Estimating an Open-Economy Phillips Curve for Papua New Guinea

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Abstract

We estimate a Phillips Curve for Papua New Guinea (PNG). In doing so, we employ three different measures of the quarterly output gap to embody domestic demand pressures. The model employed is a straightforward auto-distributed lag model, and is estimated using a general-to-specific methodology. The output gap is seen to be a statistically significant variable in the determination of inflation dynamics, with sensible estimated magnitudes and signs. Depending on which measure is adopted, the long-run pass-through of the output gap into inflation roughyl between 30 and 60 percent. A historical decomposition of the model, charting the relative contributions of the various endogenous variables to inflation, is discussed and interpreted in light of the macroeconomic conditions experienced by PNG over the last two decades. The output gap is seen to account for inflation in certain periods, such as 2007-2009, better than others, such as 2006-2007.

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Contents

1 Introduction

It is well documented that PNG's economy has been experiencing a significant boom in recent years. Factors such as the commencement of major resource projects, such as the PNG Liquified Natural Gas (LNG) project, a rise in commodity prices, structural reforms and the subsequent political and macroeconomic stability have lead a non-mineral real GDP growth of around 7 percent over the last five years. These buoyant demand conditions are of great interest to the Bank of PNG, as excess domestic demand can lead to price pressures, a relationship embodied in the Phillips curve. Previously, the relationship between domestic demand and inflation was insignificant, since PNG's small open economy was driven largely by external factors.[1] However, in light of the recent surge in domestic activity, there is renewed interest in capturing the effect of domestic demand on inflation, i.e. estimating a Phillips Curve relationship. More precisely, since price pressures are generated through *excess* demand, the central variable for such an analysis is the output gap, which represents the mismatch between aggregate demand and potential supply, or actual output and potential output.

This paper is the second in a two-part analysis. The first paper was devoted solely to the construction of quarterly measures of the output gap.[2] This paper is concerned with employing these measures in the estimation of a Phillips curve relationship for PNG. It is structured as follows. Chapter 2 gives a qualitative description of the prevailing macroeconomic environment in PNG over the last decade or so. Chapter 3 outlines the theoretical underpinnings of the Phillips curve. Chapter 4 estimates the structural model for PNG and interprets the results in light of the description in Chapter 2. The paper concludes with some final remarks.

2 A Short Macroeconomic History of PNG

Before we estimate a Phillips Curve relationship, it is instructive to take a more qualitative view of recent demand conditions in PNG. The purpose of such an analysis is to construct an economic narrative on which to benchmark econo-

[1] [Sampson et al., 2006] show how inflation was mainly driven by the nominal effective exchange rate and foreign imported inflation, with the output gap proving insignificant.

[2] ([Vellodi, Aba, 2012]).

metric results. For instance, it may be the case that the final model satisfies the statistical conditions required for accurate inference, as well as being comprised of significant variables, yet fails to explain inflation dynamics in PNG in a manner consistent with the historical profile. This would be a greater failing than any diagnostic test failure. In order to build such an intuition, we will proceed to discuss the macroeconomic environment of PNG over the last decade in seven sections. The account that follows may not be universally accepted, insofar as macroeconomic analysis is as much an art as it is a science. It also aims to trade off simplicity and clarity with depth, and hence makes no allusion to being comprehensive.

2000-2010: Potential Output Growth in PNG

Before discussing prevailing demand conditions, it is worth briefly considering supply conditions, i.e. those conditions affecting the growth of *potential output*, or the level of output an economy can achieve whilst utilizing factors of production as efficiently as possible. Since it is the output gap, rather than the level of output, that affects inflation, we are just as interested in supply as demand. The reasons so much attention in this paper is devoted to demand is two-fold. First, demand conditions are both more transient and more volatile, whereas underlying supply conditions are seen to take much longer to evolve. As such, the former play a dominant role in affecting inflationary pressures. Second, demand management is seen as a central objective of monetary policy, for instance, through the interest-rate channel.[3]

PNG has seen a strong and sustained growth in potential output through the last decade. Factors contributing to this growth may include strong growth in employment, private sector credit and imports of capital goods.[4]

2003-2007: Commodity Prices I

The period in question was characterised by rapidly increasing global commodity prices. The majority of PNG's exports experienced positive price effects,

[3] The Bank sets a target interest rate, which in turn affects market rates and subsequently agents' consumption and investment decisions, which finally effect demand conditions.

[4] Labor and capital goods are direct factors of production, and hence an increase in these variables will necessarily contribute to an increase in potential output. Growth in private sector credit is synonamous with increased investment, which in turn increases the capital base of the economy. See [Herd, 1989].

resulting in a favorable overall terms-of-trade position. The typical response of a developing economy rich in natural resources to a commodity price boom could be described as follows. Rising export prices lead to a surge in revenues. These revenues are largely spent by the government to satisfy pressing infrastructural needs. Such spending would result in a positive output gap and a fiscal deficit. Demand-pull inflation ensues, as well as an appreciation of the real exchange rate through "Dutch disease"effects[5]. This account does not entirely describe the PNG experience. The Government of PNG did indeed accrue sizeable mineral revenues from the price effect. However, they did not spend the large part of these earnings. Rather, they saved them, both in the form of trust accounts at commercial banks, and indirectly as foreign reserves at BPNG. As a result, the real exchange rate remained relatively stable, and inflation was limited.

2007-2008: Commodity Prices II

Whilst commodity prices had been steadily increasing in the previous period, this period witnessed a rapid acceleration, accompanied by a spike in oil prices. These extreme movements in international prices resulted in a surge in headline CPI inflation in PNG. More importantly, however, was the concurrent surge in underlying inflation, as measured by trimmed mean and exclusion based inflation measures[6]. This was characterized by both *cost-push* and *demand-pull* inflation. Rising oil prices passed through into transport costs and other domestic prices, affecting costs throughout the supply chain. Simultaneously, demand conditions had been swelling, as indicated by both a positive output gap, as well as a surge in the volume of private sector credit. These in turn fuelled expectations of positive growth and the resultant wage-price spiral.

2008-2009: Global Financial Crisis

The advent of the Global Financial Crisis (GFC) swiftly brought to an end the period of high commodity prices, precipitated by a collapse in oil prices. Global

[5] More specifically, government spending on non-tradables shifts demand to this sector and away from tradables. This demand shock causes the price of non-tradables to rise, whilst the lack of competitiveness in tradables causes tradable prices to decline. Viewing the real exchange rate as the ratio of the former to the latter, the appreciation follows immediately.

[6] Trimmed-mean inflation cuts 33 percent off the higher end and 27 percent off the lower end of the distribution of prices in the headline CPI basket. Exclusion-based gives a zero-weighting to certain groups exhibiting persistent volatility. See [Nindim, 2006].

demand plummetted, causing a drop in inflation in PNG's trading partner countries. Export earnings fell as a result of both the drop in foreign demand and low export prices. At this point, one would assume these developments were accompanied by negative growth, disinflation and a weakening currency. However, to counteract the negative external conditions, the Government of PNG embarked on a countercyclical fiscal policy, ramping up spending to prop up domestic demand in the absence of external demand. The result was a positive output gap, a budget deficit, mild inflation and an appreciation of the real exchange rate.

2010- : Monetary Expansion

The external conditions prevailing through this period have been similar to the 2007-2008 period, with PNG yet again experiencing an improving current account balance and terms-of-trade from rising commodity prices. However, in contrast, it now experiences a large positive output gap and soaring headline inflation. The central driver behind these developments come not from abroad, but from within PNG. Commencement of the construction phase of the "PNGLNG"project, a multi-billion dollar natural gas project, has resulted in a considerable improvement in domestic demand conditions, fuelling inflation. Something of a concern has been the monetary landscape, in particular, excess liquidity in the commercial banks. The source of this liquidity is largely Government deposits at the banks; the Government receives its mining and petroleum taxes (MPT) in dollars, converts them to kina at BPNG, and then either redeposits them at BPNG or at commercial banks, whence the funds are drawn down for expenditure purposes. Prior to this period, the Government was depositing the funds at BPNG. Recently, they have been depositing them largely with commercial banks. Under this arrangement, the funds are liquidity impacting, and hence drive up the domestic money supply. One might ask whether such monetary expansion has contributed to inflation. This does not seem to be the case. Under the loanable funds model, a glut of free reserves should translate into increased lending. However, through the period, the growth rate of private sector credit has been largely decreasing, whilst lending rates have remained static. Furthermore, BPNG has largely sterilized the build-up of its net foreign assets (NFA) caused by the revenue inflows.

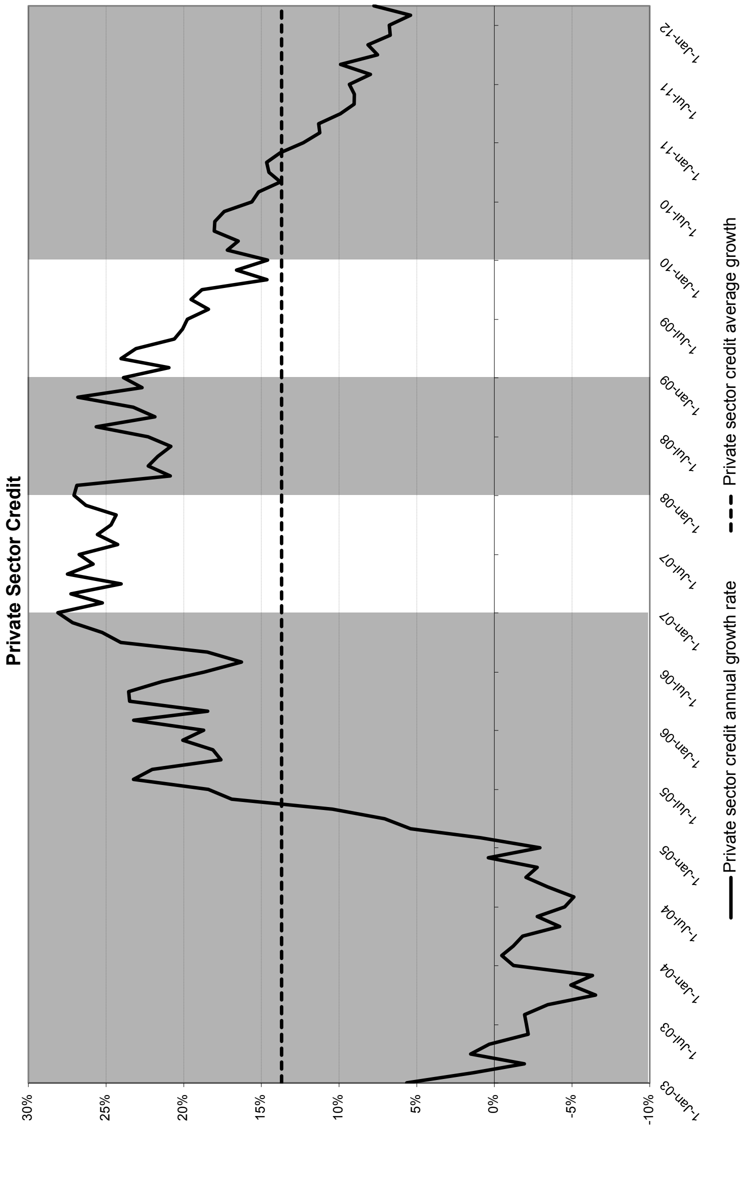

Figure 1: Private Sector Credit

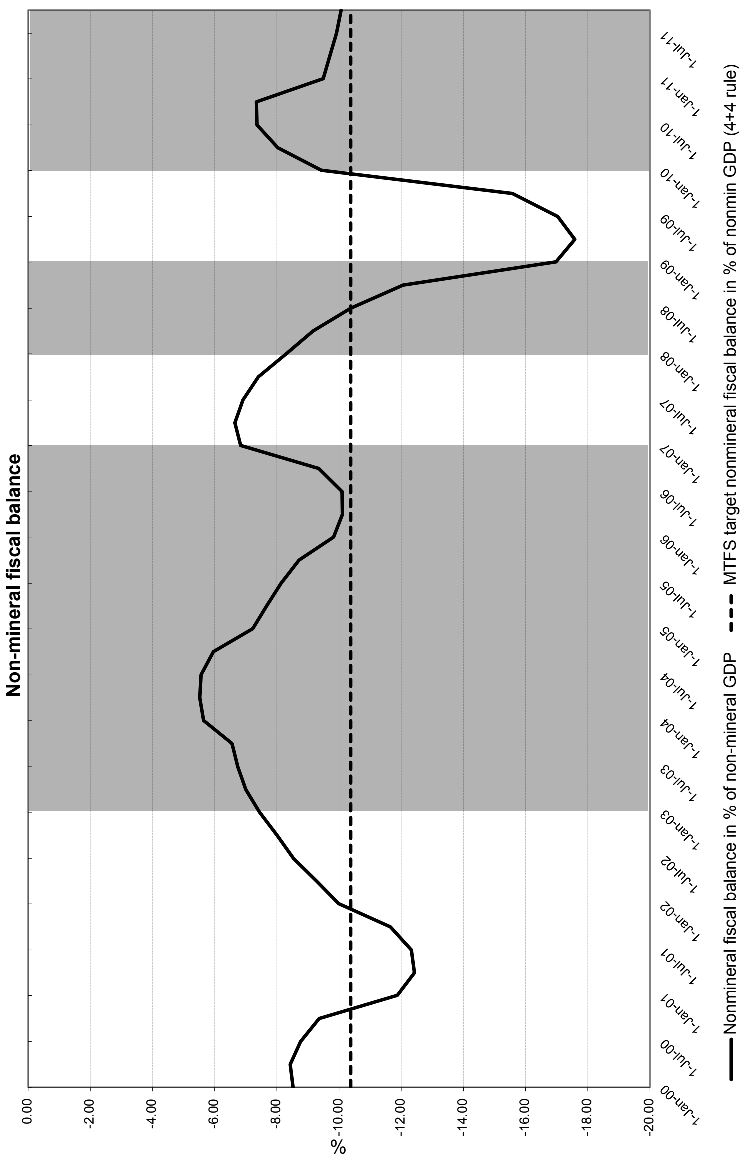

Figure 2: Non-mineral fiscal balance

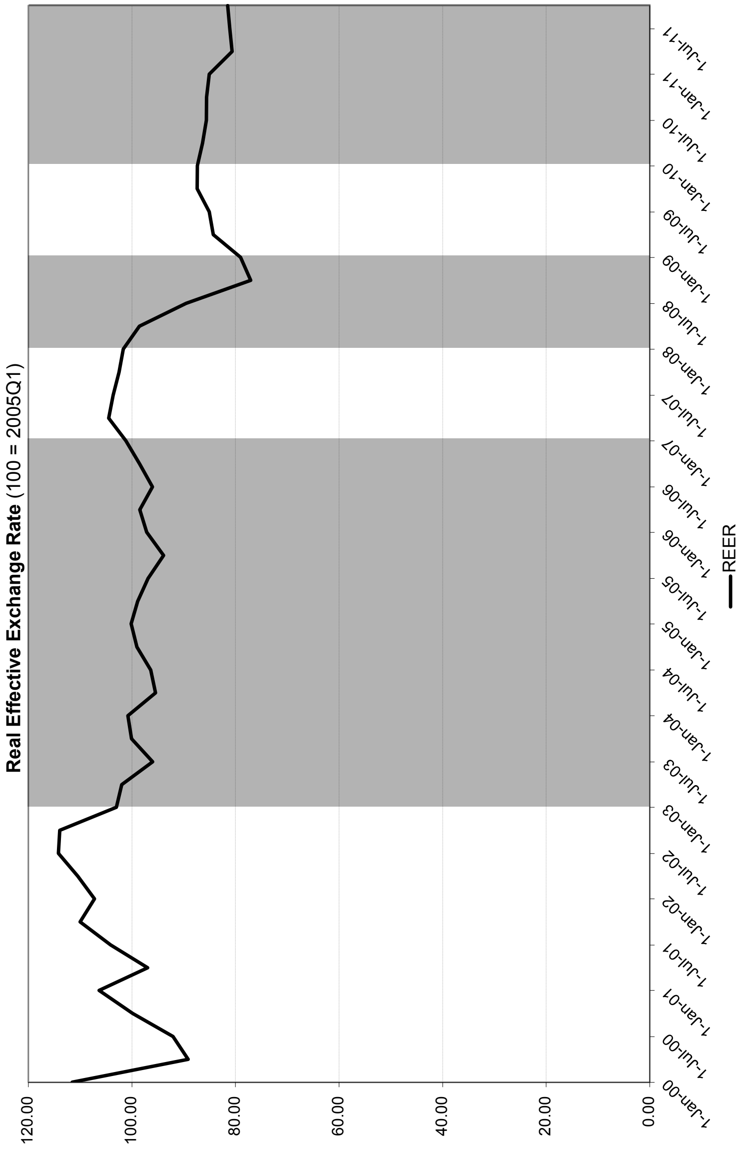

Figure 3: Real Effective Exchange Rate

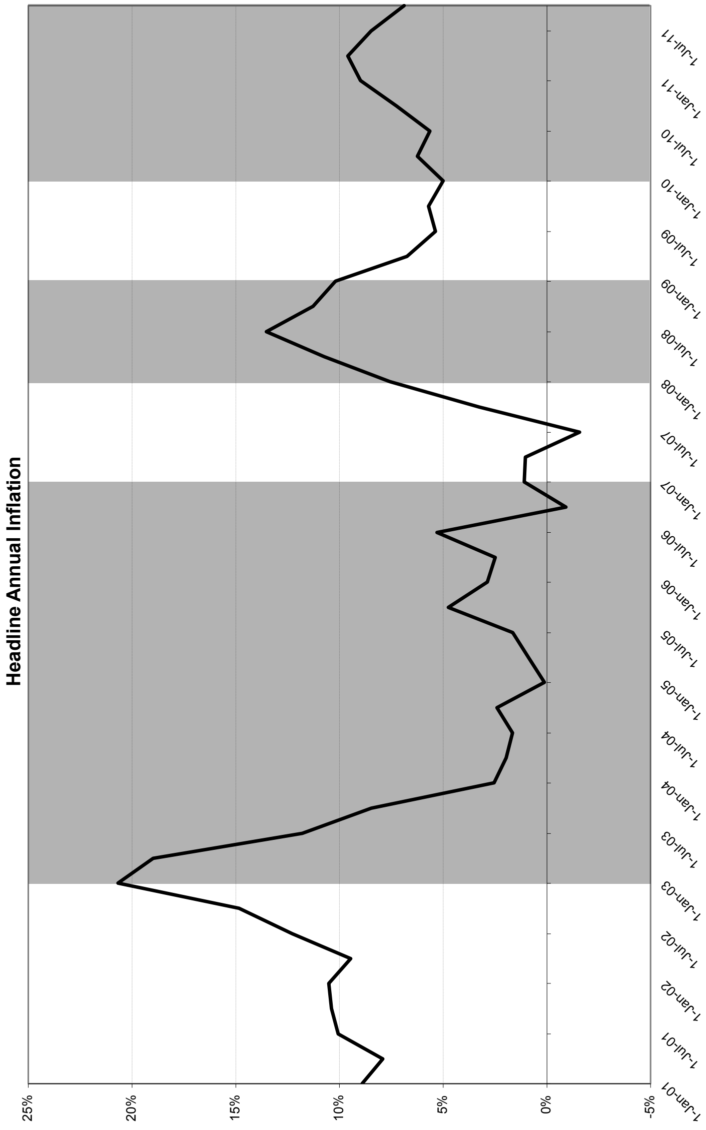

Figure 4: Annual headline CPI inflation

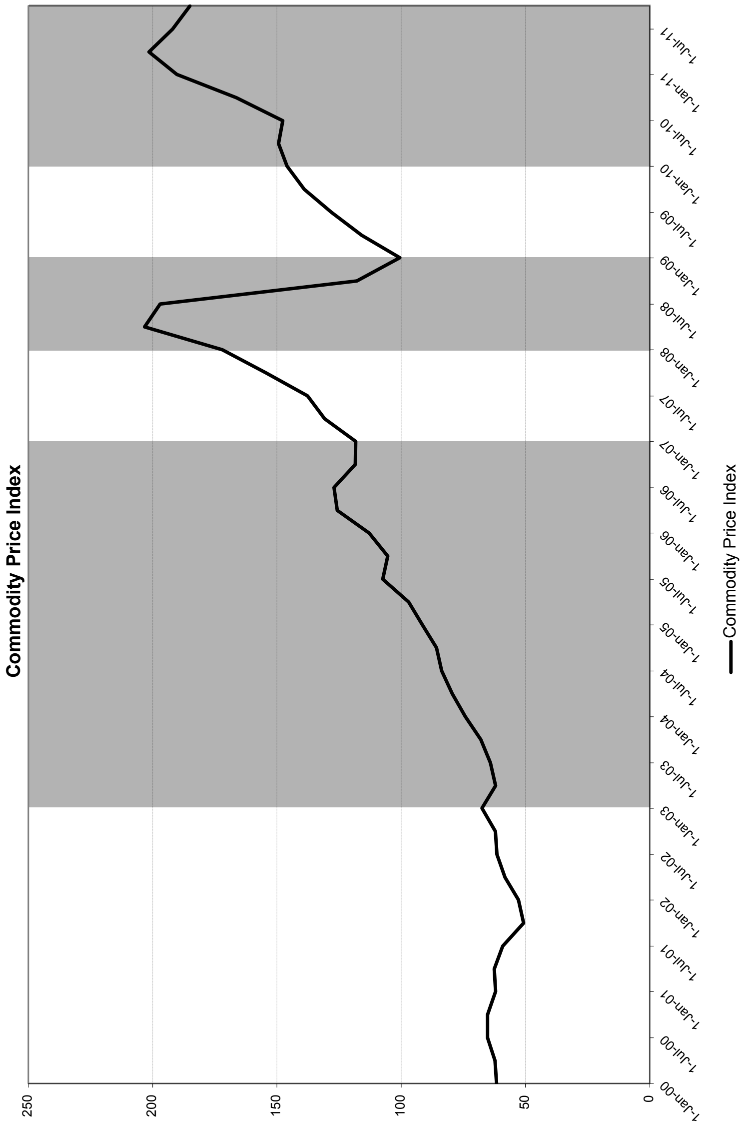

Figure 5: Nominal commodity prices

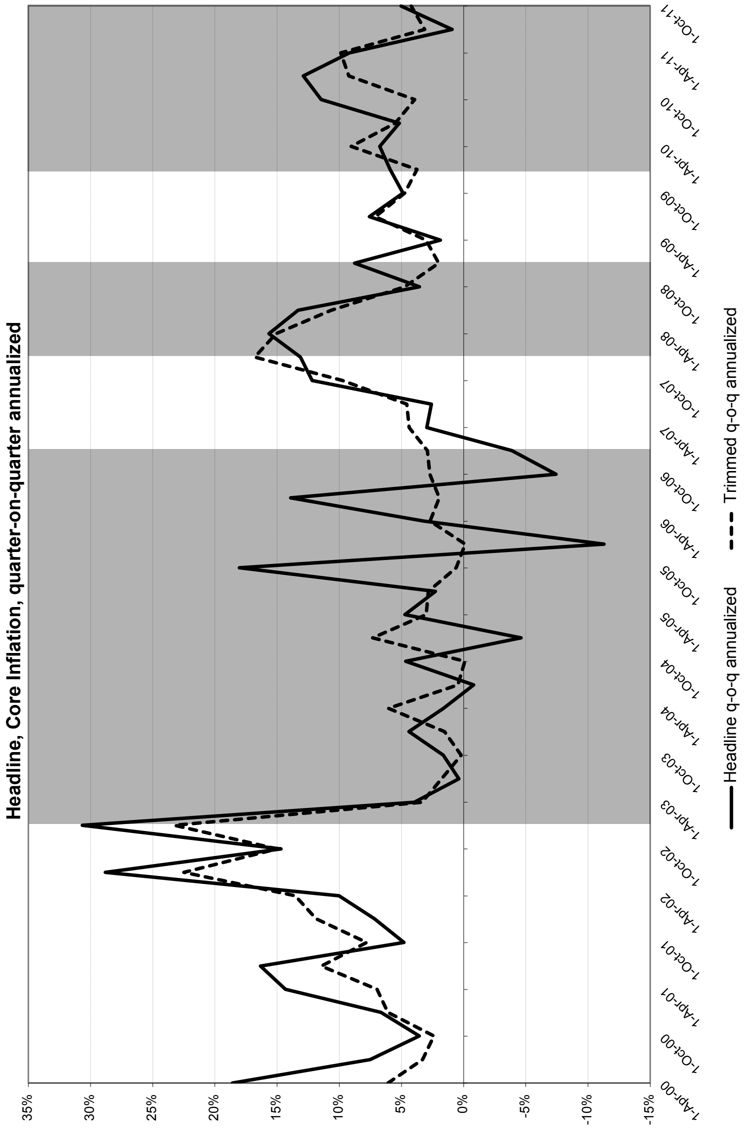

Figure 6: Headline, core inflation, annualized quarter-on-quarter

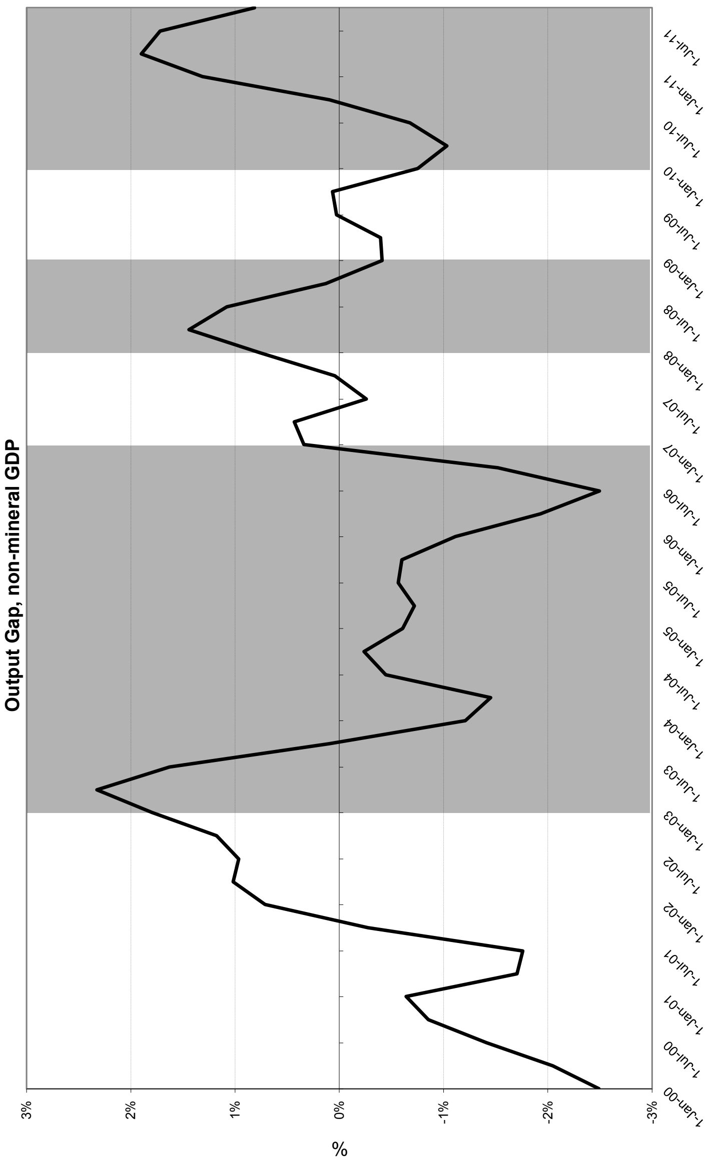

Figure 7: Domestic output gap

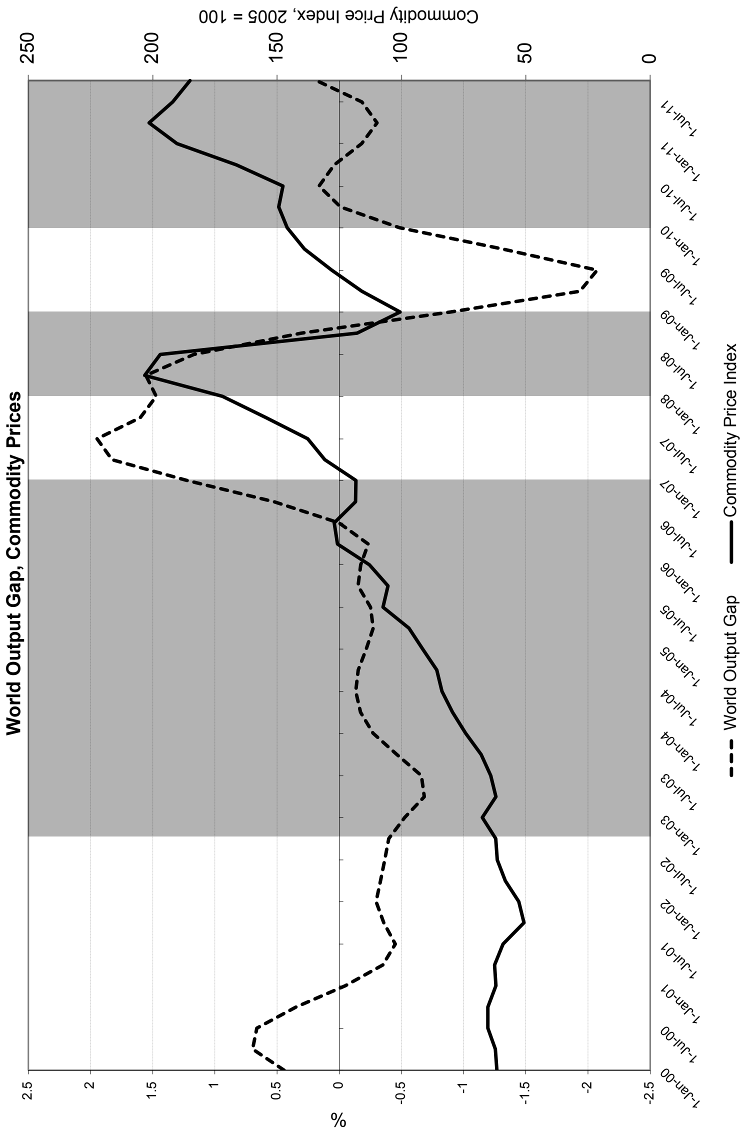

Figure 8: World output gap, commodity prices

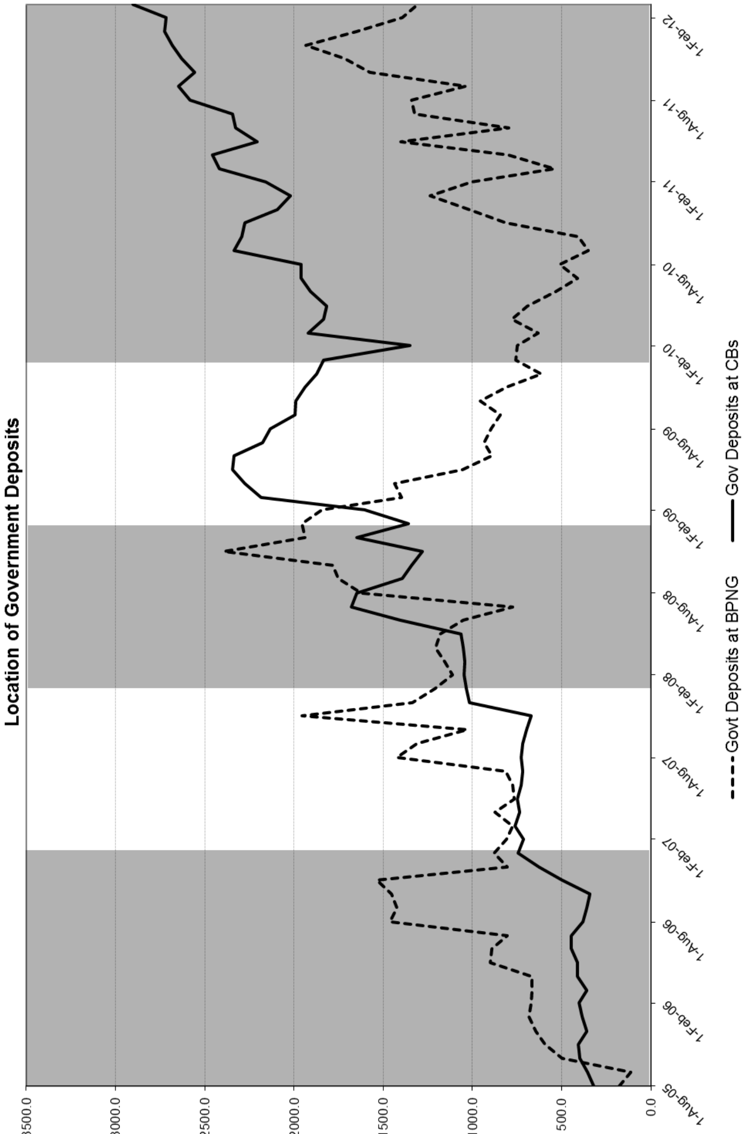

Figure 9: Location of government deposits

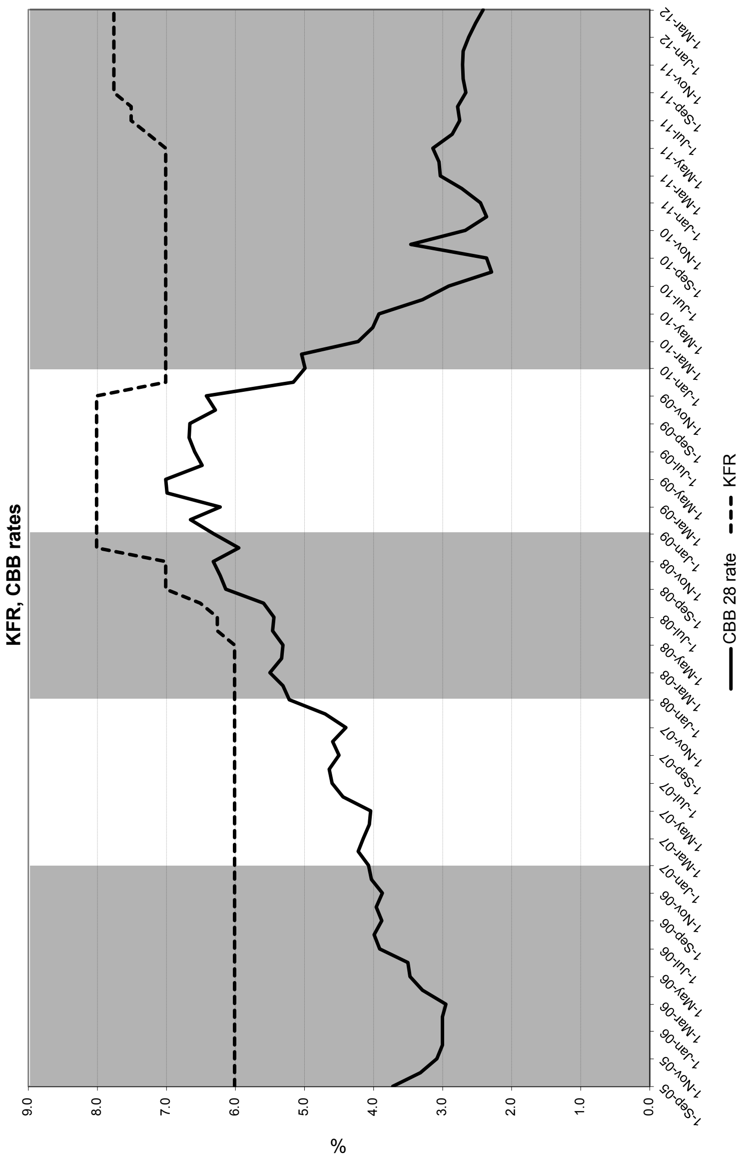

Figure 10: Central Bank Bill, KFR rates

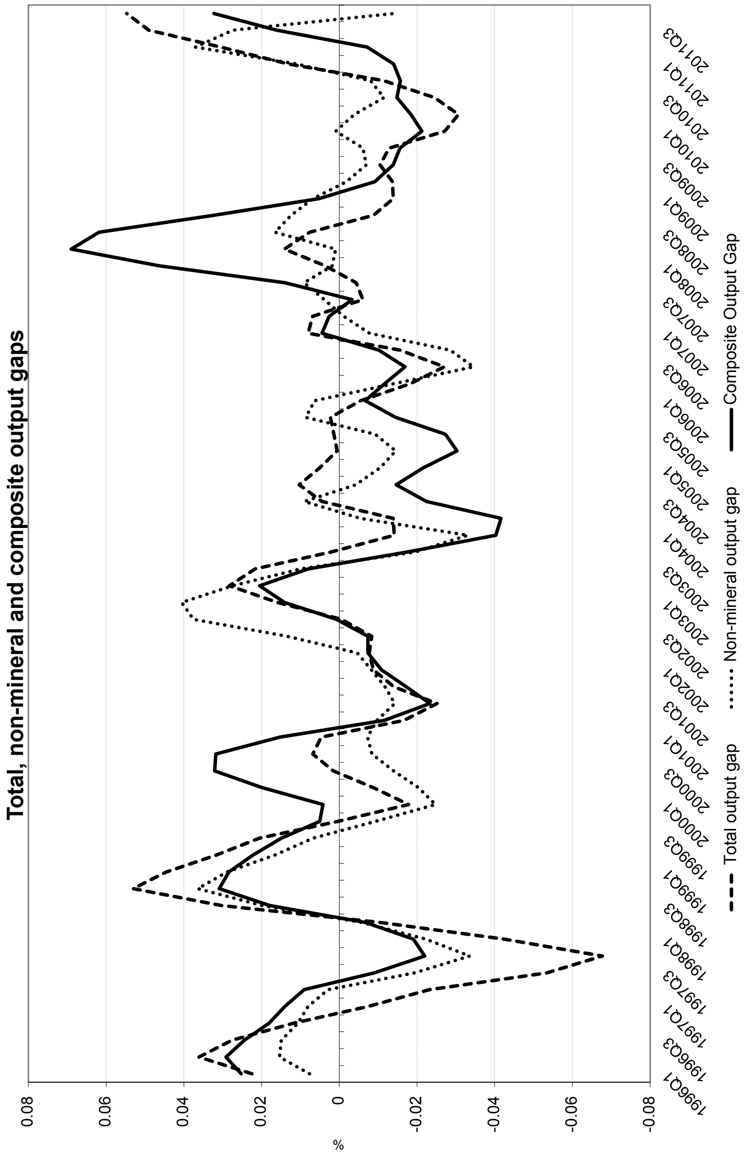

Figure 11: Composite, non-mineral and total output gaps

3 Estimating the Phillips Curve

Now that we have a reasonable idea of the macroeconomic conditions that prevailed over the last decade or so, we are in a position to estimate and analyse a Phillips Curve for PNG. The relationship between inflation and output as intially proposed in [Phillips, 1958] is possibly the most well-documented and extensive researched topics in macroeconomics.[7] As such, it would be futile to attempt to provide either an exhaustive review of the related literature or a full-blooded theoretical exposition. We make no allusion to originality of theory in this paper; our aim is essentially to find a Phillips Curve relation for PNG that best fits both the data and our intuitive understanding of the prevailing demand conditions. As such, we provide a brief introduction to the topic, focussing on areas that directly pertain to our approach.

We estimate a purely backward-looking version of the New Keynesian Phillips Curve (NKPC), as found in [Clarida et al., 1999]. In its pure form, the NKPC specifies that inflation today is a result of today's expectations of inflation tomorrow, the real marginal cost gap today and cost-push shocks, i.e.[8]

$$\pi_t = E_t \pi_{t+1} + \lambda \hat{mc}_t + u_t \tag{1}$$

The marginal cost term represents an activity variable, and as such can be proxied by other variables quantifying excess demand, such as the output gap, $\hat{y}_t$. [Gali, 2008] links marginal costs and the output gap through the equation:[9]

$$\hat{mc}_t = (\sigma + \phi)\hat{y}_t \tag{2}$$

Hence, the NKPC becomes

$$\pi_t = E_t \pi_{t+1} + \kappa \hat{y}_t + u_t \tag{3}$$

where $\kappa = \lambda(\sigma + \phi)$. This formulation of the NKPC proved empirically weak (see

[7] More specifically, Phillips investigated the link between nominal wages and unemployment, which, assuming Okun's Law holds, can be proxied by output in the New Keynesian Phillips Curve.

[8] The marginal cost gap is analagous to the output gap, in that it is the deviation of real marginal costs from their long-run level. Henceforth, variables embelished with a $\hat{}$ are in gap terms.

[9] The relationship is predicted on the assumption that all output is consumed ($y_t = c_t$) and perfect competition in labor markets ($w_t - p_t = \sigma c_t + \phi n_t$). Hence, equating the marginal cost to the real wage yields $mc_t = \sigma c_t + \phi n_t = (\sigma + \phi)\hat{y}_t$.

[Ball, 1994] and [Fuhrer, Moore, 1995]), leading to the construction of a so-called "hybrid"NKPC by [Gali, Gertler, 1999], which incorporates explicitly persistent inflation dynamics:

$$\pi_t = \lambda E_t \pi_{t+1} + (1-\lambda)\pi_{t-1} + \kappa \hat{y}_t + u_t \tag{4}$$

This hybrid NKPC was empirically far stronger than the pure forward-looking NKPC. However, both formulations fail to accomodate features important to small open economies, of which PNG is a good example. [Gali, Monacelli, 2005] derive a NKPC for a small open economy, but show that the equation doesn't change in structure. Rather, the degree of openness affects inflation through its impact on the coefficient of the output gap term. A more ad hoc approach to modelling important supply side affects is found in [Mehra, 2004]. This approach is empirically motivated, and as such not concerned with its microfoundations. We will adopt a similar approach.
A previous attempt at estimating a Phillips Curve relation can be found in [Sampson et al., 2006]. Whilst not the explicit objective of the paper, they estimate an inflation model with external factors and proxies for domestic demand. External factors can be interpreted as supply-side shock variables, such as commodity prices and/or terms-of-trade effects.[10] The output gap is a suitable measure of domestic demand. As such, the current paper is essentially a formalized extension of this previous work.

4 Methodology

Our basic structural equation takes the following form:

$$\pi_t = \alpha(L)\pi_{t-1} + \beta(L)\hat{y}_t + \gamma(L)\hat{z}_t + \delta(L)\pi_{w,t} + \epsilon_t \tag{5}$$

where π_t is the trimmed mean core inflation rate, $\hat{y}_t$ is the output gap, z_t is the growth rate of the nominal exchange rate and $\pi_{w,t}$ is foreign inflation. $\alpha(L), \beta(L), \gamma(L)$ and $\delta(L)$ are lag polynomials in coefficients, the structures of which will be determined via a general-to-specific estimation process. The external variables, namely foreign imported inflation and the nominal exchange

[10] Such considerations are made in [Goodhart, Hofmann, 2005], who looks at primary commodity prices and [Mehra, 2004], who looks at supply side shocks.

rate, are chosen roughly in accordance with [Sampson et al., 2006]. The combination of the exchange rate and foreign prices account for potential terms-of-trade shocks, whilst the exchange rate itself captures movements in commodity prices.[11]

[Sampson et al., 2006] use two different multilateral approaches for modelling external variables. The first weights nominal exchange rates and foreign inflation by country of origin, the second by country of transaction, each yielding substantially different weightings.[12] We also use two approaches to modelling external variables. However, we substitute the country of origin approach with a bilateral approach, owing to Australia's continued dominance over PNG trade flows. In both cases, we use three different output gap measures. The first is a composite output indicator, formed as a weighted average of electricity production and non-mineral employment data. The second is constructed from non-mineral output, using the Chow-Lin procedure for temporal disaggregation. The third also uses the Chow-Lin procedure, but is based on total output. See Figure 11. For a full description of how these output gaps were constructed, refer to the sister publication of the present paper, [Vellodi, Aba, 2012]. For more details on general data definitions, see Appendix A.

Since the variables enter the model as either growth rates or gaps, we would expect them to all be trend and difference stationary. However, for the sake of rigor, we perform unit root tests using the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schimdt-Shin (KPSS) tests. The results are reported in Table 1.[13]

4.1 Results

Owing to the multitude of combinations of variables and lag structures, we present a select subset of our findings in two tables, Tables 2 and 3. Since we exclusively employ stationary variables, all regressions were performed using

[11] [Sampson, Kauzi, 2009] show that the PNG kina is a commodity currency. To capture foreign importated inflation, it would have been desirable to use a tradable CPI component from the trading partner(s). This data was not available for our analysis, and as such we used the full CPI.

[12] Specifically, country of origin weights heavily towards Australia, whilst country of transaction weights towards the US.

[13] In all cases, we test for an intercept but no linear trend term. The values reported are the test statistics. For the ADF and PP, the critical values are taken from [MacKinnon, 1996]. For the KPSS, they are taken from [Kwiatkowski et al, 1992].

Table 1: Unit root tests

Variable	ADF	PP	KPSS
dlog_cpi_trimmed	-4.557***	-4.575***	0.214
dlog_kina_aud	-6.155***	-5.936***	0.290
wgtcpi	-6.209***	-6.156***	0.314
wgtxrmct	-5.743***	-5.786***	0.674**
ygap_elecemp	-3.760***	-2.790*	0.138
ygap_nmin	-4.656***	-3.107**	0.056
ygap_lqrtly_ind	-5.262***	-2.813*	0.039

OLS.[14]

In all cases, the output gap terms are highly significant, up to the second lag, demonstrating not only that domestic demand conditions are important for the determination of price movements in PNG, but also that they feed through to inflation in a lagged and persistent manner.

Focussing firstly on the bilateral results, in the case of the model using the total output gap, the long-run coefficient on the output gap is negative. This flies in the face of the theoretical underpinnings outlined in 3, and so we reject this model. This leaves the bilateral models with the composite and non-mineral output gaps, which will be denoted models 1 and 2 henceforth.

The long run pass through of the output gap into inflation is 24 and 22 percent respectively, which seems commensurate with the size of the domestic economy and degree of openness in PNG. Tests show normally distributed errors, as well as no signs of serial correlation or heteroskedasticity in the error terms, indicating that the Gauss-Markov conditions hold.[15] However, both models show signs of structural instability within the period 2007-2008.[16] To get a better understanding of why this is, Figures 12 to 14 show historical decompositions

[14] t-stastistics are reported in parentheses. The 10, 5 and 1 percent levels of significance are indicated with the symbols *,** and *** respectively. The Breusch-Godfrey test measures serial autocorrelation, with the statistic $nR^2 \sim \chi^2_p$ under the null of no serial correlation. The Breusch-Pagan test measures heterosckedasticity, with the statistic $nR^2 \sim \chi^2_{p-1}$ under the null of homoskedasticity. The Jarque-Bera test adopts a null hypothesis of normally distributed errors. For further details, see
[Jarque, Bera, 1987]. In all cases, the table reports the p-value for the test statistic under these asymptotic distributions.

[15] The Gauss-Markov conditions are necessary and sufficient conditions for OLS estimators to be unbiased and efficient. Normality of the error distribution is required for the t-test to be valid.

[16] For detailed results from stability tests, see Appendix B.

Table 2: Regression results, bilateral variables

Coefficient	Composite gap	Non-mineral gap	Total gap
c	0.007** (2.486)	0.007** (2.455)	
dlog_cpi_trimmed			
dlog_cpi_trimmed(-1)			
dlog_cpi_trimmed(-2)	0.228** (2.656)	0.269*** (2.808)	0.252*** (3.293)
dlog_cpi_trimmed(-3)			
dlog_cpi_trimmed(-4)			
dlog_cpi_trimmed(-5)	-0.218*** (-2.817)		
dlog_auscpi	0.463** (2.275)	0.750*** (3.336)	0.613*** (3.160)
dlog_auscpi(-1)	0.400* (1.903)		0.496** (2.627)
dlog_auscpi(-2)		-0.414* (-1.858)	
dlog_kina_aud	0.076*** (3.227)	0.068** (2.637)	0.080*** (3.259)
dlog_kina_aud(-1)	0.151*** (5.739)	0.153*** (5.723)	0.169*** (6.761)
dlog_kina_aud(-2)	0.055*** (3.143)	0.050** (2.655)	0.107*** (4.036)
inf_stab_dlogfxrate	-0.050** (-2.466)	-0.092** (-2.429)	-0.089** (-2.408)
inf_stab_dlogfxrate(-1)	-0.116*** (-3.108)	-0.140*** (-3.643)	-0.148*** (-4.020)
inf_stab_dlogfxrate(-2)			-0.094** (-2.523)
ygap	0.491*** (4.029)	0.654*** (3.222)	0.168** (2.073)
ygap(-1)	-0.658*** (-3.438)	-0.845*** (-2.823)	-0.266*** (-3.112)
ygap(-2)	0.402*** (3.275)	0.349* (1.704)	
dum_vat	0.019** (2.013)		
R^2 (adj)	0.681	0.617	0.626
Breusch-Godfrey	0.601	0.906	0.351
Breusch-Pagan	0.102	0.498	0.241
Jarque-Bera	0.381	0.463	0.174

Table 3: Regression results, multilateral variables

Coefficient	Composite gap	Non-mineral gap	Total gap
c	0.007* (1.842)		
dlog_cpi_trimmed			
dlog_cpi_trimmed(-1)			
dlog_cpi_trimmed(-2)	0.290*** (3.167)	0.264*** (3.627)	0.320*** (3.848)
dlog_cpi_trimmed(-3)			
dlog_cpi_trimmed(-4)			0.178* (1.720)
dlog_cpi_trimmed(-5)	-0.161** (-2.058)	-0.172** (-2.570)	-0.200** (-1.989)
wgtcpi	0.696** (2.508)	0.773*** (3.823)	0.577** (2.268)
wgtcpi(-1)	0.751*** (2.710)	1.333*** (5.739)	0.921*** (3.556)
wgtcpi(-2)	-0.621** (-2.085)		
wgtxrmct	-0.071*** (-3.048)	-0.085** (-4.010)	-0.073*** (-3.011)
wgtxrmct(-1)	-0.163*** (-6.326)	-0.136*** (-6.503)	-0.171*** (-6.426)
wgtxrmct(-2)	-0.132*** (-3.197)	-0.128*** (-5.228)	-0.087*** (-3.640)
inf_stab_wgtxrmct			
inf_stab_wgtxrmct(-1)	0.180*** (2.700)		0.128** (2.244)
inf_stab_wgtxrmct(-2)		0.176 (3.430)	
ygap	0.372*** (2.869)	0.884*** (5.285)	0.368*** (2.794)
ygap(-1)	-0.486** (-2.424)	-1.230*** (-4.900)	-0.578*** (-2.783)
ygap(-2)	0.304** (2.371)	0.920*** (5.182)	0.316** (2.236)
dum_vat		0.021** (2.515)	
R^2 (adj)	0.660	0.732	0.649
Breusch-Godfrey	0.292	0.699	0.134
Breusch-Pagan	0.302	0.115	0.420
Jarque-Bera	0.005***	0.287	0.166

for each model, i.e. profiles of how each variable has contributed to inflation over the sample period, whilst Figures 15 to 17 show the fitted regression lines for each model.

The fitted lines clearly demonstrate that model 1 is far better at explaining the surge in inflation during the period 2007-2008. Indeed, the overall fit of model 1 is far better, with an R^2 of 0.681, over the R^2 of 0.617 for model 2. As such, we will focus on model 1 henceforth. From Section 2, we know that around this period, the country experienced both demand-pull and cost-push inflation. In our model, external variables should capture the latter, since the cost-push was caused by external price movements, whilst the output gap should capture the former. It would seem, for this period, that the composite output gap captured the effect of this demand spike on inflation with greater accuracy.

The historical decomposition further corroborates this observation. Around this period, the output gap accounts for a far greater portion of inflation than normal, suggesting that the demand-pull effect was exceptionally strong. It also supports the presence of counter-cyclical fiscal policy through the global financial crisis. Even though inflation was relatively low, a significant portion of it was attributed to domestic demand, as external variables such as foreign inflation subsided. However, it also gives rise to a number of observations inconsistent with the macroeconomic narrative outlined in Section 2. Firstly, through the recent period from 2010-2011, the output gap has a negative effect on inflation. This contradicts the notion that during this period, PNG has experienced a domestic boom, fuelled by the construction phase of the PNGLNG project. From a purely mathematical point of view, the explanation is simply that the composite output gap is deeply negative around 2010, becoming positive and growing sharply into 2011. However, with the lag structure of the output gap, the effect of this sharp growth takes several periods to manifest.[17] Hence, the model attributes the moderate rise in core inflation to the external variables. From an economic perspective, there are two possible explanations for this disparity. Firstly, it could be that the output gap is poorly constructed through this period. It is contructed from underlying series that may not have experienced growth commensurate with the broader domestic demand. If this is the case, the Phillips Curve relation will be imperfectly represented by the data series through this

[17]It is also important to note that the historical decomposition is presented in annualized form, whilst the model was estimated on a quarterly basis. This adds a further layer of persistence to presentation.

period. Secondly, it is possible that our intuition regarding the impact of the PNGLNG construction phase on domestic demand and inflation may be flawed. Whilst detailed study on project's financial profile suggests that much of the capital expenditure for the project will be spent in the period 2008-2011, much of this spending will be in the form of direct imports.[18] The impact on the domestic economy will come both in the form of domestic contractors hired directly by the project, and further spin-off activities related to increases in demand in related sectors such as construction, manufacturing, transport and retail. There may also be further income effects through a multiplier process, whereby direct increases in income from wages associated to the project lead to further spending in the economy, thereby boosting GDP further. These combined domestic effects may take some time to manifest, and as such, may affect inflation with a significant lag.

There are other shortcomings of the model worth mentioning. As discussed earlier, there are signs of structural instability in the coefficients, as demonstrated in Appendix B. Whilst tests for autocorrelation came back clear, by inspecting the historical decomposition, we can observe periods were the residuals are persistently large, signalling the presence of an omitted variable. For instance, around 2006-2007, the model persisently overestimates inflation, implying that the external variables and demand conditions should have lead to greater price pressures than were realized. One possible explanation for this anomaly might be that Australian CPI inflation in 2006 was driven largely be non-traded goods. If this were the case, the pass through of inflation from Australia to PNG would be significantly lower than predicted by the model, which uses total Australian CPI inflation, rather than just tradable CPI inflation.

We now turn to the multilateral models. The coefficient estimates and diagnostic tests are similar for all of them, so we restrict our analysis to the model with the non-mineral output gap, henceforth model 3, which demonstrates the best fit ($R^2 = 0.732$).[19] As with the bilateral models, the estimation of this model is absent of serial autocorrelation and heteroskedasticity, as well as having normally distributed errors. The long-run pass through of the output gap in this model is roughly 64 percent, significantly higher than the pass through for the bilateral model 1. To fully grasp the significance of this result, it is best to

[18] See [ACIL Tasman, 2008], figure 2.

[19] The model with the composite output gap has evidence of non-normally distributed errors at the 1 percent level.

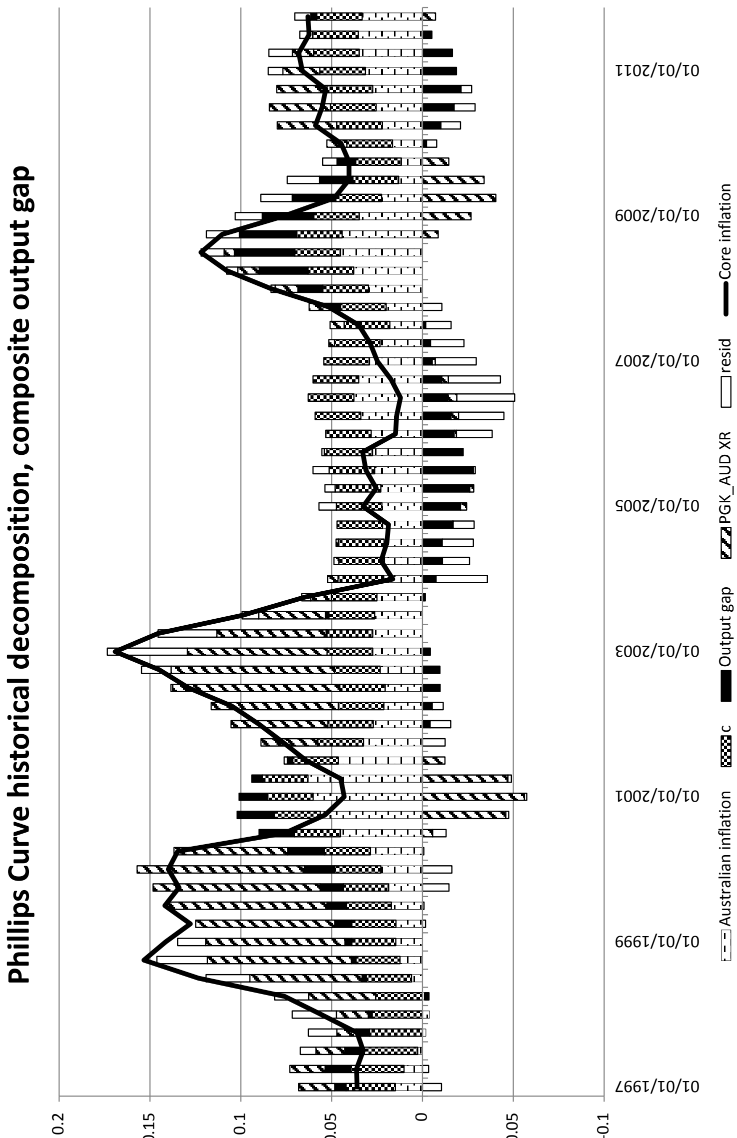

Figure 12: Historical decomposition for model 1

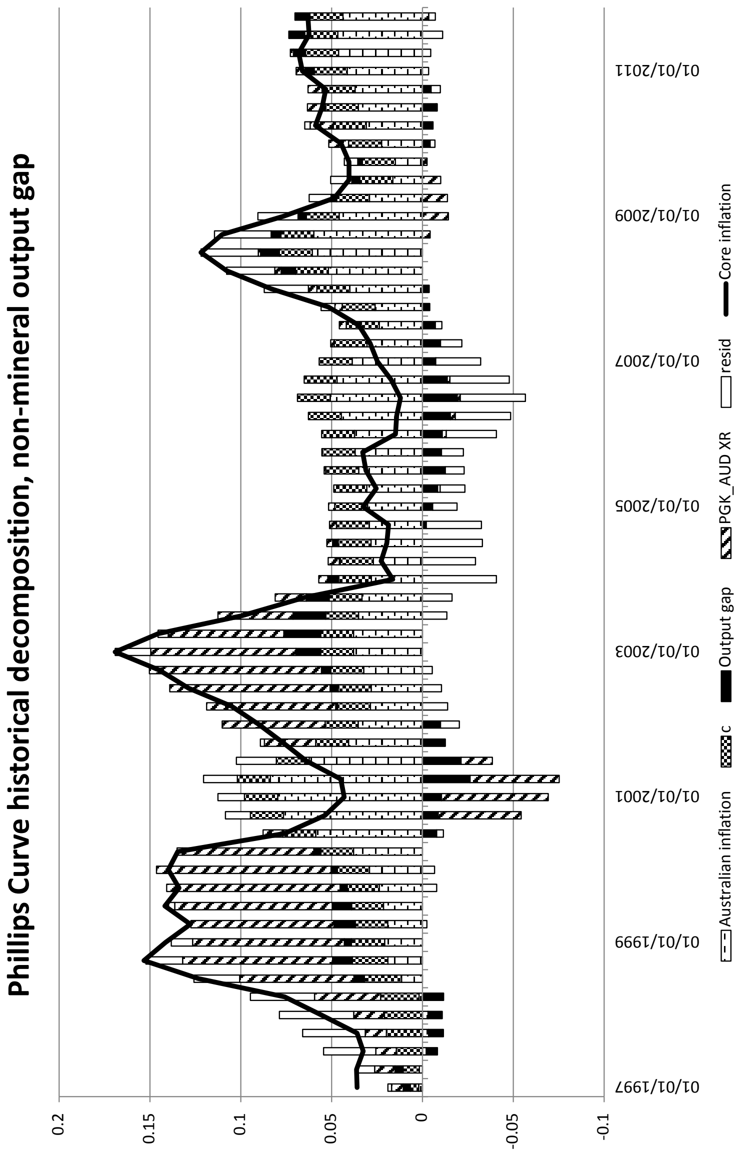

Figure 13: Historical decomposition for model 2

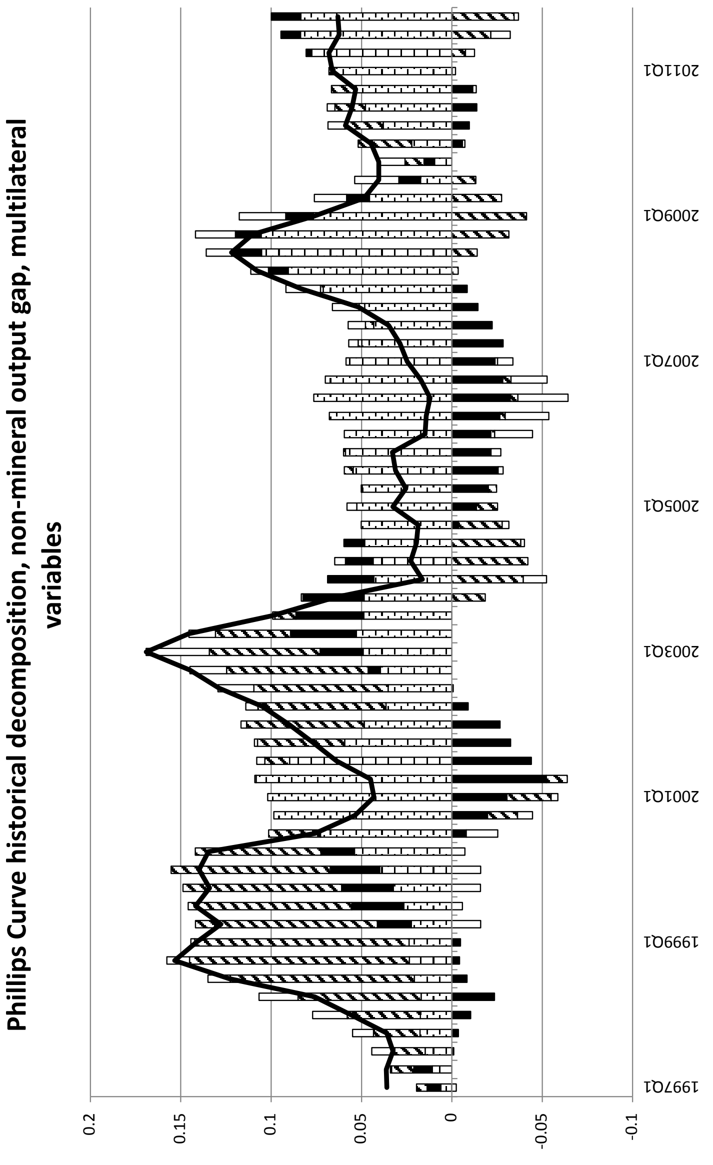

Figure 14: Historical decomposition for model 3

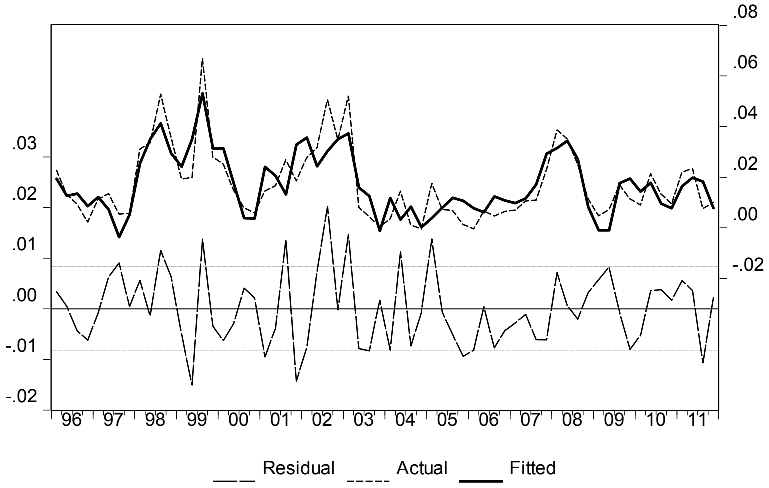

Figure 15: Fitted regression line for model 1

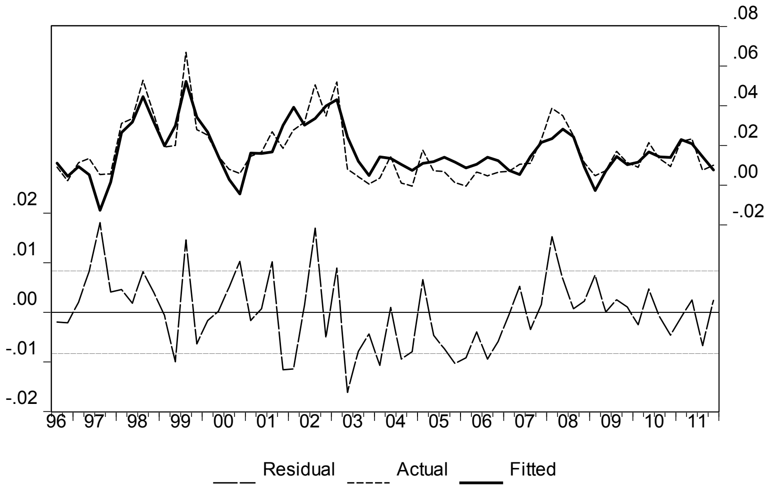

Figure 16: Fitted regression line for model 2

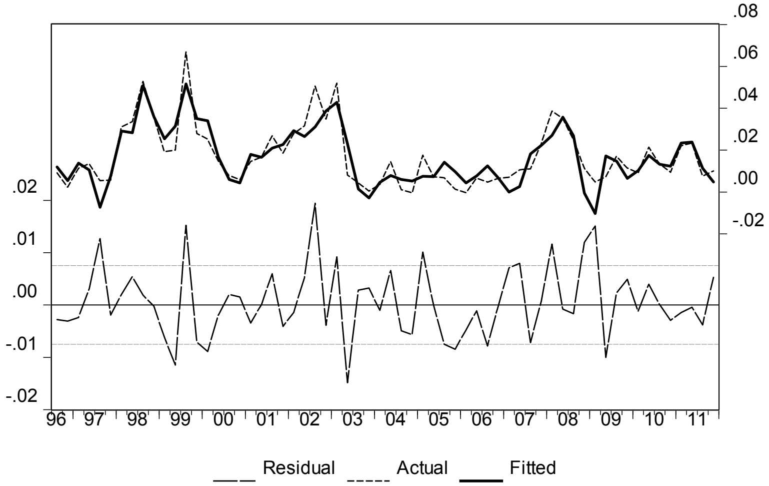

Figure 17: Fitted regression line for model 3

analyse the historical decomposition, as shown in Figure 14. Whilst The results generated here for the pass through of the exchange rate make for an interesting comparison to those of [Sampson et al., 2006]. Model 3 suggests a pass through of roughly 38 percent. This is in line with the findings of [Sampson et al., 2006], which estimated pass-through effects in the range 50-60 percent, but is slightly lower, indicating that the determination of inflation, whilst still largely externally driven, has shifted towards domestic factors in recent times. Furthermore, the insignficance of the third and fourth lags of the NEER suggests that domestic prices have responded faster to international price movements over the new sample period. The model seems to capture the demand effect over the last two years better than model 1 and similarly to model 2.

There are again, however, signs of mild parameter instability around 2008-2009, as indicated by the CUSUM of squares test in Appendix B. One potential explanation for this could come from foreign inflation movements during the crisis. Whilst Australia experienced strong disinflation, PNG's major trading partners suffered even greater disinflation, notably the US. As such, model 3 predicts a greater pull down on domestic inflation through imported disinflation than was actually experienced. Model 1 captures the reality with greater effective.

5 Conclusion

In this paper, we began by providing an account of PNG's macroeconomic history over the past decade or so. We then proceeded to estimate a Phillips Curve relationship for PNG, which modelled core inflation as a function of the output gap and external variables such as nominal exchange rates and foreign inflation. We arrived three final specifications that demonstrated how the output gap is statistically significant in determining inflation. With the aid of a historical decomposition of the estimated models, we saw how certain periods in time, for instance 2007-2009, are well accounted for, whereas other periods, such as the last two years and the period 2006-2007, were not so well accounted for.

There are several possible avenues for further work. As discussed in [Vellodi, Aba, 2012], the construction of the output gap could be refined further by considering alternative underlying data series. The methodology employed here was relatively simple in nature, using de-trended time series and estimating a basic auto-distributed lag model with OLS. It could be worthwhile considering more advanced estimation and modelling techniques, such as casting the model into a vector autoregression or vector error correction framework.[20] Whilst this basic approach is sufficient for the purely backward-looking relationship our model embodied, it would not suffice for a true expectations-augmented NKPC. In this case, more advanced estimation techniques such as generalized methods of moments (GMM) estimation or two-stage least squares (2SLS) would be preferred.

[20] See [Fanelli, 2006].

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A Description of Data

Unless otherwise stated, all series are at the quarterly frequency, with sample period 1996Q1 - 2011Q4.

- **d_log_cpi_trimmed** Quarterly core (trimmed) domestic CPI inflation for PNG.
- **dlog_auscpi** Quarterly Australian CPI inflation.
- **dlog_kina_aud** Quarterly growth rate of bilateral nominal exchange rate, expressed as AUD/PGK.
- **inf_stab_dlogfxrate** Multiplicative dummy, constructed as dlog_kina_aud*dummy2004, where dummy2004 takes values 0 for 1996Q1 - 2003Q4, and 1 for 2004Q1 - 2011Q4. Inserted to capture the relative stability of the exchange rate in the post-2004 period. The kina was floated in 1994, and in the immediate subsequent period, there was significant exchange rate volatility as the kina devalued to find a new equilibrium level. By 2004, this process was complete, leading to a period of relative exchange rate stability. Combined with broader political reforms, this stability was accompanied by widespread macroeconomic stability.
- **wgtcpi** Quarterly growth rate, multilateral foreign CPI. Calculated by weighting CPI indices for PNG's top five trading partners. The weightings are updated annually. Currently, the weightings are 0.594, 0.181, 0.085, 0.043 and 0.097 for Australia, US, Japan, New Zealand and Singapore respectively.
- **wgtxrmct** Quarterly growth rate, nominal effective exchange rate. Calculated by weighting foreign currency by PGK bilateral rates for PNG's top five trading currencies. Currently, the weightings are 0.354, 0.524, 0.051, 0.032 and 0.039 for Australia, US, Japan, New Zealand and Singapore respectively.
- **inf_stab_wgtxrmct** Multiplicative dummy, similar to inf_stab_dlogfxrate, now using wgtxrmct instead of dlog_kina_aud.
- **dum_vat** Impulse dummy, capturing the one-off rise in inflation due to the introduction of the goods and services tax (GST) in 1999Q3.

B Stability Tests

We use the CUSUM and CUSUM of squares tests for parameter instability. For further details, see [Brown et al., 1975]. The graphs plot the test statistic against the 5 percent critical lines. Movement outside the critical lines is suggestive of parameter instability.

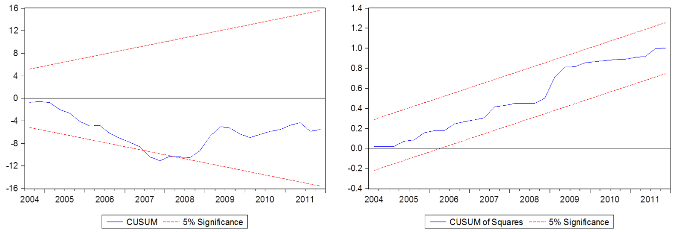

Figure 18: CUSUM, CUSUM squares stability tests, model 1.

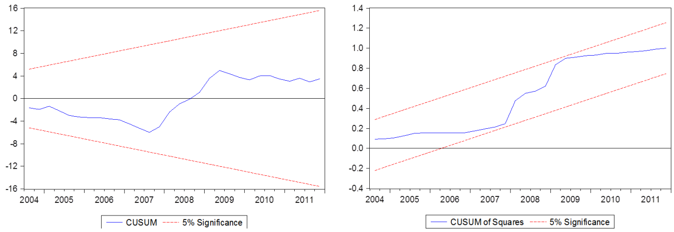

Figure 19: CUSUM, CUSUM squares stability tests, model 2.

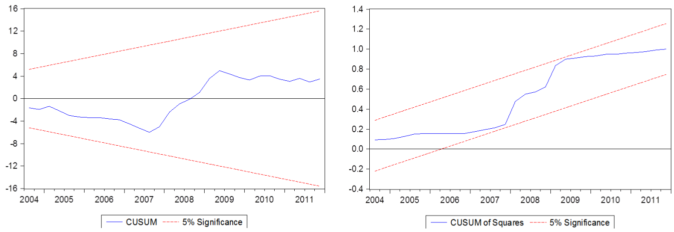

Figure 20: CUSUM, CUSUM squares stability tests, model 3.