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# Does Output Predict Unemployment?

## A Look at Okun's Law in Greece

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Revised

### ABSTRACT

This paper examines the unemployment-output relationship in Greece, using a dynamic version of Okun's Law. The Granger causality tests indicate that real output is important to understanding future movements in unemployment. The Okun's ratio is 3-to-1, implying that one percent increase in unemployment has been associated to a three percent decrease in real output during the last thirteen years. In addition, the response of unemployment to real output is found to be stronger when there is a contraction rather than an expansion of real activity. This empirical fact is consistent with the developments of the Beveridge curve, which illustrate that a significant portion of actual unemployment is structural in nature. Therefore, a fall in unemployment will require not only a pick-up in aggregate demand but also structural reforms in the Greek labour market, which will make the economy competitive and reduce long-term unemployment.

**JEL classification:** E24, E32, E37

**Keywords:** Okun's Law, real output, unemployment, business cycles, Beveridge curve, VAR model, Granger causality

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# 1. Introduction

In 1962 Arthur Okun published his paper on “Potential GNP” where he developed his model for the correlation between output and unemployment and therefore bears his name. Okun found that for the United States one percent increase in unemployment was associated to a three percent decrease in output, which amounted to a regression coefficient of -0.33. Thus, Okun’s Law supposes a negative correlation between the unemployment rate and real output. Since then, the Law has been used as a rule of thumb and extensively investigated for many countries. Gordon (1984) estimated Okun’s Law in the United States from 1954 to 1979 and concluded that the 3-to-1 ratio popularized by Okun’s original work had decreased to 2-to-1. Using this relationship, he found that the trend output growth had declined significantly in the 1980s. Kaufman (1988) estimates the Okun’s Law for six industrialized countries and finds that the cyclical response of unemployment rate differs significantly among countries. Prachowny (1993) examines the relationship between changes in unemployment and output in the United States, having derived the output gap from a production function, and concludes that the familiar 3-to-1 ratio is only 1.5-to-1. Moosa (1997) estimates the Okun’s coefficient for the G7 countries and infers that the highest values are found for the United States and Canada, and the lowest for Japan. Lee (2000) evaluates the robustness of Okun’s Law for 16 OECD countries. While the Okun relationship is valid for most countries, the estimates are far from uniform and depend on the specification of the model. Knotek (2007) addressed the issue of the structural stability of the relationship between output and unemployment in the United States from 1948 to 2007. The analysis showed that Okun’s Law was not a stable relationship and a part of the variation was related to the state of the business cycle. In addition, the contemporaneous relationship was weaker and the dynamic relationship was stronger.

In the aftermath of the global financial crisis, where output growth declined and unemployment rose in most of the industrial countries, a renewal for Okun’s Law has been emerged. Neely (2010) claims that the unemployment rate in the United States tended to vary more for a given real output fluctuation than did that in other industrial countries. This situation reveals that the labor markets across countries have different structures, something which is depicted in the employment protection index compiled by

the OECD, where the United States is ranked first, while France 25, among 30 countries. Daly and Hobijn (2010) argued that the deviation from the familiar Okun's 2-to-1 ratio, which was observed in the United States during 2009, was driven by an unusually strong growth in average labour productivity. Elsby *et al.* (2011) argued that Okun's Law performed remarkably well from the first part of the 2007 recession through the first quarter of 2009. However, in the last nine months of 2009 a divergence from the rule was observed as output rebounded, but unemployment continued to rise, which was attributed to labour productivity growth during the period. Balakrishnan, *et al.* (2010) examine Okun's Law across countries and over time and conclude that the observed variation in dynamic Okun's coefficients is related to labour market institutions. Qwyang and Sekhposyan (2012) examined the degree of time variation of Okun's Law in the United States over the business cycle, using data from 1949 to 2011 and various specifications. The evidence suggested that the unemployment-output relationship exhibited a great degree of instability and the breakdowns of the Law were highly correlated with the business cycle. Ball *et al.* (2013) considered the relationship between unemployment rate and output growth in the United States from 1948 to 2011, and in twenty advanced economies from 1980 to 2011. The evidence for the United States suggested that Okun's coefficient was equal to -0.45 and was not affected by the Great Recession of 2008-2009. In the other countries, the coefficient was also stable, but it varied from -0.14 in Austria to -0.85 in Spain.

The global economic crisis that started to take hold in 2008 unveiled the chronic and structural weaknesses of the Greek economy. Apart from the external imbalances, with the current account deficit rising to 12.1 percent of GDP in 2012 and the net international investment position amounting to -92.5 percent of GDP in the same year, the main economic problems of Greece were located in the sphere of fiscal imbalances, with the structural deficit approaching at 10 percent of GDP in 2008 and the public debt exceeding 110 percent of GDP during the same year. Since 2010, Greece has embarked on an adjustment program, implemented with the technical and financial support of the International Monetary Fund, the European Union and the European Central Bank, which aimed at tackling the fiscal imbalances and setting the economy on the right track with growth and prosperity. The austerity program has been primarily relied on cutting wages

and salaries, and increasing taxes. As a result, the domestic demand has been severely decreased and the real economy has been fallen in a Great Recession. The real GDP in constant prices was reduced from EUR 225.3 billion in 2009 to EUR 168.5 billion in 2012, which amounted to a reduction of about 25 percent, while unemployment jumped from an average rate of 9.5 percent in 2009 to an average rate of 24.3 percent in 2012.

In the light of these developments, we focus on three basic questions. First, are changes in unemployment rate systematically related to changes in output, since Greece has joined the euro area? Second, is the unemployment-output link different in contractions and expansions? If the adjustments in unemployment are related to the state of the business cycle, then, by taking into account these asymmetries, an erroneous inference in hypothesis testing will be avoided, the forecast of unemployment will be improved and fiscal policy, mainly tax policy, and labour market institutions will be better designed. Third, is the recent increase in unemployment a cyclical phenomenon, or is there an indication that it is also related to structural factors and thus a pick-up in aggregate demand would not have the expected effect on unemployment?

The paper is organized as follows. Section 2 presents the stylized facts of output and unemployment in Greece. Section 3 discusses theoretical issues. Section 4 presents and discusses the regression results. Section 5 presents the Beveridge curve in Greece and relates its behavior with the results of Okun's Law, and Section 6 concludes.

## 2. Stylized facts

We have used data for real output, measured by the real GDP in constant prices, and unemployment from 2000:Q1 to 2012:Q4, which have been obtained from the Hellenic Statistical Authority.<sup>1</sup> The unemployment is defined as the fraction of working-age population (15 to 74 years old) that, at the reporting week, it is not working or looking for a work, or it has obtained a job which will take over during the next three month. Since the data were not adjusted for seasonality, we have used the United States Census Bureau's X-12-ARIMA quarterly seasonal adjustment method. Figure 1 plots the levels

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<sup>1</sup> The data for unemployment are available from 1998. We have started our sample in 2000, a year before Greece joined the euro area, in order to account for the positive effects of imminent participation on macroeconomic environment.

of the two series. The real output has steadily increased up to the second quarter of 2007, and then, as a result of the global financial crisis and the subsequent eruption of the Greek debt crisis, it has gradually declined. The unemployment has decreased up to the second quarter of 2008, and since then it has steadily increased. In Figure 2, we plot the growth rates of the two variables. Since the second quarter of 2007, real output has started to decelerate and the economy slipped into recession in early 2008, with the real activity dropping cumulatively by 25.7 percent until the fourth quarter of 2012. The unemployment has exhibited mild fluctuations up to the second quarter of 2008, with the exception of the first quarter of 2004, and ever since it has steadily accelerated, picking up at the fourth quarter of 2011. The cumulative increase in unemployment from early 2008 to 2012 amounted to 18.4 percent.

Figure 1. Real Output and Unemployment Rate

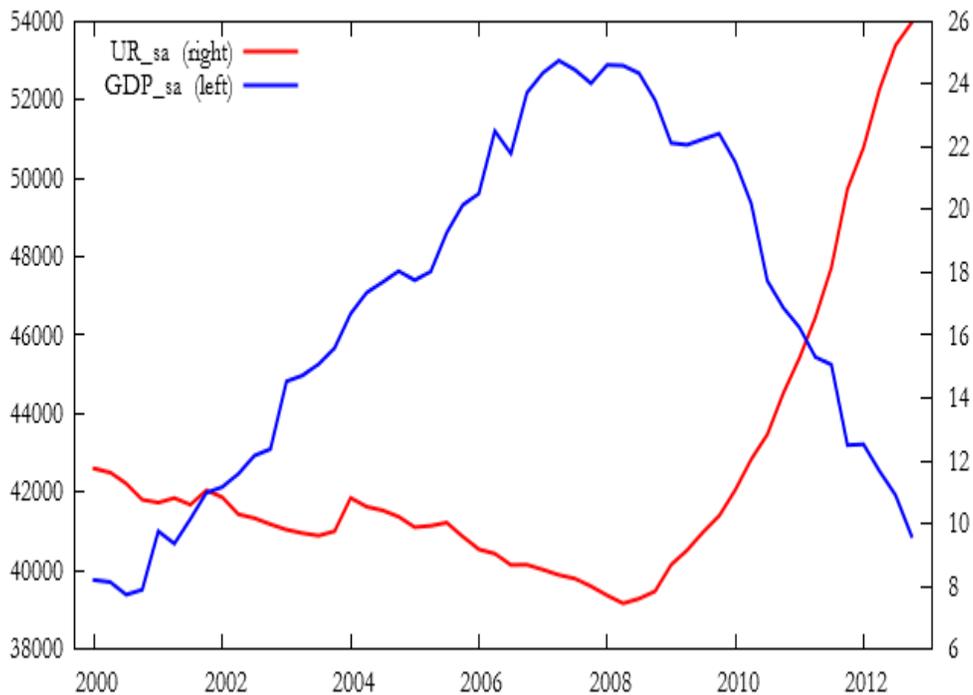
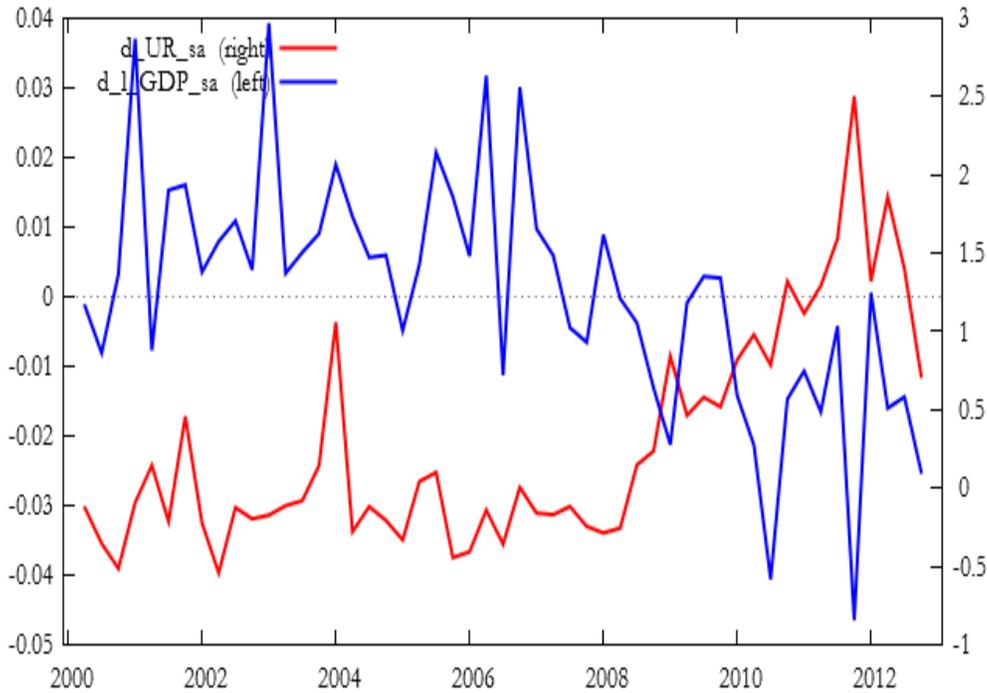


Figure 2. Changes in Real Output and Unemployment Rate



### 3. Theoretical issues

The unemployment-output relationship is based on Okun's Law. This rule of thumb is a part of the traditional toolbox of macro-economic models in which shifts in aggregate demand cause movements in real output, which in turn leads firms to demand labour, thus reducing unemployment. If unemployment is below the natural rate, inflation will rise, and vice versa. Thus, adapting Okun's Law to the non-accelerating inflation rate of unemployment, the aggregate supply curve will be derived.

Let us start with a simple inverted linear production function which relates changes in employment ( $\Delta l$ ) to changes in real output ( $\Delta y$ ),

$$\Delta l_t = \frac{1}{\alpha} \Delta y_t + v_t \quad [3.1]$$

where small-case letters depict the logarithms of the corresponding variables,  $\Delta$  is the first-difference operator,  $\alpha$  is the average productivity of labour, and  $v$  is an error term,

which captures capital utilization and technological progress. Since movements in employment cause changes in unemployment in opposite direction, that is

$$\Delta u_t = -\beta \Delta l_t + \omega_t \quad [3.2]$$

where  $\omega$  is an error term, which captures the labour force participation, then, combining [3.1] and [3.2], we can derive a relationship between changes in unemployment and changes in real output, which reflects the growth rate version of Okun's Law:

$$\Delta u_t = -\gamma \Delta y_t + \varepsilon_t \quad [3.3]$$

where  $\gamma$  is the coefficient of the Law which is equal to  $\beta/\alpha$ , and  $\varepsilon$  is the error term, which includes the other inducement terms. The value of  $\gamma$  would be less than the value of the coefficient of equation [3.1], in absolute terms, for two reasons (Ball, *et al.* 2013). First, if employment is costly to adjust to output fluctuations, because labour is regarded as a quasi-fixed factor, firms will accommodate aggregate fluctuations by adjusting either hours worked per employee or the work effort of employees, which is reflected in larger increases in productivity. In this case, the coefficient of equation [3.1] would have a smaller size than its size implied by the parameter  $\alpha$  of the production function. Second, an increase in employment by raising the return to job search, will increase the labour force participation. In this case, changes in unemployment are less than proportional to changes in employment, and thus the coefficient  $\beta$  would be less than one. Apart from the growth rate version, there also exists the gap version, which relates the deviations of the unemployment from its natural rate to deviations of real output from its potential level. Both versions of Okun's Law describe the static co-movements in real output and unemployment. A dynamic specification of Okun's Law also includes lagged values of  $\Delta u$  and  $\Delta y$ .

#### 4. Empirical analysis

We start our analysis by testing whether the variables concerned are stationary processes in order to avoid the spurious regression problem. We have used two types of unit root tests. The first type employs five traditional statistics without structural breaks, while the second type uses two advanced tests, which account for structural breaks in the mean and the trend of each time series. The results are presented in Table 1. The ADF

test, using a model with a mean, a linear trend and a quadratic trend, shows that  $\Delta u$  does not seem to contain a unit root. Elliott, *et al.* (1996) efficient ADF-GLS test, and Phillips and Perron (PP, 1988) test, using a model with a mean and linear trend, both provide similar evidence. These tests have also indicated that  $\Delta y$  is a stationary process. The rejection of a unit root in both  $\Delta u$  and  $\Delta y$  is also established by Kwiatkowski *et al.* (KPSS, 1992) test, using a model with a mean. On the other hand, the LM test (Schmidt and Phillips, 1992) shows that the series concerned are not stationary processes. After allowing for a structural break, the LM test (Lee and Strazicich, 2004) has rejected the null hypothesis of a unit root. This finding is also supported by the test proposed by Perron (1989). The discrete jump in  $\Delta u$  at 2004Q1, which is identified as a break point, possibly reflects an outlier, while the break points at 2007Q2 and 2008Q1/Q3 capture changes in trends of  $\Delta y$  and  $\Delta u$ , respectively.

A preliminary analysis of the unemployment-output relationship has been conducted by looking at the co-movements of the two variables, using cross correlation analysis. We say that real output is leading by  $k$  quarters, is synchronous, or is lagging by  $k$  quarters the unemployment rate, if the correlation coefficients:  $corr(\Delta u_t, \Delta y_{t-k})$ ,  $corr(\Delta u_t, \Delta y_t)$ ,  $corr(\Delta u_t, \Delta y_{t+k})$ , respectively, take on the largest value (in absolute terms) at that quarter. In addition, a positive and significant value indicates that the two variables are procyclical, a negative and significant value indicates that the two variables are countercyclical, and a number close to zero indicates that the two variables are uncorrelated. The results reported in Table 2 indicate that real output is leading unemployment by two quarters and the relationship between the two variables is strongly countercyclical.

Having established that real output leads unemployment, we proceed then to analyze the unemployment-output relationship in the context of a forecasting model of the form,

$$\Delta u_t = a + \sum_{j=1}^p \rho_j \Delta u_{t-j} + \sum_{j=1}^q \gamma_j \Delta y_{t-j} + \varepsilon_t \quad [3.4]$$

This specification illustrates that changes in unemployment are determined by its own lagged values and the lagged values of changes in real output. The short-run effect of real output on unemployment is obtained by calculating the sum of coefficients  $\gamma_j$ , that

is  $\sum \gamma_j$ . On the other hand, the long-run effect is obtained by calculating the function:  $\sum \gamma_j / (1 - \sum \rho_j)$ .

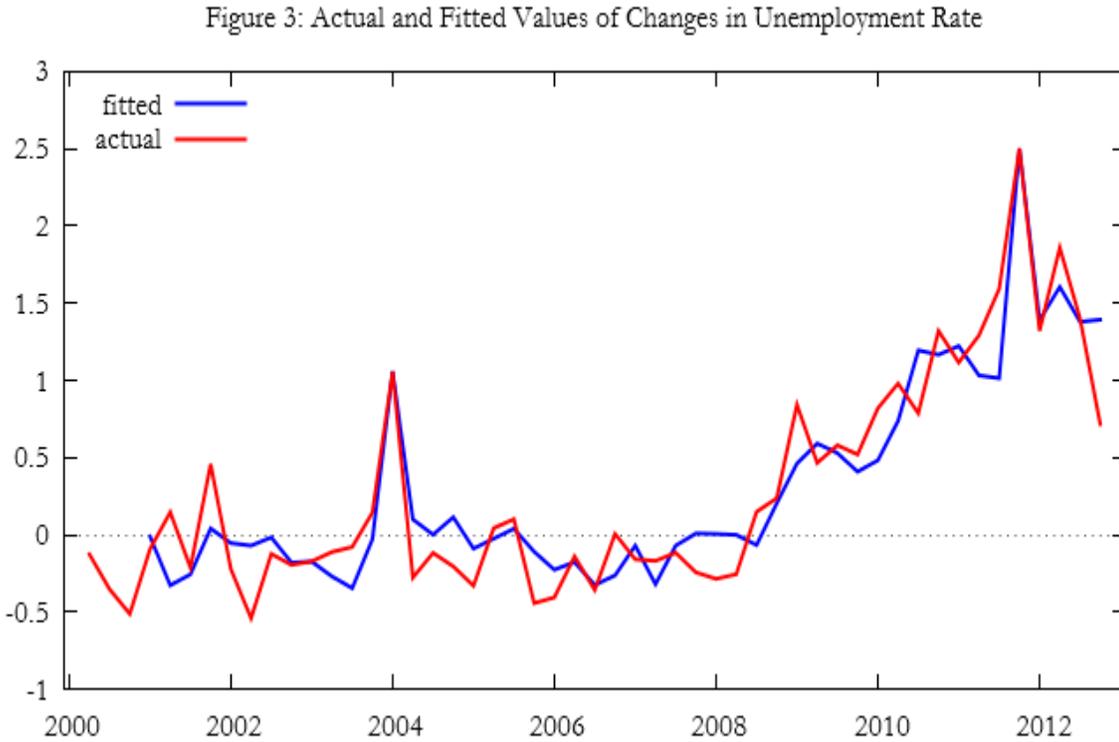
The estimated equation includes two crash dummies, which capture the jumps of  $\Delta u$  at 2004Q1 and 2011Q4 and have improved the diagnostics of the model. Since the present recession is not like earlier recessions, we have added a special dummy, which takes the value one from 2008 onwards and zero elsewhere, and has been multiplied with the change in real output. The maximum lag length of  $p$  and  $q$  is set at 4. The three selection statistics suggest that  $p=3$  and  $q=2$ . Therefore, the forecasting model we consider has the form:

$$\begin{aligned} \Delta u_t = & \alpha + \sum_{j=1}^3 \rho_j \Delta u_{t-j} + \gamma_1 \Delta y_{t-1} + \gamma_2 \Delta y_{t-2} \\ & + \lambda_1 D04 + \lambda_2 D11 + \lambda_3 D08 + \varepsilon_t \end{aligned} \quad [3.5]$$

Our primary focus is on real output as the predictor variable in unemployment equation, which is examined by applying in-sample and out-of-sample Granger-causality tests, using HAC standard errors. The conventional in-sample Granger causality test uses an  $F$ -statistic for testing the null hypothesis that  $\gamma_1 = \gamma_2 = 0$ . On the other hand, the out-of-sample Granger causality test, proposed by McCracken (2007), compares the predictive ability of Okun's Law equation [3.5] with the predictive ability of its restricted version, which excludes the lagged values of real output. If the mean prediction error (MPE) is used as a measure of prediction performance, then, if the MPE of Okun's Law equation is smaller than the MPE of its restricted version it will imply that real output Granger causes unemployment.

The estimated equation is reported in Table 3. The diagnostic tests indicate that it is well-specified, as there is no evidence of serial correlation, functional misspecification, heteroscedasticity, while the estimated residuals are normally distributed. Figure 3 plots the actual and fitted values. The model explains a significant part of unemployment variation. In the context of the backward-looking model [3.5], the Lucas Critique may apply with particular force, so it is important to gauge the historical importance of the unemployment equation with stability tests. The temporal stability of the estimated equation is tested by means of the sup-Wald statistic, which has good power against other

forms of parameter instability (Stock and Watson, 1998). The value of Quandt likelihood ratio (QLR) statistic, computed over all possible break dates in the central 70 percent of the sample, is equal to 2.9842, which is not statistically significant at 5 percent level, revealing that the regression coefficients have been stable over the sample.



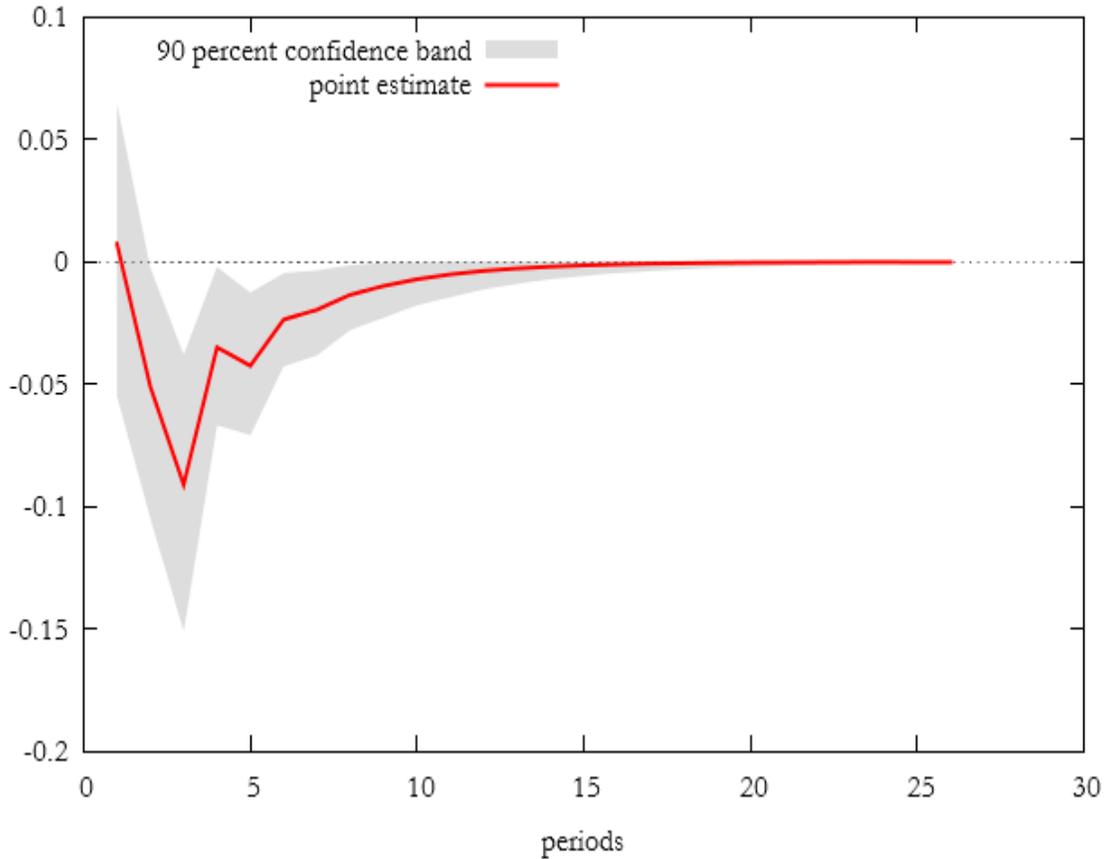
Panel A of Table 4 presents the in-sample Granger causality results. The value of the  $F$ -test for the hypothesis that the lagged values of  $\Delta y$  do not Granger-cause the current value of  $\Delta u$  is equal to 7.6708, with a  $p$ -value of zero. This finding, which is consistent with the evidence derived from the correlation analysis, indicates that the past history of real output has information content that helps predict future movements in unemployment. Then, we have split the sample at the fourth quarter of 2007 and evaluated the forecasting accuracy of the model over the crisis period 2008Q1-2012Q4. We have not applied a rolling regression approach to forecasting because the estimated equation does not exhibit parameter instability. The results are presented in Panel B of Table 4. The out-of-sample

Granger causality  $F$ -test indicates that the MPE of Okun's Law is significantly lower than the MPE of its restricted version, implying that the information contained in real output significantly improves the forecast of unemployment. This finding is consistent with the results obtained from the in-sample Granger causality test. An empirical implication of these findings is that an analysis of unemployment variation based on models that ignore real output will produce inadequate results.

Table 5 reports Okun's coefficients. The sum of the lagged values of real output is highly significant and is equal to  $-0.1548$ . This figure shows the short-run impact of  $\Delta y$  on  $\Delta u$  and constitutes the short-run Okun's coefficient. On the other hand, the long-run Okun's coefficient is equal to  $-0.32$ , which is double the short-run coefficient. Thus, one percent increase in unemployment was associated to a three percent decrease in real output, during the last 13 years. This long-run impact is different and more important than the short-run impact, because, after a negative demand shock, firms take time to lay off workers, as they are uncertain whether the demand shock is temporary or permanent (Balakrishnan, *et al* 2010).

An additional test of the dynamic Okun's Law is conducted in the context of a vector autoregressive (VAR) model. We estimate a two-lag VAR in  $\Delta y$  and  $\Delta u$  and simulate the response of unemployment to one-standard error shock in real output, using a Cholesky decomposition. Figure 4 shows the impulse response function. As this graph illustrates, unemployment initially declines but the significant impact is felt with a time lag of about two quarters. Then, it gradually increases and becomes insignificant after the elapse of 10 quarters. This finding suggests that the negative persistent demand shock, which the Greek economy has experienced since the implementation of the adjustment programs, has driven real output into a Great Recession and kept unemployment at a high level.

Figure 4: Response of  $\Delta u$  to a shock in  $\Delta y$ , with bootstrap confidence interval



Having established that real output is important to understanding future movements in unemployment, we are proceeding now to explore whether the unemployment-output relationship is related to the state of the business cycle. The asymmetry hypothesis has been empirically documented for other countries (Lee, 2000, Harris and Silverstone, 2001; Silvapulle *et al*, 2004). In equation [3.5], we have split  $\Delta y$  in positive ( $\Delta y^+$ ) and negative ( $\Delta y^-$ ) values, which indicate the expansion and contraction phases of real output, using zero as threshold. Table 6 presents the asymmetric values and the testing restrictions of the asymmetry hypothesis. The sum of  $\Delta y^+$  is equal to -0.0779 and is statistically significant at 6% level, while the sum of  $\Delta y^-$  is equal to -0.2228 and is statistically significant at a level less than zero. The *p-value* of the *F*-statistic for the restriction that the sum of the positive values is equal to the sum of the negative values is less than zero, implying that the unemployment-output relationship is asymmetric. Thus,

the response of unemployment to real output is found to be stronger when there is a contraction rather than an expansion of the real activity.

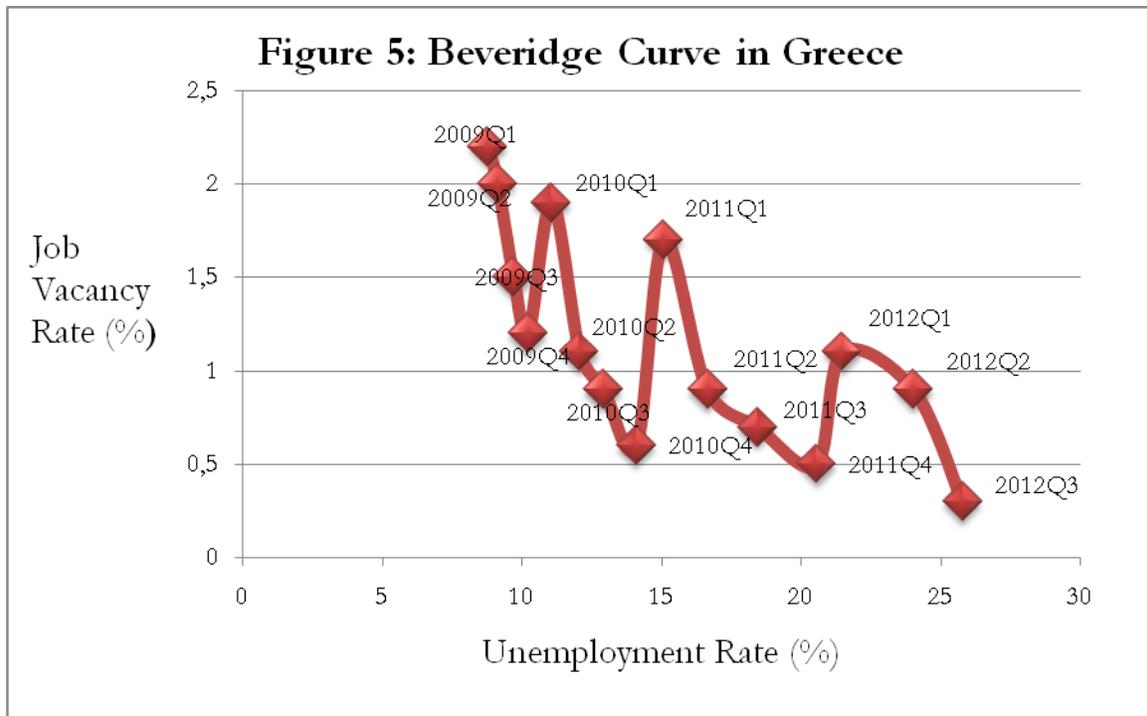
## 5. Beveridge curve in Greece

The empirical fact that unemployment has increased more in the contraction phase than it has declined in the expansion phase of the real activity may indicate that some other factors, which are structural in nature, appear to have played a significant role in the downturns of the economy. If the long-term unemployment had not increased, after the eruption of the debt crisis, then the current unemployment would have responded to real output, according to the prediction of Okun's Law, and thus unemployment would have followed suit when the real activity peaked up. However, the soaring in the unemployment after the eruption of the crisis may indicate that structural factors are a major cause of the increase in unemployment in Greece. To shed some light on the nature of unemployment increase, we examine the relationship between the job vacancy rate (a measure of the supply of jobs) and unemployment rate (a measure of the demand for jobs). The link between the two variables is known as the Beveridge curve. Movements along this curve reflect cyclical developments, that is during a recession cycle job vacancies fall and unemployment rises. A rightward shift in the Beveridge curve indicates that, for a given vacancy rate, unemployment is higher. Thus, the supply of jobs does not match with the demand for jobs. This situation shows a structural change in the labour market. Figure 5 plots Beveridge curve in Greece from 2009 to 2012. This graph illustrates that the vacancy rate has dropped from 2.2 percent in 2009Q1 to 0.3 percent in 2012Q3, and the unemployment rate has increased from 8.8 percent to 26 percent in the same period.<sup>2</sup> These changes indicate that during the Great Recession rising unemployment in Greece has been associated with falling vacancies, indicating a cyclical in nature unemployment. At the same time, the outward shift of the Beveridge curve shows that as job vacancies rebounded in the periods between 2009Q3-2009Q4, 2010Q4-2011Q1 and 2011Q4-2012Q1, the unemployment rate continued to rise. In addition, the curve has become more flat since the middle of 2011. These developments in the

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<sup>2</sup> The job vacancy rate, as published by the Eurostat, measures the percentage of vacant posts compared with the total number of occupied and unoccupied posts.

Beveridge curve constitute a sign of deterioration of the matching process in the Greek labour market. Given that the bulk of unemployment has appeared to low-skilled-intensive sectors, such as industry, construction and retail trade, the labour market mismatches is likely to indicate restricted labour mobility due to inadequate labour skills. The *Joint Employment Report* of European Commission (2012) shows that the long-term unemployment rate as percentage of active population in Greece has increased from about 4 percent in 2008Q2 to about 13 percent in 2012Q2. Since the actual rate of unemployment was amounting to 24 percent at 2012Q2, the long-term unemployment rate was accounting for about 54 percent of the actual unemployment rate. Therefore, a pick-up in aggregate demand would not significantly reduce unemployment unless it would be supported by structural reforms. Since 2011, Greece has embarked on a series of reforms in the labour market referring to labour cost reduction, flexible forms of employment, collective bargaining flexibility, simplifying private employment services, and changing and readjusting unemployment benefits (Ministry of Finance, 2012). These reforms would stimulate demand by cutting production costs relative to the rest of the euro area, thus constituting a mechanism for short-term macroeconomic stabilization. At the same time, they would affect the long-term supply side of the economy, leading to a reduction in structural unemployment.



## 6. Concluding remarks

In this paper, we have presented empirical evidence about the unemployment-output relationship in Greece. The Granger causality tests indicate that real output is important to understanding future movements in unemployment. The Okun's ratio is 3-to-1, implying that one percent increase in unemployment has been associated to a three percent decrease in real output during the last thirteen years. In addition, the response of unemployment to real output is found to be stronger when there is a contraction rather than an expansion of real activity. This empirical fact is consistent with the developments of the Beveridge curve, which illustrate that a significant portion of actual unemployment is structural in nature. Therefore, the present analysis suggests that the reduction in unemployment below the threshold rate of 10 percent, which is determined in the *Hellenic National Reform Programme 2012-2015*, will require not only a pick-up in aggregate demand but also structural reforms in the Greek labour market which will make the economy competitive and reduce long-term unemployment.

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Table 1  
Unit root tests

V/bles	<i>Tests without structural breaks</i>						<i>Tests with one structural break</i>				
	ADF	ADF-GLS	PP	KPSS	LM	Result	Perron	Break	LM	Break	Result
$\Delta u$	-1.43(1)	-1.28(1)	-2.09	0.65***	-1.82(1)	I(1)	-5.37(0)**	2004:Q1	-2.33(1)	2008:Q4	I(0)/I(1)
	-3.54(0)**	-2.24(1)	-3.60**	0.19**		I(0)/I(1)	-5.54(0)**	2004:Q1	-5.44(0)***	2008:Q1	I(0)/I(0)
$\Delta y$	-2.39(0)	-2.40(0)**	-5.17***	0.72***	-1.62(4)	I(0)/I(1)	-8.33(0)***	2008:Q3	-7.41(0)***	2008:Q3	I(0)/I(0)
	-7.27(0)***	-3.87(1)***	-7.278***	0.23		I(0)	-8.88(0)***	2007:Q2	-8.03(0)***	2005:Q1	I(0)/I(0)

*Notes:* The entries in the first line are derived from a model with a mean (M), and in the second line from a model with a mean and linear trend (M/T). The selected lag are given in parentheses and based on SIC. ADF and PP tests use Mac Kinnon (1996) one-sided  $p$ -values. The critical values at 5% significance level are as follows:

	M	M/T
ADF-GLS	-1.95	-3.19
KPSS	0.46	0.14
LM	-3.11	
LM (break)	-3.56	-4.47
P	-5.23	-5.59

\*\*\* 1%, \*\* (5%)

Table 2

*Cross correlations of unemployment with output at various leads and lags*

$\Delta y_{t-4}$	$\Delta y_{t-3}$	$\Delta y_{t-2}$	$\Delta y_{t-1}$	$\Delta y_t$	$\Delta y_{t+1}$	$\Delta y_{t+2}$	$\Delta y_{t+3}$	$\Delta y_{t+4}$
-0.498	-0.539	<b>-0.619</b>	-0.534	-0.576	-0.560	-0.539	-0.497	-0.604
[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

*Notes:* The entries are the values of the correlation coefficients. The highest value is boldly marked. The null hypothesis is that the correlation coefficient is zero. The numbers in square brackets are marginal significance levels which refer to a two-tailed  $t$ -test.

Table 3

*Estimated Okun's Law Equation*

<i>Regressors</i>	<i>coefficients</i>	<i>std. error</i>	<i>t-ratio</i>	<i>p-value</i>
<i>Intercept</i>	0.1084	0.0455	2.380	0.0223**
$\Delta y_{t-1}$	-0.0662	0.0297	-2.225	0.0319**
$\Delta y_{t-2}$	-0.0886	0.0249	-3.547	0.000***
$\Delta u_{t-1}$	0.1803	0.0907	1.987	0.0540*
$\Delta u_{t-2}$	0.1496	0.0879	1.700	0.0971*
$\Delta u_{t-3}$	0.1954	0.0759	2.573	0.0140**
<i>D04Q 1</i>	1.0738	0.0501	21.40	0.0000***
<i>D11Q4</i>	1.0429	0.2544	4.099	0.0000***
<i>D08</i>	-0.1028	0.0590	-1.742	0.0895*

### ***Diagnostic tests***

*Adjusted R*<sup>2</sup>=0.8378; *SEE*=0.2821

*Test for serial correlation:*  $F(26,13)=1.0107$  [ $p$ -value=0.5127]

*Test for normality of residual:*  $\chi^2(2)=0.6719$  [ $p$ -value=0.7147]

*RESET test for specification:*  $F(2,37)=2.4610$  [ $p$ -value=0.10]

*Test for heteroskedasticity:*  $\chi^2(8)=10.6094$  [ $p$ -value=0.2251]

*QLR test for structural break:* Null hypothesis: no structural break

Test statistic:  $\max F(7, 32) = 2.9842$  [5% critical value=3.15]

Notes: HAC standard errors (bandwidth 2, Bartlett kernel) are used.

Table 4  
*Granger Causality Tests*

**A. In-sample test**

$$H_0: \gamma_1 = \gamma_2 = 0$$

$$F(2, 39) = 7.6708 [0.001]***$$

**B. McCracken out-of-sample forecasting test (2008Q1-2012Q4)**

	<i>Okun's Law [3.5]</i>	<i>Restricted version (<math>\gamma_1 = \gamma_2 = 0</math>):</i>
MPE	0.9718	1.5227
$F_{2,0.4}$	11.3358***	
	<i>Critical value at 1% = 3.241</i>	

Notes:  $F_{2,0.4}$  is the  $F$ -statistic, where 2 denotes the two lagged values of real output in [3.5], reflecting the excess parameters, and 0.42 is the value of  $\pi=20/48$  (see Table 6 in McCracken (2007)).

Table 5  
*Okun's Law Coefficients*

**1. Short-run effect:**

$$\gamma_1 + \gamma_2 = -\mathbf{0.1548} (0.0418)$$

$$t(39) = -3.6957 [p\text{-value} = 0.000]***$$

**2. Long-run effect:**

$$\varrho_1 + \varrho_2 + \varrho_3 = 0.5253 (0.0945)$$

$$t(39) = 5.5544 [p\text{-value}=0.000]***$$

$$\frac{\gamma_1 + \gamma_2}{1 - (\varrho_1 + \varrho_2 + \varrho_3)} = -\mathbf{0.32}$$

**3. Okun's ratio = 3/1**

Table 6  
*Testing Asymmetries in Okun's Law Equation*

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1. *Short-run asymmetric effects*

$$\gamma_1^+ + \gamma_2^+ = \mathbf{-0.0779}(0.0398)$$

$$t(38) = -1.9592 [p\text{-value}=0.0574]^*$$

$$\gamma_1^+ = \gamma_2^+ = 0$$

$$F(2,38) = 8.1306 [p\text{-value} = 0.0011]^{***}$$

$$\gamma_1^- + \gamma_2^- = \mathbf{-0.2228}(0.0553)$$

$$t(38) = -4.0231 [p\text{-value}=0.000]**$$

$$\gamma_1^- = \gamma_2^- = 0$$

$$F(2,38) = 2.2607 [p\text{-value} = 0.1181]$$

2. *Testing asymmetric restrictions*

$$\gamma_1^+ + \gamma_2^+ = \gamma_1^- + \gamma_2^-$$

$$F(1,38) = 7.4762 [p\text{-value} = 0.009]^{***}$$

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