credit channel (the impact of interest rate on the output gap and its impact on inflation) might have little impact on price stability.

We are currently below the natural rate of interest which may exert inflationary pressures on the economy in the future. Therefore we must be cautious, as our efforts to promote growth (through the current easing of monetary policy) may exert demand pressures on the economy that may lead to an increase in inflation. The current situation may not reveal any particular concern given the weak state of demand as the economy attempts to emerge from the impact of the global recession. However, inflationary impulses could arise from a pickup in demand over time.

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Appendices

Table 5: Correlation Analysis, Inflation and Output Gap

	Output Gap	Core Inflation	HeadlineInflation
Output Gap	1.000		
Core Inflation	0.341	1.000	
Headline Inflation	0.215	0.685	1.000

Table 6: Correlation Analysis, Inflation and Interest Rate Gap

	Interest rate gap	Core inflation	Headline Inflation
Interest Rate Gap	1.000		
Core Inflation	-0.224	1.000	
Headline Inflation	-0.544	0.497	1.000

Table 7: Correlation Analysis, Output Gap (HP filter estimate) and Inflation

	Output Gap_hp	Core Inflation	Headline Inflation
Output Gap_hp	1.000		
Core Inflation	0.063	1.000	
Headline Inflation	0.068	0.678	1.000

Table 8: Correlation Analysis, Interest Rate Gap (HP filter estimate) and Inflation

	Interest Rate Gap	Core Inflation	Headline Inflation
Interest Rate Gap	1.000		
Core Inflation	-0.351	1.000	
Headline Inflation	-0.322	0.688	1.000

Figure 4: Headline and core inflation

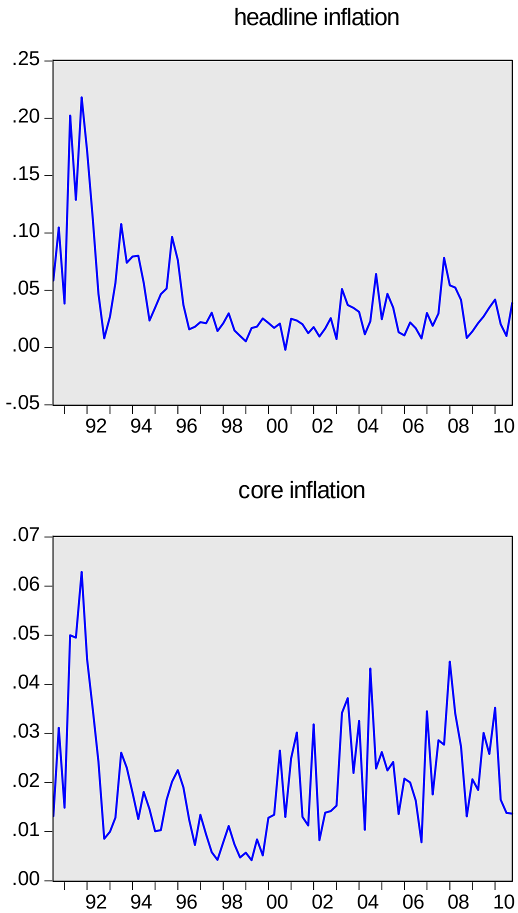

Figure 5: Actual Output and Potential Output (HP filter estimate)

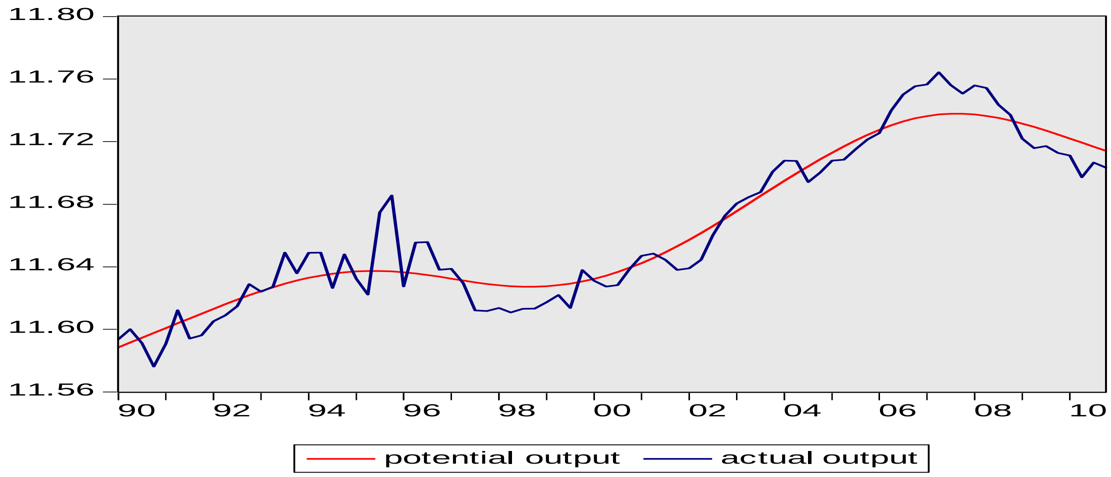

Figure 6: Actual Interest Rate and the Natural Rate of Interest (HP filter)