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ESTIMATING THE NEW KEYNESIAN OUTPUT GAP FOR ARMENIA VIA A BAYESIAN APPROACH

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ABSTRACT

As the New Keynesian output gap cannot be observed in practice, there is quite some debate on what this variable actually looks like. Rather than taking the standard approach of using a time trend or the HP-filter to estimate it, this paper separates trend from cycle via Bayesian estimation of a New Keynesian model, augmented with an unobserved components model for output.This provides us with a model-consistent estimate of the output gap. This estimate is compared with popular proxies used in the literature. It turns out that the benefits of using the model-based approach mainly lie in real time. Model coefficients are easily interpretable, and the output gap series is consistent with a broader analysis of Armenian economic developments.

Keywords: Output Gap, Inflation, Unemployment, Unobservable Component Model, Bayesian Methods

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CONTENTS

1. INTRODUCTION

The output gap is an important index used by policymakers. It is therefore important to find reliable estimates of the output gap that will help, for example, in the determination of monetary policy, taking the output gap as an indication of inflationary pressures. The output gap is defined as the difference between actual business sector product and (unobserved) potential output. Thus, potential output must be defined at the outset. Okun (1962) defines it as output that can be produced under full employment (long-term output). Another widespread approach in economic literature, and on which De Masi (1997) concentrates, views potential output as the maximum that can be produced without causing inflationary pressures. These differing definitions lead to the situation in which the output gap derived from the latter definition constitutes an indication of inflationary pressures, whereas the former definition expresses business cycles in terms of long-term business-sector product.

In addition to the different definitions of potential output and hence the different output gaps derived from them, there are several approaches to the analysis of the output gap, and these can sometimes lead to different conclusions regarding policy. One example of this is the difference between the approach that considers that potential output reflects the long-term trend of actual business-sector product completely independent of policy measures, and that the only effect that policy measures have is to reduce the deviations of that product from the trend, and the approach based on the assumption that policy can increase potential output. In this context it is important to consider the time scale in measuring the output gap, as if, for example, a positive shock causes a surge in economic activity and inflationary pressures in the short run, in the longer run investments may increase, thereby raising potential output and not only actual business-sector product.

One of the main approaches currently to the explanation of the output gap is that which assumes that permanent long-term shocks affect potential output, while temporary shocks affect only the output gap. Demand-side shocks may be viewed as affecting actual business sector product, and thereby the output gap, and supply-side shocks as affecting potential output. The distinction between the different shocks and their effects on the economic variables, however, is in many cases not clear cut.

Reliable measures of the gap will be especially valuable to monetary policy: first, as a guideline for the appropriate withdrawal of stimulus; second, as a public communications tool to justify the interest rate stance that this will entail. Governments would be concerned about the cyclically-adjusted budget position, to help assess whether, or not, a given budget deficit implies sustainable debt growth over time.

This paper describes a method for measuring and updating potential output and the output gap, which incorporates relevant empirical relationships between actual and potential GDP, unemployment and 12-month inflation within the framework of a small macroeconomic model.In effect, this provides a multivariate (MV) filter, adaptable to many countries[1].The approach has a flexibility, which allows the estimated growth of potential to vary with an array of recent information, while at the same time taking into account the more stable trends evident in long-run time series. I construct confidence intervals around the estimates and their contributors, to give a quantitative guide to certain risks. The results suggest that in practice, as well as in principle, the MV filter can provide useful, relatively robust, estimates of potential output.

Bayesian methods usefully combine information in the data with priors derived from previous studies and economic theory, producing better interpretable results. While technically more

[1]Benes and N.Diaye (2004), Butler (1996), Julliard and others (2007), Kuttner (1994), and Laubach and Williams (2003) have developed multivariate estimates of potential output for single countries.

challenging than classical methods, estimation of even fairly complex Bayesian models is nowadays straightforward due to great strides in econometric theory and increasing computing power.

Section 2 describes the methods of measuring output gap, its advantages and disadvantages.Section 3 outlines the small macroeconomic model.Section 4 illustrates the techniques for estimating parameters, latent variables and confidence intervals.Section 5 highlights some conclusions.Details of the estimation methodology are discussed in the appendix.

2. LITERATURE REVIEW

First and foremost, this paper builds upon the literature that uses unobserved components models to separate trend from cycle. Early papers in this literature (such as Harvey (1985), Watson (1986) and Clark (1989)) however solely used data on output to execute this task.

Kuttner (1994) then augmented the unobserved components model with the rate of inflation, recognizing that the latter contains useful information on the output gap[2].The main difference with current paper, is that these earlier contributions did not estimate the output gap within a micro-founded New Keynesian setting.Kuttner (1994) and the subsequent literature rather augmented the unobserved components model for output with a purely backward looking, Phillips curve-like relation, linking the output gap and lagged economic growth to the change in inflation. Applications of Bayesian methods to estimating output gap have been scarce, with a notable exception of Planas et al. (2008), who estimate a simple model based on Kuttner (1994) for EU and US, and Benes et al. (2010). Asmaa El-Ganainy and Anke Weber have estimated the

[2] Also see Harvey et al. (2007) and Planas et al. (2008) for more recent exercises along these lines, executed in a Bayesian fashion (Kuttner (1994) estimated his model by maximum likelihood).

Armenian output gap suggesting a significant role of the output gap and inflation expectations in determining current inflation.

3. METHODS OF MEASURING THE OUTPUT GAP

The different interpretations and approaches to the output gap led to a wide variety of methods for measuring it. These can by classified into three main groups (Yigal Menashe, Yossi Yakhin 2004): direct measurement via surveys of companies' activity, statistical (nonstructural) methods, and structural methods based on economic theory.Each method has advantages and disadvantages, described below.

- *Direct measurement of the output gap*: in the short term production technology is a given, and there is a supply-side constraint deriving from the factors of production - capital stock or the labor force. In this situation the output gap can be measured directly by using data obtained from surveys of companies' capital utilization and comparing the data received with a certain critical value, generally the average utilization during the sample period. The drawbacks of this method are: the data on utilization generally relate to only some of the companies in the economy (mainly manufacturing companies); the definition of utilization in the survey are naturally subjective and problematic; and there is no exact critical threshold for utilization.
- *Nonstructural methods of measuring the output gap*: this group includes all the methods of estimation based on particular statistical procedures and not on specific economic theory, such as those that measure potential output as a simple linear trend or as a flexible smoothed trend (the HP filter) of data on actual business-sector product. Another method, developed by Baxter and King (1995) and called the Band Pass Filter, views the business cycle as a situation in which business-sector product is either below or above the trend for a minimum number of consecutive quarters,

and the output gap is not calculated until those periods have passed. The advantage of these methods is that they do not require much information, and they can be applied even when only one data series is known. The major disadvantage of these methods is their inability to distinguish between supply shocks and demand shocks, and in the absence of an economic framework, there is no reference to the different effects of different shocks on potential output. The distinction between structural and nonstructural methods is not unequivocal, however, as in many instances structural methods, for example measuring business-sector product via the production function, employ trends and statistical methods to measure some of the components of the output gap. Nevertheless, the case can be argued on principle that a distinction should be drawn between the two systems of estimation.

- *Structural methods for measuring the output gap*: this group assumes that a particular theory exists that describes economic conduct properly. Two central approaches may be singled out: one based on statistical estimation of several series, on the assumption of long- and short-term relations derived from economic theory (SVAR), and the other based on measuring the output gap by means of a cumulative production function. The estimation of the output gap via SVAR is based on the work of Blanchard and Quah (1989). The underlying assumption is that demand-side shocks are neutral in the long term. In that sense it is supply-side shocks and a deterministic component of the model that determine potential output. The production function approach for calculating the output gap and potential output require relatively much information: an assumption about production technology, labor-market data on labor input, unemployment rates and the participation rate, as well as capital stock and total productivity.

Another problem in using this approach is the exogenous assumption of the unobserved natural unemployment rate. There are two other methods of estimation in the group of structural models in addition to the above: (1) estimation by multivariate unobserved component models, based on a number of equations that create a certain economic structure and that are estimated together with unobserved variables. The first study in which this method was used to estimate potential output was that of Kuttner (1994), which was extended by Apel and Jansson (1999), who presented a model that incorporated, in addition to the stochastic process of the unobserved variables (the NAIRU (non-accelerating-inflation rate of unemployment) and potential output),

also the equations of the Phillips curve that relates inflation to the output gap and the unemployment gap (the gap between the actual rate of unemployment and the NAIRU) and another equation that relates these two gaps in accordance with Okun's Law. (2) The multivariate HP filter: this approach estimates potential output as that which would yield a minimum of the loss function that includes two main elements—the data of the smoothed function of actual business-sector product as given by the estimate of the standard HP filter, and a second element that gives a minimum for the squares of the sums of the errors of several economic equations such as the Phillips curve and the relation between the output gap and the unemployment gap, in which the output gap is the explanatory variable.

4. MODEL AND ESTIMATION PROCEDURE

A. Model specification

The output gap (y_t) is the log difference between actual GDP (Y_t) and potential GDP ($\bar{Y}_t$):

$$y_t = 100 * Log(Y_t/\bar{Y}_t). \tag{1}$$

The unemployment gap (u_t) is the equilibrium unemployment rate, or NAIRU, ($\bar{U}_t$) minus the actual unemployment rate (U_t):

$$u_t = \bar{U}_t - U_t. \tag{2}$$

B. Three Identifying Relationships

B.1 Inflation equation

The level (y_t), the change ($y_t - y_{t-1}$) in the output gap and inflation expectations influence current 12-month inflation ($\pi 4_t$):

$$\pi 4_t = (1-\delta)\pi 4_t^{LTE} + \delta \pi 4_{t-1} + \beta y_t + \Omega(y_t - y_{t-1}) + \varepsilon_t^{\pi 4}. \quad (3)$$

The level of the gap incorporates the standard short-run tradeoff: an increased gap implies an increased rate of inflation.The change in the gap would reflect certain rigidities in the adjustment of the economy - for example, coming out of a recession it would capture speed-limit effects due to capacity constraints in some sectors of the economy.The lagged inflation rate, interpreted as a simple proxy for adaptive expectations of inflation. Inflation also depends on expected future inflation. Equation (3) is by no means a state-of-the-art augmented Phillips curve.

B.2 Dynamic Okun's law

Okun defined a simple relationship between the current unemployment rate and the output gap. However, both theory and the data indicate that there should be a lag between changes in output and the resulting changes in employment. Recognizing a lag effect, we use this equation to link the unemployment gap to the output gap:

$$u_t = \phi_1 u_{t-1} + \phi_2(y_t) + \varepsilon_t^u. \quad (4)$$

C. Laws of Motion for Equilibrium Variables

C.1 Equilibrium unemployment rate or NAIRU

A stochastic process that includes transitory, level shocks ($\varepsilon_t^{\bar{U}}$) as well as more persistent shocks ($G_t^{\bar{U}}$), provides a useful empirical description of the history of equilibrium unemployment ($\bar{U}_t$):

$$\bar{U}_t = \bar{U}_{t-1} + G_t^{\bar{U}} - \frac{\omega}{100} y_{t-1} - \frac{\lambda}{100}(\bar{U}_{t-1} - U^{ss}) + \varepsilon_t^{\bar{U}}. \quad (5)$$

The inclusion of the output gap in the NAIRU represents a partial hysteresis effect from economy-wide demand fluctuations - see Ball (2009) for a recent discussion.[3] The persistent shocks to the NAIRU follow a damped autoregressive process:

$$G_t^{\bar{U}} = (1-\alpha)G_{t-1}^{\bar{U}} + \varepsilon_t^{G^{\bar{U}}}. \tag{6}$$

Notice that, while we allow for persistent deviations in the NAIRU, we assume a fixed steady-state level of unemployment in the long run, U^{ss}.

C.2 Potential output

Potential output ($\bar{Y}_t$) depends on the underlying trend growth rate of potential ($G_t^{\bar{Y}}$), and on changes in NAIRU:

$$\bar{Y}_t = \bar{Y}_{t-1} + G_t^{\bar{Y}}/4 - \theta(\bar{U}_t - \bar{U}_{t-1}) + \varepsilon_t^{\bar{Y}}. \tag{7}$$

In equation (7) ($\bar{U}_t - \bar{U}_{t-1}$), captures the impact of changes in the equilibrium level of unemployment on the growth of potential output, via a Cobb-Douglas production function, in which θ is the labor share.

The underlying trend growth rate ($G_t^{\bar{Y}}$) is not constant, but follows serially correlated deviations (long waves) from the steady-state growth rate, $G_{SS}^{\bar{Y}}$.

$$G_t^{\bar{Y}} = \tau G_{SS}^{\bar{Y}} + (1-\tau)G_{t-1}^{\bar{Y}} + \varepsilon_t^{G^{\bar{Y}}}. \tag{8}$$

C.3 Perceived long-term inflation objectives

$$\pi4_t^{LTE} = \pi4_{t-1}^{LTE} + \varepsilon_t^{\pi4^{LTE}}. \tag{9}$$

The sample period contains 2 monetary policy regimes over time.I postulate that the expected objective, $\pi4_t^{LTE}$, follows an adaptive process, with revisions to last quarter's expectation

[3]Blanchard and Summers (1986) introduced the idea of hysteresis to the behavior of equilibrium unemployment.They explained the long duration of shocks to unemployment by distinguishing between insiders and outsiders in the wage bargaining process. Ball (2009) presents evidence that NAIRU remainsstrongly history-dependent.

embodied in the term $\varepsilon_t^{\pi 4^{LTE}}$. In the event of a regime change, the variations in $\varepsilon_t^{\pi 4^{LTE}}$would be large.In contrast, however, the past 7 years has seen stable, and more or less explicit, inflation objectives. I use data on long-term inflation expectations as a moving average of current, lagged and forecasted rates of inflation. The moving average makes expected inflation $\pi 4_t^{LTE}$ a simple function of current, past and forecasted rates of inflation.

D. Output Gap Equation

In conventional monetary policy models, over time, an interest rate reaction function keeps inflation on target. Changes in the policy interest rate influence inflation through a complex transmission mechanism in which the Phillips curve is a key link. In effect, monetary policy exerts its influence on the inflation through the output gap. For present purposes, it is useful to recognize this through the following equation:

$$y_t = \rho_1 y_{t-1} - \frac{\rho_2}{100}(\pi 4_{t-1} - \pi 4_{t-1}^{LTE}) + \varepsilon_t^y . \qquad (10)$$

Notice that the negative effect on demand from inflation deviations from target is consistent with a broad range of monetary regimes. In Armenian case of an inflation-targeting regime, the inflation resulting from a period of excess demand is met by a tightening in monetary conditions by the central bank, reducing the output gap. Other factors (e.g. demand shocks) driving the output gap are summarized in the stochastic term ε_t^y.

5. ESTIMATING AND TESTING

A. Estimation Technique and used data

Univariate filters have many shortcomings.Most importantly, they ignore relevant economic information, which can create large biases. For instance, estimates of potential output for 2009 using the HP filter, production function approach, or a simple Kalman filter ignore the significant decline in inflation that has been observed in early 2009 in Armenia. A possible definition of potential output would be the level of output that can be sustained indefinitely without creating a tendency for inflation to rise or fall (Benes et al., 2009). Thus, potential output should be estimated jointly with an inflation equation. Another important economic indicator is unemployment. Incorporating these economic variables into a UC model leads to a multivariate framework, which in principle could be estimated in the same way as the simple multivariate Kalman filter. However, with a number of state and measurement equations to estimate, the choice of initial conditions for the filter becomes even more important. Therefore, this section follows Benes et al. (2009) and estimates a structural macroeconomic model with Bayesian techniques.This methodology makes it possible to define prior distributions that ensure that parameter values stay in sensical regions.

The above model is estimated by regularized maximum likelihood (see Appendix) using Iris, a toolbox for estimating macroeconomic models based on Matlab.This estimation procedure obtains the most likely estimates of the output gap given our initial priors on parameters. It interprets the data on 12- month inflation, the unemployment rate and real GDP through the lens of the model outlined above. The regularized maximum likelihood procedure will thus find the best estimates conditional on the above model.The posterior estimates of parameters are then a combination of the initial priors and an adjustment to make those priors more consistent with the model.

The estimates of the within-sample confidence intervals are derived analytically, taking the model and its parameters as the true data generating process.They incorporate the sampling uncertainty of the unobservable component estimates.

The following assumptions were made in the estimation: First, the steady state growth rate was set to 5 percent, labor share was calculated as Total labor costs into the Gross Value Added, the steady state unemployment rate was set to 14 percent. The priors for these steady-state parameters are based on broadly based on values reported in the literature (see Berg et al. 2006 a, 2006 b), with some modifications to reflect specific features on the Armenian economy. I also estimated the model with different steady state and prior assumptions and found that the results were not very sensitive to those. All priors for coefficients in the output gap, Okun's law and inflation equations are distributed according to normal distributions conditional on other parameters of the model, and subject to restrictions.

Priors are relatively imprecise, in order to allow information in the data have a meaningful influence on posteriors.Priors for variances of shocks are also relatively non-informative and proportional to modeled time series (see Appendix, Figure 1 and Table 1).

The model is estimated using quarterly data for 2000 Q1 to 2014 Q1 subject to standard adjustments.Time series are provided by the Central bank of Armenia (CBA), National Statistical service of Armenia (GDP, CPI, unemployment). Real GDP series is logged and seasonally adjusted using Tramo/Seats. It is helpful to incorporate GDP, CPI, unemployment projections into the estimation. CBA staff projections for real quarterly GDP, CPI, unemployment for 2014 were used.

6. RESULTS

A. Posterior distributions of parameters

The means and standard deviations of the posterior distributions of the parameters are also displayed in Table 1[4].Although these parameter estimates are not the main focus of this study, I do discuss them briefly.First, note that most posteriors differ substantially from the priors. Together with the observation that all posterior standard deviations are smaller than the prior ones, this suggests that the data are quite informative about the parameters.

Second, I find a significant role for the backward looking component in the New Keynesian Phillips curve (NKPC). The posterior mean of δ (0:591) suggesting that backward looking behavior to be dominant in the NKPC.

Third, the results also attribute an important role to the lagged New Keynesian output gap in the dynamic IS equation (the posterior mean for ρ_1 is 0:674), thereby suggesting that habit formation is important to match the data. This confirms the finding by Christiano et al. (2005) and is consistent with the FIML-estimate of Lippi and Neri (2007, who estimated this exact coefficient to be equal to 0:79 on European data).

Fourth, the estimate of the slope of the NKPC (β is 0,163) is at the low end of the spectrum, but higher than the estimates of for example Cho and Moreno (2006).

The estimate for the coefficient of Okun's law (ϕ_2) is 0.237 and in line with world average estimated by IMF staff.

Output and unemployment gap decomposition allows to determine contribution of each shock.

Finally, the 67 percent credible interval for output gap does not include unity.

[4] Graphs are recorded in the Appendix.

B. New Keynesian Output Gap

Figure 1 shows the results for potential and actual level of output, the growth rate of potential output, potential and actual level of unemployment, the unemployment gap, and output gap.The toolkit for the Bayesian estimation also provides forecasts of the output and unemployment gaps (shaded areas in the charts) and their decomposition into different shocks (Figure 2).

Figure 1: Model-based estimates

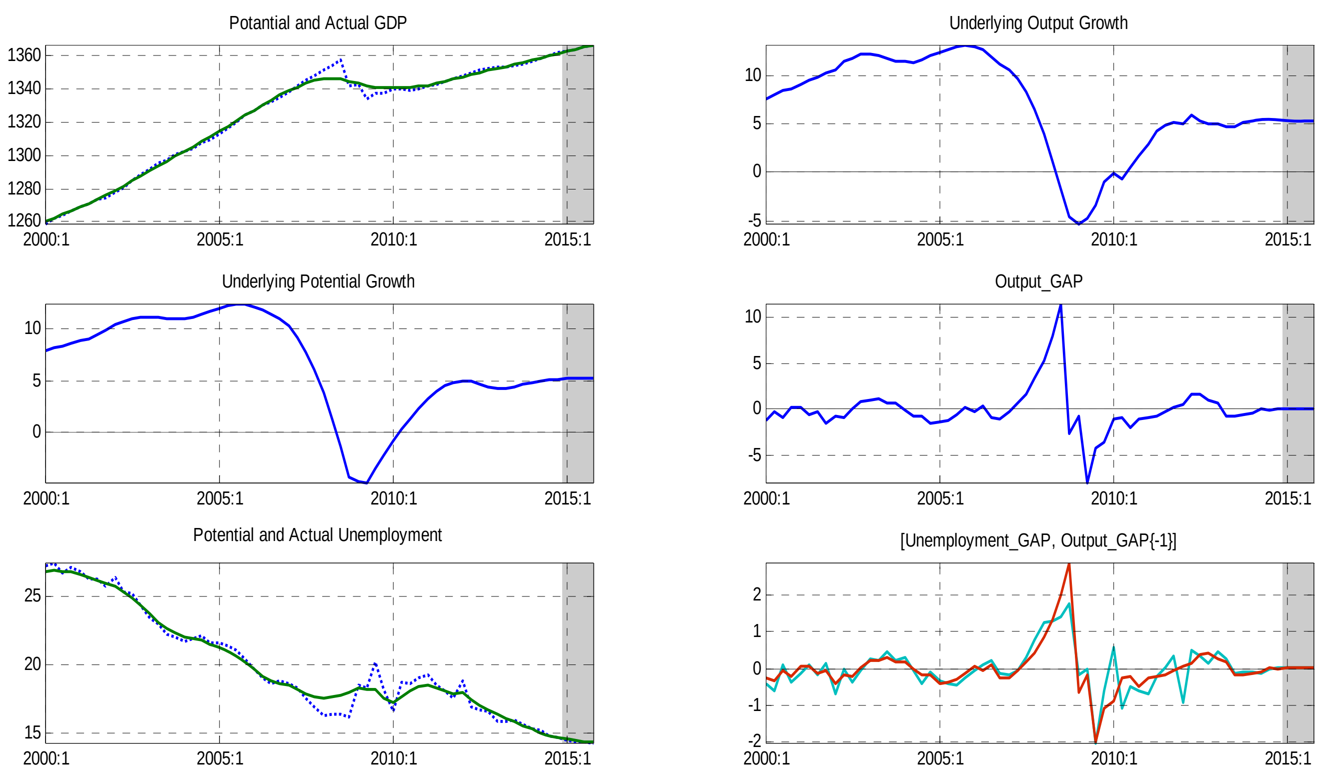
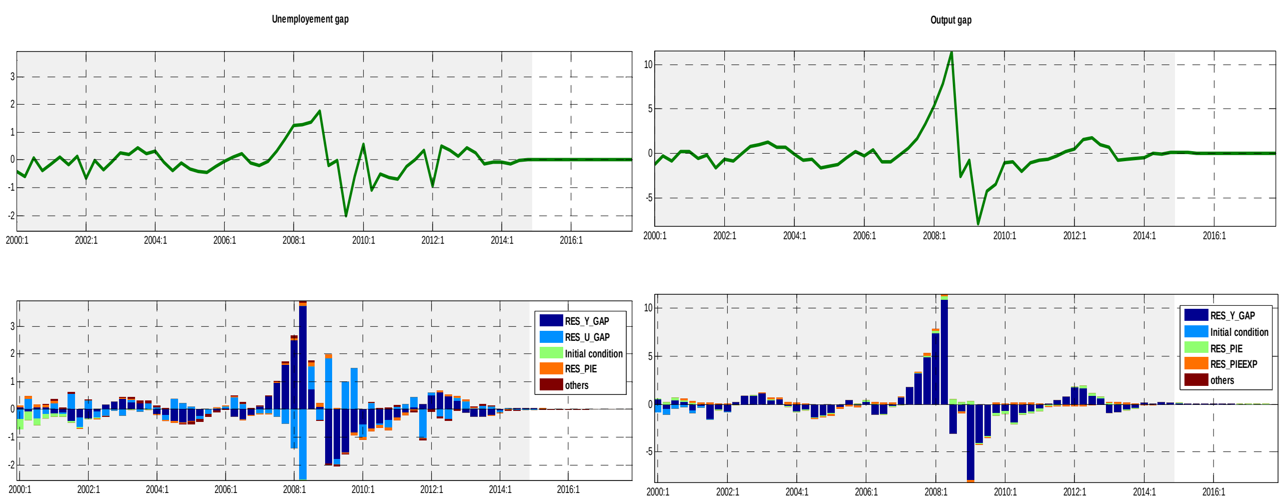


Figure 3 shows the results for output gap with confidence interval: Armenia enjoyed a progressive strengthening of economic growth in 2006 and 2007 within a low inflation macroeconomic environment.However, these developments came to a sudden halt when Armenia was severely hit by the global economic crisis in 2008.The economy was confronted by a number of external shocks including large falls in remittances and capital inflows. GDP contracted by more than 14 percent in 2009 reflecting a collapse in the construction sector, which previously had been an engine of growth.The severe contraction of the Armenian economy raises the question of the effects of the financial crisis on potential output and the output gap. It is likely that the global economic crisis has reduced potential output in Armenia because it has led to slower capital inflows, higher government debt and thus a higher cost of capital. It is also likely to have severely reduced the capital stock through business failures and weak investment inlight of unusual uncertainties and extreme tightness of credit.

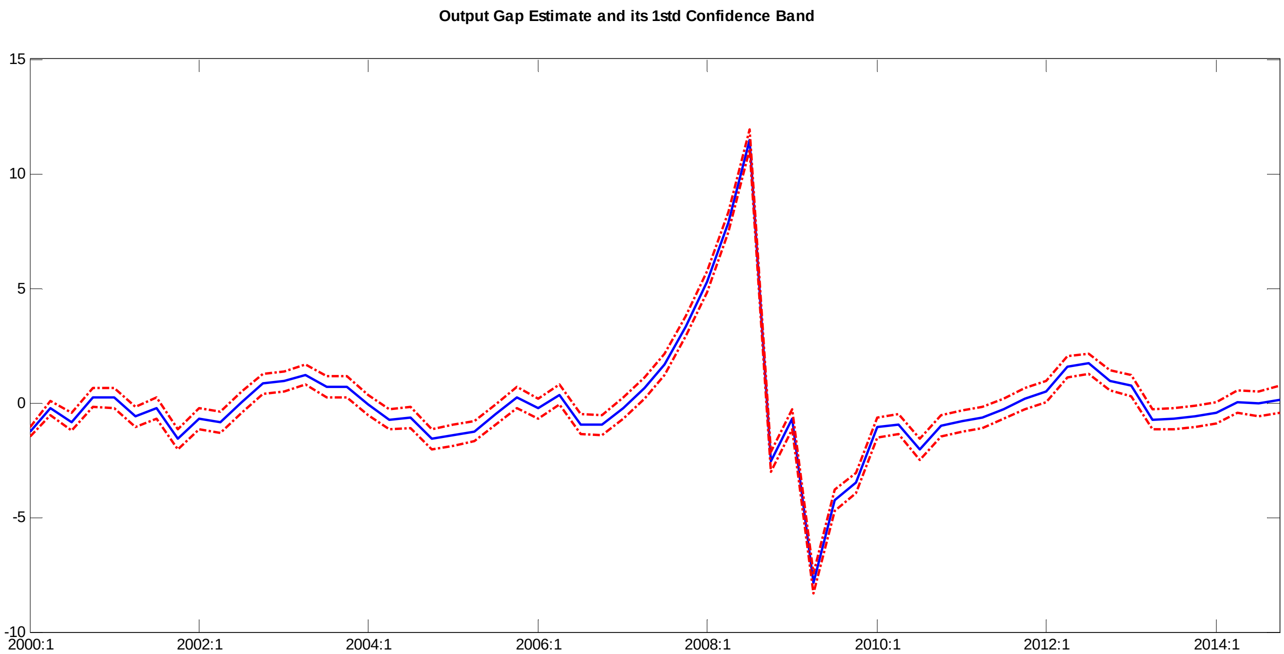
Figure 2: Output gap and Unemployment gap decomposition[5]



The findings show that the output gap is significantly positive in 2007 and 2008 and is falling dramatically in 2009. The estimations indicate that the output gap returns into positive territory at the end of 2011, when real GDP growth accelerated slightly.It then becomes significantly negative in 2013 in the face of the tightening fiscal policy. Figure 1 shows that negative output gap in 2013 narrows in 2014 and turns zero in 2015.

[5] In the graph RES_Y_GAP, RES_U_GAP, RES_PIE and RES_PIEEXP are the residuals of equations 10, 4, 3 and 9 respectively.

Figure 3: Output gap estimates with confidence interval



These findings have important implications for the monetary policy framework in Armenia since they indicate that the central bank should closely monitor output gap developments and inflation expectations of the private sector.

7. CONCLUSION

In this paper, the unobserved components approach is used to estimate a New Keynesian model. Consequently, it is possible to feed raw output data into the estimation procedure and to obtain model-consistent estimates of the natural level of output and the New Keynesian output gap for Armenia.

The estimates confirm that the growth rate of potential GDP varies substantially over time. Marked changes in the growth rate are correlated with the business cycle.However, the estimated gaps between actual and potential output also show important -fluctuations, consistent with the historical movements in inflation.

As the New Keynesian model estimated here still is overly simplified, this paper also leaves several issues for further research. One could for example extend this paper's setup by combining the unobserved components approach with a much richer DSGE model (enabling the researcher to include more observables in the analysis).

Most notably, the current model abstracts from the accumulation of capital so investigating whether the addition of capital alters the conclusions of this paper, would be a logical next step.

It could however be that considering such a richer setup delivers further improvements in the model's real time performance.

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APPENDIX

A. Maximum Regularized Likelihood

Let θ be a vector of parameters, let Y be the data and $L(\theta;\,\mathrm{Y})$ be the data likelihood function. Then the objective function is

$$max \log L\,(\theta; Y) - p \sum \frac{(\theta_i - \bar{\theta}_i)^2}{\delta_{\bar{\theta}_i}^2}$$

Where $\theta_i \in [\theta_i^L, \theta_i^U]$.

This method can be interpreted as a simple Bayesian technique where the prior for each parameter is a normal distribution with mode $\bar{\theta}_i$and variance $\frac{2\delta}{p\bar{\theta}_i}$, truncated at θ_i^L from below and θ_i^U from above. The parameter estimate can be seen as the mode of the posterior distribution.

Notice that the smaller p, the looser the prior for each parameter, for any given$\delta_{\bar{\theta}_i}^2$. Weuse $p = 1$ so that the numbers presented in Table 1 are readily interpreted as the standard deviations of the priors. For more information on the technique, please see (Ljung, 1999).

Table 1: Prior and Posterior Distribution

Parameter	Prior		Posterior	
	Mode	Dispersion	Mode	Dispersion
Ω	0.28	0.03	0.211	0.03
ϕ_1	0.6	0.05	0.614	0.05
ϕ_2	0.25	0.02	0.237	0.018
ω	0.3	0.02	0.291	0.02
λ	2	0.1	2	0.107
α	0.3	0.02	0.305	0.019
β	0.3	0.05	0.163	0.038
τ	0.85	0.01	0.856	0.009
δ	0.65	0.067	0.591	0.043
ρ_1	0.7	0.057	0.674	0.053
ρ_2	5	1	5.134	0.965
$\delta\varepsilon^{\pi 4}$	0.4	0.08	0.35	0.044
$\delta\varepsilon^{G^U}$	0.35	0.02	0.33	0.022
$\delta\varepsilon^{u}$	0.4	0.022	0.37	0.022
$\delta\varepsilon^{G^Y}$	0.45	0.02	0.47	0.018
$\delta\varepsilon^{y}$	0.55	0.05	0.59	0.042
$\delta\varepsilon^{\pi 4^{LTE}}$	0.4	0.067	0.48	0.038

Figure 1a: Prior and Posterior Distribution

Figure 1 shows the prior and posterior distributions of the variables estimated in model.