2015

An Unobserved Components Model Approach to the Relationship between Real GDP and Unemployment for Cyprus

Volos, Christos

NEAPOLIS UNIVERSITY OF PAPHOS (NUP)

WORKING PAPERS SERIES

2015/5

TITLE: "An Unobserved Components Model Approach to the Relationship between Real GDP and Unemployment for Cyprus"

AUTHOR: Christos Christodoulou-Volos & Andreas Hadjixenophontos

An Unobserved Components Model Approach to the Relationship between Real GDP and Unemployment for Cyprus

Christos Christodoulou-Volos*
Neapolis University Pafos

Andreas Hadjixenophontos
Neapolis University Pafos

Abstract This empirical study employs a bivariate unobserved components model to estimate the permanent and transitory movements in real GDP and the unemployment rate and the relationships between them, using information from observable aggregates for the economy of Cyprus. The main motivation for quantifying this relationship is the absence of any measure for the Okun's law that can be used to evaluate the effects of macroeconomic policy. The results suggest that both the transitory movements in Cypriot output and unemployment rate are critical for explaining overall fluctuations. The estimated Okun's coefficient for transitory movements implies that a 1% change in transitory unemployment causes 1.73% change in transitory real GDP in the opposite direction.

JEL Classifications: C32, E23, E24, E32

Keywords: unobserved components, business cycle, trend GDP, cyclical unemployment, Cypriot economy

* Corresponding author, Neapolis University Pafos, 2 Danais Avenue, 8042 Pafos, Cyprus, tel.: 26843508, e-mail: c.volos@nup.ac.cy.

1 Introduction

Unobserved Components Models (UCM) have been used for an analysis of many macroeconomic time series that can be decomposed into permanent, or trend, movements and transitory movements in the series of various countries. Sinclair (2009) showed that there is an important relationship between the permanent and transitory movements in U.S. output and the unemployment rate, as specified by Okun's law. Okun's law is an empirically observed relationship linking unemployment to losses in a country's production.[2]

From the viewpoint of time series analysis, the estimation of the relationship between the two requires the decomposition of the observed output and unemployment series into the non-stationary permanent and the stationary transitory component. In many studies a variety of detrending techniques is used to carry out the trend-cycle decomposition. In the current study, a bivariate correlated unobserved components model (UCM), used in Sinclair (2009), is employed for decomposing output (measured as real GDP) and the unemployment rate for Cyprus into the permanent and transitory components and investigating the relationships between the two using information from observable aggregates and presents results for the economy of Cyprus. The model was developed by Sinclair (2009) as a two series extension of the correlated UCM as proposed by Morley, Nelson and Zivot (2003). Similar multivariate UCM have been applied to macroeconomic variables for single individual economies such as the US (Morley 2007, Sinclair 2009) and Canada (Basistha 2007) and for groups of countries like Eurozone aggregates (Xiaoshan C., and T. Mills, 2012).

As Harvey and Jaeger (1993) argue, this class of models provides a useful framework as they "are explicitly based on the stochastic properties of the data". They are based on interpretable and well-defined models for the individual components, are very flexible in accommodating peculiar features of the time series and can be scrutinized by rigorous tests. The correlated UCM can distinguish cross-series correlations driven by the relationships between permanent shocks, caused by real shocks, from those between transitory movements, caused by changes in aggregate demand or monetary shocks. It does not require any prior transformation or detrending of the data and places fewer restrictions among the series than other models. In particular, this approach combines the detrending and correlation estimation into a single stage which improves both the estimates of the trend and cycle as well as the estimates of the correlations. Furthermore, this model nests many of the common detrending methods (Harvey and Trimbur, 2003) and is thus more general than selecting a more restrictive model.

The bivariate correlated UCM simultaneously decomposes each series into a permanent component and a stationary transitory component. The permanent component is assumed to be a process of random walk with drift (Stock and Watson, 1998) in order to capture the long term potential (or steady-state level) output of the economy. The transitory component, defined as real GDP deviations from the permanent trend, is assumed to be stationary following a second order autoregressive process, or AR (2). In this way the model can identify the correlation of the shocks to permanent and transitory

[2] In Okun's original statement of his law, a 3% increase in output corresponds to a 1% decline in the rate of unemployment; a .5% increase in labor force participation; a .5% increase in hours worked per employee; and a 1% increase in output per hours worked (labor productivity).

components of each series. This is particularly important for macroeconomic fluctuations of developing countries such as Cyprus, which may not experience typical traditional business cycle fluctuations.

This paper is divided into four sections. Section (2) briefly introduces the relationship between output and unemployment and the unobserved components model (UCM) in time series. Section (3) presents the application of UCM and the empirical results from the first quarter of 2004 to the first quarter of 2013.The final section provides the concluding remarks.

2 The Okun's Law and the Unobserved Components Model

2.1 The Okun's Law

Okun's law (1962) is an empirically observed relationship relating unemployment to losses in a country's production. There are several versions of this rule of thumb but the "difference version" states that a one point increase in the unemployment rate is associated with two percentage points of negative growth in real GDP. The relationship varies depending on the country and time period under consideration.

This version describes the relationship between quarterly changes in unemployment and quarterly changes in real GDP. The stability and usefulness of the law has been disputed. The relationship has been tested by many researchers by regressing GDP growth on change in the unemployment rate and they argued that most of the change in output is actually due to changes in factors other than unemployment, such as capacity utilization and hours worked.

The difference version of Okun's law may be written (Abel & Bernanke, 2005) as:

$$(\overline{y}_t - y_t)/\overline{y}_t = \lambda(u_t - \overline{u}_t) + v_t \qquad (1)$$

where $\overline{y}_t$ is potential GDP, y_t is actual output, $\overline{u}_t$ is the natural rate of unemployment, u_t is actual unemployment rate, λ is the factor relating changes in unemployment to changes in output, $(\overline{y}_t - y_t)$ and $(u_t - \overline{u}_t)$ as the transitory components of output and the unemployment rate respectively, and v_t represents a random error. Generally the relationship between output and the unemployment rate is expected to be negative and therefore the estimate of λ must be, accordingly, negative. In particular, it is expected that the transitory components of real GDP and the unemployment rate must be negatively correlated.

2.2 The Unobserved Components Model

The UCM may be considered to be a multiple regression model with time-varying coefficients. It is based on the principles that (i) it is useful to view time series as being decomposable into trend, seasonal, and cycle components and (ii) time series models that give equal weight to both near and far distant observations (as in the deterministic trend model to be discussed later) are often not very useful. With respect to point (i) inefficient and inaccurate forecasting is likely to arise if the salient characteristics of the time series to be forecasted are ignored. With respect to point (ii), in many time series the adjacent observations are more closely correlated with each other than observations that are far apart. As a result, time series models that are "local" in nature and place more weight on recent observations than those in the far past, tend to predict better when applied to economic and business time series than models that treat time series data "globally" as in the deterministic time trend model.

Output (y) and the unemployment rate (u) can each be represented as the sum of a permanent component and a transitory component. The permanent component (τ) is the steady-state level after removing all temporary movements. The transitory component (c) embodies all temporary movements and is assumed to be stationary:

$$y_{it} = \mu_{it} + c_{it}, i = y \text{ or } u \tag{2}$$

Each of the trend components is assumed to be a random walk to allow for permanent movements in the series:

$$\tau_{it} = \mu_i + \tau_{it-1} + \eta_{it} \tag{3}$$

For output, the model allows for a drift (μ_y) in the permanent component, but the drift for the unemployment rate was insignificant and is not included in the reported models.

Following Morley, Nelson, and Zivot (2003), Clark (1987 and 1989), and Watson (1986), each transitory component is modeled as an autoregressive process of order two (AR(2)). Including a third lag does not qualitatively change the results and a likelihood ratio test indicates that a third lag is not significant.

$$c_{it} = \varphi_{1i} c_{it-1} + \varphi_{2i} c_{it-2} + \varepsilon_{it} \tag{4}$$

The correlated unobserved components model assumes the permanent and transitory innovations (η_{it}, and ε_{it}) are jointly normally distributed random variables with mean zero and a general covariance matrix (allowing possible correlation between any of the unobserved innovations). The model can be represented in state-space form so that the Kalman filter can be applied for maximum likelihood estimation of the parameters and the components.

The variance-covariance matrix is

$$\Sigma = \begin{bmatrix} \sigma^2_{\eta y} & \sigma_{\eta_y \eta_u} & \sigma_{\eta_y \varepsilon_y} & \sigma_{\eta_y \varepsilon_u} \\ \sigma_{\eta_y \eta_u} & \sigma^2_{\eta u} & \sigma_{\eta_u \varepsilon_y} & \sigma_{\eta_u \varepsilon_u} \\ \sigma_{\eta_y \varepsilon_y} & \sigma_{\eta_u \varepsilon_y} & \sigma^2_{\varepsilon y} & \sigma_{\varepsilon_y \varepsilon_u} \\ \sigma_{\eta_y \varepsilon_u} & \sigma_{\eta_u \varepsilon_u} & \sigma_{\varepsilon_y \varepsilon_u} & \sigma^2_{\varepsilon u} \end{bmatrix} \tag{5}$$

It is well known in the advanced time series literature that UC models can be thought of as being special cases of more general models called Gaussian State Space Models (GSSM). Once the specific UCM has been cast in State Space form the various unobserved components can be estimated using the Kalman Filter for maximum likelihood estimation of the parameters and the components.

3 Data and Results

The data used in this study consist of real GDP and unemployment observations of quarterly frequency for Cyprus. The GDP series is represented in (natural) logarithms multiplied by 100 (y). The main motivation to work with logarithms, instead of levels, is that they are usually stationary (covariance-stationary) and they represent the behavior of the conditional volatility of the series in a more intuitive manner. All data was obtained from the statistical service's database of Cyprus and span from the first quarter of 2004 to the first quarter of 2013.

Figures 1 and 2 present the estimated permanent and transitory components of real GDP and the unemployment rate respectively along with the observed series. They are produced using the Kalman smoother, which uses all information available in the sample, thus providing a better in-sample fit as compared to the basic Kalman filter which only uses information available at time t. In the case of both real GDP and the unemployment rate, using the additional information results in a less variable trend and a more variable transitory component than using the basic filter.

Figure 1 shows the estimate of the permanent and transitory components of the Cypriot real GDP based on the bivariate UCM along with the series itself. It looks like most of the movement in real GDP appears to arise from transitory movements. These estimates suggest that that the transitory movements are substantial. The transitory components appear very similar to the series itself.

Insert Fig. 1 About Here

The estimated permanent and transitory components of real GDP presented in Figure 1 raise two important points. First, movements in the permanent component for real GDP are relatively stable. Second, innovations to the permanent component are not significantly correlated with innovations to the transitory component. The transitory movements are the difference between the real GDP series and the permanent component. The estimate of the transitory component looks very similar to the real GDP series. This result contradicts the findings of Beveridge-Nelson (1981) decomposition of U.S. real GDP and the ones of Morley, Nelson and Zivot (2003) and Morley (2007a). They found that the estimated permanent component resembled to a large degree the original U.S. real GDP series.

Figure 2 presents the estimate of the permanent component of the Cypriot unemployment rate along with the unemployment rate series. In this case, however, it appears that most of the movements in the unemployment rate arise from permanent shocks. These estimates suggest that that the transitory movements are small and noisy. Similar to real GDP, the transitory components appear very similar to the series itself.

Insert Fig. 2 About Here

3.1 Correlated Unobserved Components Model Parameter Estimates

Although the estimates presented in the following tables come from joint estimation, the results for each series are first obtained by estimating the univariate models expecting to produce guess values.[3]

Table 1 reports the parameters of the maximum likelihood estimation of the correlated unobserved components models for the entire sample period. The estimated value of the drift term (μ) is 0.8343 and is statistically significant at the 1% with a p-value less than 0.000. Since the real GDP series is in logs and multiplied by 100, the estimated drift term multiplied by 4 can be interpreted as the average annual growth of the permanent component. According to our estimates, GDP's average permanent real growth rate is 3.34% annually. This estimate is very close to the estimates reported by IMF, Eurostat, Central Bank of Cyprus, and Finance Ministry of real GDP's average growth of 3.88% annually.

Insert Table 1About Here

The estimated autoregressive coefficients reflect the dynamics of the transitory components.[4] The estimated first autoregressive coefficients of -0.0068, in the case of real GDP, is statistically insignificant whereas the second one as well as the estimated parameters for the unemployment rate are statistically significant. The sum of the autoregressive coefficients, which provides a measure of persistence of the transitory components, suggests that the unemployment rate series has a persistent transitory component. In addition, the estimates of the autoregressive parameters for real GDP are relatively small, suggesting that most of the persistence of real GDP is captured in the permanent component.

Table 2 presents the standard deviation of permanent and transitory components for both series. The standard deviation of permanent shocks for real GDP is larger than the standard deviation of the transitory shocks whereas the standard deviation of permanent shocks for the unemployment rate is smaller than the standard deviation of the transitory shocks. As a result, this finding suggests that permanent shocks are relatively more important than the transitory shocks for real GDP whereas transitory shocks are relatively more important than the permanent shocks in the case of the unemployment rate. The estimates in Table 2 also suggest that movements in the permanent component for the unemployment rate are highly variable and that movements in the permanent component for real GDP are less variable.

Insert Table 2 About Here

Table 3 shows the within series correlations between the permanent and transitory components over the entire sample period. The estimates indicate that the correlation between permanent and temporary innovations for the unemployment rate and the correlation between permanent and temporary innovations for real GDP are both positive and insignificantly different from zero.

---

[3]The univariate models end up not helping much, since the two models end up with shocks that are almost perfectly (negatively) correlated, so there's quite a bit of crossvariable information.

[4] The transitory components are simply the stationary part of the data.

Insert Table 3 About Here

Positive correlation between permanent and transitory components can be interpreted as due to quick adjustment of the actual output of the economy to the permanent shocks on the output. As explained by Stock and Watson (1988) and Morley, Nelson and Zivot (2003), negative correlation of the permanent components with the transitory ones implies that the economic fluctuations are driven mainly by permanent shocks and while the permanent shocks immediately shift the long term path of the output, the short run movements may include adjustments toward the shifted trend.

Table 4 presents the results of the cross-series correlation analysis between real GDP components and the unemployment rate components over the entire sample period. As indicated in table 4, the two correlation coefficients of interest (between real GDP and unemployment permanent components and real GDP and unemployment between transitory components) are moderately high and statistically significant at the 1% level. The value of -.585 indicates that the transitory components of real GDP and unemployment are negatively related (as expected) and that the relationship is rather strong. Surprising, the correlation coefficient of .507 shows that the permanent components of real GDP and unemployment are positively related and that the relationship is relatively strong.

3.1.1 The Relationship between the Transitory Components

The relationship between the transitory components of real GDP and the unemployment rate is of critical interest for understanding the effects of macroeconomic policy. This correlation provides an estimate of the coefficient traditionally associated with the Okun's Law (Okun, 1962) which suggests that an increase in transitory output is accompanied by a decrease in transitory unemployment. Traditionally, Okun's coefficient has been estimated by first estimating the unobserved components and then estimating the correlation between the estimated components. In this paper, however, the correlation is directly estimated within the model. The correlation between the transitory components of real GDP and the unemployment rate is -0.585 and statistically significant at the 1% significant level.

In order to quantify Okun's law, the estimated correlations from Table 4 must be related with the regression coefficient (λ) from eq. 1. The hypothesis that the autoregressive coefficients are the same for GDP and the unemployment rate cannot be rejected, so eq. 1 is rewritten by substituting in the innovations to transitory real GDP and transitory unemployment (which are denoted ε_{yt} and ε_{ut} respectively):

$$\varepsilon_{yt} = \lambda\varepsilon_{ut} + (1 - \varphi_1 L - \varphi_2 L^2)v_t, \qquad (6)$$

where L is the lag operator and where $\varphi_1 \equiv \varphi_{1y} = \varphi_{1u}$ and $\varphi_2 \equiv \varphi_{2y} = \varphi_{2u}$.

Assuming that ε_{yt} and ε_{ut} are jointly normally distributed and that v_t is an independent normal random variable, we find that $\lambda = \rho_{\varepsilon y \varepsilon u} \cdot \sigma_{\varepsilon y} / \sigma_{\varepsilon u} = -1.73$. This estimate implies that a 1% decrease in transitory unemployment corresponds to a 1.73% increase in transitory real GDP. The estimated coefficient of -1.73% is smaller in absolute value than is typically found in other countries. However, it remains within the range of acceptable estimates.

3.1.2 The Relationship between the Permanent Components

Finally, the correlation between the permanent components of real GDP and the unemployment rate, which is not statistically significant, measures "Okun's coefficient for permanent movements."

Insert Table 4 About Here

This relationship can be investigated in precisely the same way as the traditional Okun's coefficient. Assuming that β denotes "Okun's coefficient for permanent movements," then $\beta = \rho_{\eta y \eta u} \cdot \sigma_{\eta y} / \sigma_{\eta u}$.

4 Conclusion

The main motivation for this empirical study is the absence of any numerical measure regarding the relationship between output and the unemployment rate in Cyprus. Knowledge about this relationship is extremely useful in terms of macroeconomic policy. This study jointly estimated the permanent and transitory movements in Cypriot output and the unemployment rate as well as the relationships between them. The estimated components, assuming both series have random walk components, suggest that both real GDP and the unemployment rate have highly variable movements in their permanent components that look similar to the series themselves. Moreover, due to innovative changes the permanent component and the transitory component are negatively correlated for both output and the unemployment rate. Therefore it would be inappropriate to treat these components as independent. Finally, the negative correlation between the transitory components of to real GDP and the unemployment rate of -1.73 indicates that real GDP and the unemployment rate are even more strongly linked through their transitory movements than through their permanent ones.

References

Abel, Andrew B. & Bernanke, Ben S. (2005). *Macroeconomics* (5th ed.). Pearson Addison Wesley.

Attfield, C. L. F. and B. Silverstone (1998).“Okun’s Law, Cointegration and Gap Variables.” *Journal of Macroeconomics* 20(3): 625-637.

Barreto, H. and F. Howland (1993). “There are Two Okun’s Law Relationships Between Output and Unemployment.” Wabash College Working Paper.

Basistha, A. and C. R. Nelson (2007). “New Measures of the Output Gap Based on the Forward-Looking New Keynesian Phillips Curve.” *Journal of Monetary Economics* 54(2): 498-511.

Basistha, A. and R. Startz (2008).“Measuring the NAIRU with Reduced Uncertainty: A Multiple Indicator-Common Cycle Approach.” *Review of Economics and Statistics*. vol. 90 (4): 805-811.

Berger, T. and L. Pozzi (2013). “Measuring time-varying financial market integration: an unobserved components approach.” *Journal of Banking and Finance*, 37(2): 463-473.

Beveridge, S. and C. R. Nelson (1981). “A New Approach to Decomposition of Economic Time Series into Permanent and transitory Components with Particular Attention to Measurement of the Business Cycle.” *Journal of Monetary Economics* 7: 151-174.

Clark, P. K. (1987). “The Cyclical Component of U.S. Economic Activity.” *The Quarterly Journal of Economics* 102: 797-814.

Clark, P. K. (1989). “Trend Reversion in Real Output and Unemployment.” *Journal of Econometrics* 40(1): 15-32.

Dickey, D. A. and W. A. Fuller (1979). “Distribution of the Estimators for Autoregressive Time Series with a Unit Root.” *Journal of the American Statistical Association* 74: 427-431.

Gordon, R. J. (1997). “The Time-Varying NAIRU and its Implications for Economic Policy.” *Journal of Economic Perspectives* 11(1): 11-32.

Grant, A. P. (2002). “Time-Varying Estimates of the Natural Rate of Unemployment: A revisitation of Okun’s Law.” *The Quarterly Review of Economics and Finance* 42: 95-113.

A. C. Harvey and A. Jaeger (1993). “Detrending, Stylized Facts and the Business Cycle.” *Journal of Applied Econometrics*, Vol. 8, No. 3.: 231-247.

A. C. Harvey and T. M. Trimbur (2003). “General Model-Based Filters for Extracting Cycles and Trends in Economic Time Series.” *The Review of Economics and Statistics* 85(2): 244-255.

Hodrick, R. J. and E. C. Prescott (1997).“Postwar U.S. Business Cycles: An Empirical Investigation.” Journal of Money, Credit, and Banking 29(1): 1-16.

Johansen, S. (1991).“Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models.”*Econometrica* 59: 1551-80.

Johansen, S. (1995).Likelihood-based Inference in Cointegrated Vector Autoregressive Models. Oxford, Oxford University Press.

Kim, C.-J.and C. R. Nelson (1999). “Has the U.S. Economy Become More Stable? A Bayesian Approach Based on a Markov-Switching Model of the Business Cycle.”*The Review of Economics and Statistics* 81(4): 608-616.

King, T. B. and J. C. Morley (2007).“In Search of the Natural Rate of Unemployment.”*Journal of Monetary Economics* 54(2): 550-564.
Kydland, F. E. and E. C. Prescott (1982).“Time to Build and Aggregate Fluctuations.”*Econometrica*50(6): 1345-1370.
George Kyriacou, G., Louca, M., and Ktoris, M. (2009). “Unemployment in Cyprus: Comparison between Two Alternative Measurement Methods.” *Central Bank of Cyprus* Working Paper 2009-2.
Lippi, M. and L. Reichlin (1994).“Diffusion of Technical Change and the Decomposition of Output into Trend and Cycle.”*The Review of Economic Studies* 61(1): 19-30.
MacKinnon, J. G. (1996). “Numerical Distribution Functions for Unit Root and Cointegration Tests.” *Journal of Applied Econometrics* 11: 601-618.
McConnell, M. and G. Perez-Quiros (2000). “Output Fluctuations in the United States: What has changed since the early 1980s?” *American Economic Review* 90(5): 1464-76.
Morley, J. C. (2007a). “The Slow Adjustment of Aggregate Consumption to Permanent Income.”*Journal of Money, Credit, and Banking* 39: 615-638.
Morley, J. C., C. R. Nelson, and E. Zivot (2003). “Why Are the Beveridge-Nelson and Unobserved-Components Decompositions of GDP So Different?” *The Review of Economics and Statistics* 85(2): 235-243.
Oh, K. H. and E. Zivot (2006). “The Clark Model with Correlated Components.”University of Washington Working Paper.
Oh, K. H., E. Zivot and D. Creal (2007). “The Relationship between the Beveridge-Nelson Decomposition and Unobserved Components Models with Correlated Shocks.” University of Washington Working Paper.
Okun, A. M. (1962). “Potential GNP: Its Measurement and Significance.” American Statistical Association: Proceedings of the Business and Economic Statistics Section: 98-104.
Papell, D. H., C. J. Murray and H. Ghiblawi (2000). “The Structure of Unemployment.”*The Review of Economics and Statistics* 82(2): 309.
Perron, P. and T. Wada (2005). “Let’s Take a Break: Trends and Cycles in U.S. Real GDP”. Working Paper.
Phillips, P. C. B. and P. Perron (1988).“Testing for a Unit Root in Time Series Regression.”*Biometrika* 75: 335-346.
Prachowny, M. F. J. (1993). “Okun’s Law: Theoretical Foundations and Revised Estimates.” *Review of Economics and Statistics* 75: 331-336.
Prescott, E. C. (1987). “Theory Ahead of Business Cycle Measurement.” Carnegie-Rochester Conference on Public Policy 25: 11-44.
Salemi, M. K. (1999). “Estimating the Natural Rate of Unemployment and Testing the Natural Rate Hypothesis.” *Journal of Applied Econometrics* 14: 1-25.
Schleicher, C. (2003). “Structural Time Series Models with Common Trends and Common Cycles. “University of British Columbia Working Paper.
Sensier, M. and D. van Dijk (2004). “Testing for Volatility Changes in U.S. Macroeconomic Time Series.” *The Review of Economics and Statistics* 86(3): 833-839.
Sinclair, T. M. (2009). “The Relationships between Permanent and Transitory Movements in U.S. Output and the Unemployment Rate.” *Journal of Money, Credit and Banking* 41 (03): 529-542.

Stock, J. H. and M. W. Watson (1998). “Median Unbiased Estimation of Coefficient Variance in a Time-Varying Parameter Model.” *Journal of the American Statistical Association* 93(441): 349-358.
Watson, M. W. (1986). “Univariate Detrending Methods with Stochastic Trends.” *Journal of Monetary Economics* 18: 49-75.
Xiaoshan C., and T. Mills (2012). “Measuring the Euro area output gap using a multivariate unobserved components model containing phase shifts.” *Empirical Economics* 43(2): 671-692.

Figure 1: Real GDP and estimated permanent and transitory components.

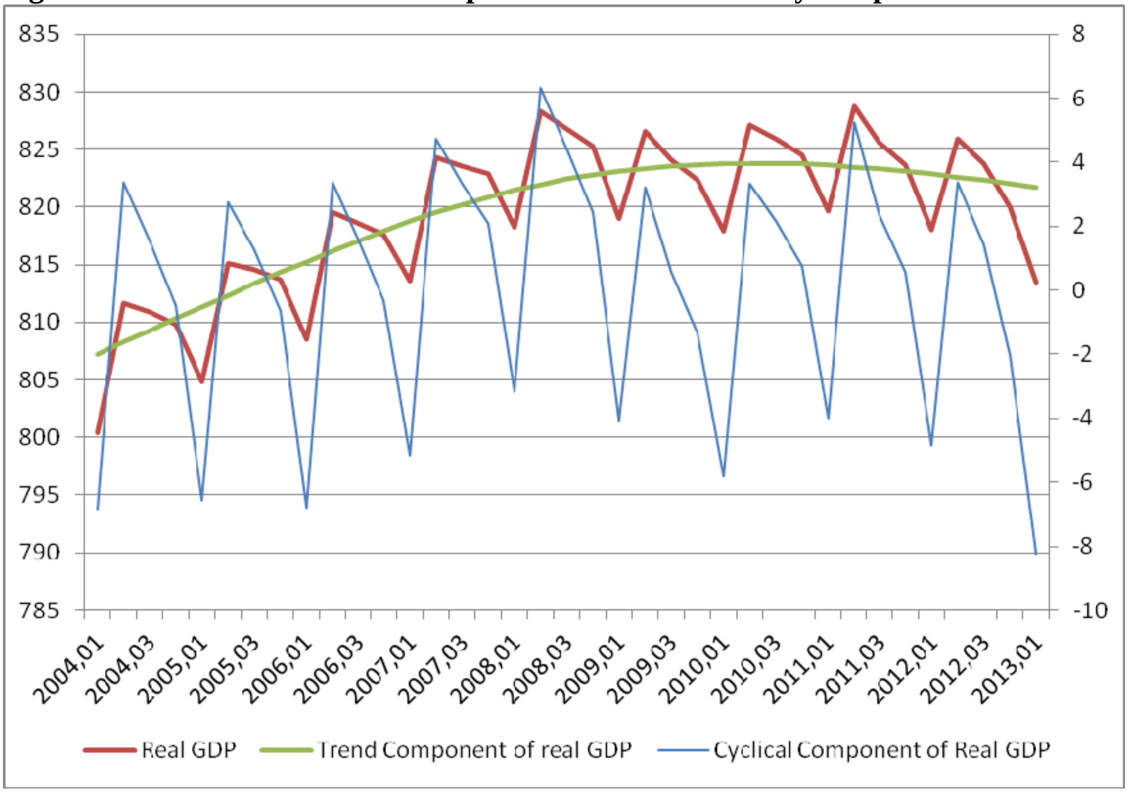

Figure 2: Unemployment rate and estimated permanent and transitory components.

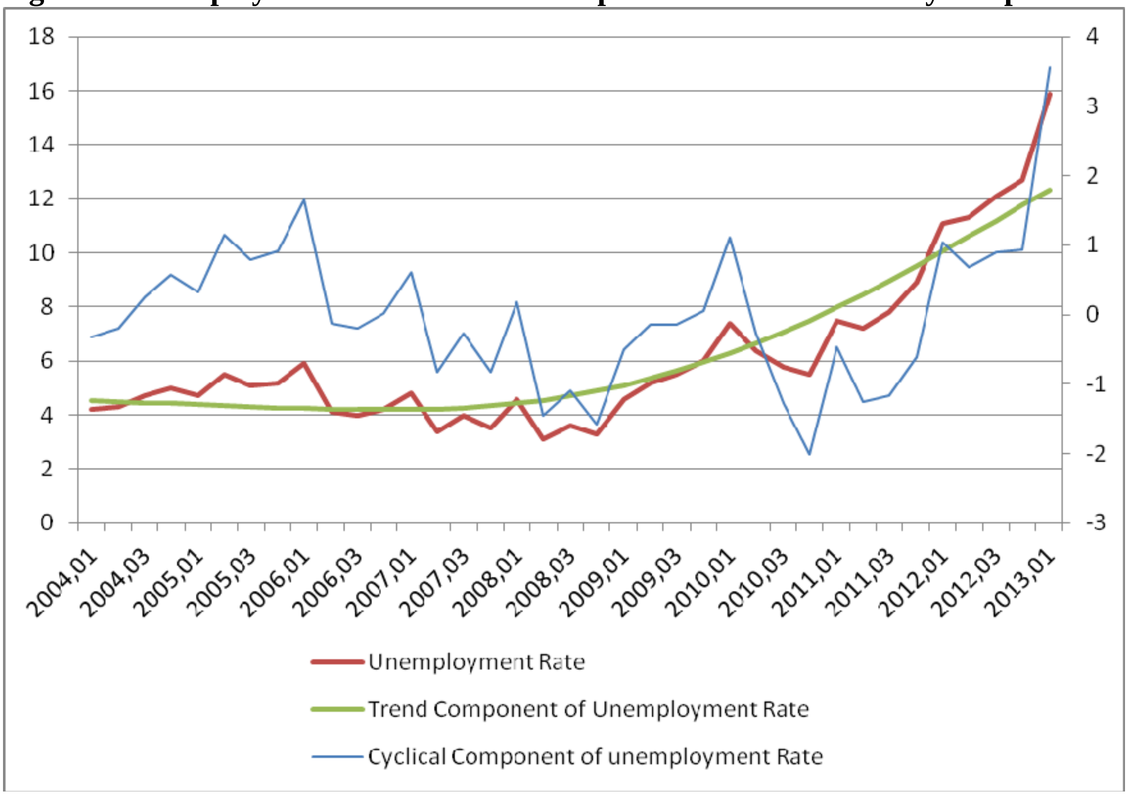

Table 1. Maximum Likelihood Estimation Results for Real GDP

Description	Parameter	Estimate	Standard Error	p-Value
Log Likelihood Value	*mlv*	-128.6911		
		Real GDP		
Real GDP Drift	μ_y	0.8343	0.105	0.000
1st AR parameter	φ_{1y}	-0.0068	0.024	0.779
2nd AR parameter	φ_{2y}	-0.8631	0.045	0.000
		The Unemployment Rate		
1st AR parameter	φ_{1u}	-1.3854	0.114	0.000
2nd AR parameter	φ_{2u}	-0.7374	0.106	0.000

Table 2. Standard Deviations of Shocks

Description	Parameter	Estimate	Standard Error	p-Value
S.D. of permanent GDP component	$\sigma_{\eta y}$	2.9746	0.4935	0.000
S.D. of cyclical GDP component	$\sigma_{\varepsilon y}$	-0.0001	1.2626	0.999
S.D. of permanent unemployment component	$\sigma_{\eta u}$	-0.0889	0.1114	0.424
S.D. of cyclical unemployment component	$\sigma_{\varepsilon u}$	0.0000	0.4269	0.999

Table 3. Within Series Correlations of Shocks

Description	Parameter	Estimate	p-Value
Correlation between real GDP Components	$\rho_{\eta y \varepsilon y}$	.145	.393
Correlation between unemployment Components	$\rho_{\eta \varepsilon u}$	.268	.109

Table 4. Cross Series Correlations of Shocks

Description	Parameter	Estimate	p-Value
Permanent Unemployment/ Permanent GDP	$\rho_{\eta y \eta u}$	.507	.001
Permanent GDP/Transitory Unemployment	$\rho_{\eta y \varepsilon u}$	-.256	.127
Permanent Unemployment/Transitory GDP	$\rho_{\eta u \varepsilon y}$	-.142	.403
Transitory GDP/ Transitory Unemployment	$\rho_{e y \varepsilon u}$	-.585	.000