A dynamic version of Okun's law in the EU15 countries – The role of delays in the unemployment-output nexus

Thomas Obst

European University Viadrina Frankfurt (Oder)
Department of Business Administration and Economics
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A dynamic version of Okun's law in the EU15 countries - The role of delays in the unemployment-output nexus*

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Abstract

This paper estimates Okun's law in the EU15 countries between 1980 and 2018. It employs three different versions of the law with a focus on the dynamic part of the relationship. We find that the negative relationship between unemployment and output holds for most countries and is fairly stable over time. However, Okun's coefficient varies substantially across countries. The dynamic version can shed light on the different country estimates found in the literature and is useful to assess the stability of the law. The paper argues that lag effects need to be taken into account to avoid possible misspecification of the short run unemployment-output relationship. A mixed lag structure indirectly controls for missing explanatory variables and includes possible asymmetries.

JEL classification: E24, C22, E32

Keywords: Okun's law, unemployment, growth, dynamic modelling, cycles

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†Department of Economics, European University Viadrina. Email: obst@europa-uni.de

1 Introduction

One of the most accepted ideas in economics is that economic growth is essential to create employment in an economy. Okun's law (OL) captures this idea in its essence and has become one of the most well-known concepts in macroeconomics. It is named after Arthur Okun (1962) who found a negative short-run relationship between unemployment and output in a study for the US in the post-war period. In his seminal contribution he indicated that a three-percentage increase (decrease) in output would be associated with a one-percentage point decrease (increase) in unemployment. This empirical regularity has become a rule of thumb for policy makers and regarded as a cornerstone concept in macroeconomics (Blinder, 2011). More importantly, it captures the essence of one of the most widely accepted views in macroeconomics that a sufficient growth rate of real GDP is crucial to reduce unemployment.

Economists tried to quantify OL by estimating Okun's coefficient (OC), which indicates the magnitude of the unemployment-relationship, e.g. how responsive unemployment is to a change in output. Whereas the three to one ratio was found in the early literature on OL (e.g. Blackley 1991) more recently, economists believe this rule-of-thumb to be closer to a two to one ratio. Hence, a two per cent increase (fall) in real GDP growth will be associated with a one percentage point decrease (increase) in the unemployment rate indicating that a change in unemployment to real GDP growth has become more responsive over the last decades. The simplicity of OL makes it attractive for empirical research. Hence, a substantial body of literature aimed to empirically estimate this inverse relationship by applying different econometric techniques (Moosa, 1997; Lee, 2001; Freeman, 2001; Knotek, 2007; Zanin and Marra, 2011, Ball et al. 2017).

The reliability of OL is also relevant for the conduct of monetary policy in real time (Altig et al., 1997). If the presupposed stable and relatively predictable relationship between the unemployment rate and output fails to hold this can have substantial ramifications such as sending misleading signals to the policy maker about the predicted rate of economic growth. However, it is difficult a priori to pin down the size of OC since it depends on changes of employment to output and subsequently a change in unemployment (Ball et al. 2017). Theoretically, movements in output will change employment which than move unemployment in the opposite direction. The OC thus depends on the respective effects on employment following a change in output and the effects of a change in employment on the unemployment rate[1]. Moreover, as pointed out in Prachowny (1993) and Freeman (2001) predicting that output increases by 3

[1]It should be noted, that an increase in employment is not simultaneous with a reduction in unemployment. For example, employment can be generated by accessing the pool of labour not counted in the labour force, e.g. persons who have stopped looking for work and thus dropped out of the statistics on unemployment.

per cent for every 1 percentage point reduction in the unemployment rate assumes that other factors such as weekly hours, changes in labour force participation and productivity growth rise *pari passu*.

Recent research has questioned the stability of OL and analysed whether this inverse relationship has experienced a structural change (Lee, 2000; Gordon, 2010; Knotek, 2007; Meyer and Tasci, 2012). There are two dimensions commonly discussed in that literature: The time-varying aspect and the cross-country heterogeneity of OL. Some studies focus on the time-varying aspect (Perman and Tavera, 2005; Knotek, 2007; Meyer and Tasci, 2012; Zanin and Marra, 2011) addressing the question whether Okun's coefficient has weakened or increased over time. In this context, OL was tested regarding non-linearity as well as varying estimates during expansions and recessions. Lee (2000) and Knotek (2007) for instance test the time instability of OC reflecting both changes over the business cycle as well as longer-term structural movements in the output-unemployment relationship. Owyang and Sekhposyan (2012) test tor stability of the OC over time and find that the Great recession and the three most recent U.S. recessions indicate that there has been a breakdown in OL.

Knotek (2007) finds that the OC is, on average, smaller in expansions than during recessions pointing to the fact that unemployment responses differently to economic growth during different phases in the business cycle. This phenomenon has been well researched in the literature reflecting asymmetric adjustments of Okun's law over the business cycle. Cazes et al. (2013) for instance explore the role of labour market institutions in driving these asymmetric behaviours. They find an upward trend in OC in countries such as Spain, Netherlands or France but also falling ones in Denmark. In the same vein, Dixon et al. (2016) include the effects of labour market institutions as well as gender and age effects into the inverse relationship between output and unemployment. They find that the change in unemployment in response to shocks in output have increased over time. Other studies are concerned with the cross-country heterogeneity, which might explain the difference in OC (Freeman, 2001; Perman and Tavera, 2005, Hutengs and Stadtmann, 2013; Ball et al. 2017).

Part of that literature is concerned with convergence of the estimates among European countries in the context of labour markets harmonisation in the EU (Katos et al. 2004; Perman and Tavera, 2005, Perman and Tavera, 2007). This literature finds that the Okun coefficient varies significantly across countries. What unites both approaches is that they find the Okun coefficient has kept the expected negative sign but the value of OC – in absolute terms – seems to have increased over time with exceptions in some countries (Pearman and Tavera, 2007).

Nevertheless, some studies find the alleged breakdown over-exaggerated and hence miss-leading. Ball et al. (2017) conclude that OL shows a strong and stable relationship in most countries. By the same token, Daly et al. (2014) suggest that the output-unemployment relationship still follows a typical cyclical pattern and rumours of a breakdown were exaggerated. They show that once GDP data revisions were taken into account, the apparent anomalies disappeared in the U.S.. Moreover, those temporary deviations from the two-to-one rule are common (at least) over the U.S. business cycle. Hence, they also conclude that this statistical correlation has held remarkably well over time and the unemployment rate still serves as a good proxy for economic slack in the economy. The literature can be further distinguished into groups of papers that aim to estimate the empirical regularity between unemployment and real output growth in two different ways (Pearman et. al, 2015). A first group employs the specifications suggested by Okun (1962) and estimate Okun's law in a gap and difference specification with the unemployment rate being the dependent variable. A second group of papers estimate some type of an augmented production function including additional explanatory variables on the right hand side (e.g. labour or capital productivity). The vast empirical research has found OCs around the mean of -0.77 but with a wide range between -3.22 and 0.17 (Perman et al. 2015)[2].

This paper aims to contribute to the literature by estimating OL for the EU15 countries between 1960 and 2018 using time series analysis. It moves beyond the current literature by estimating annual and quarterly data for the Okun relationship, carefully paying attention to the issue of delayed responses in the unemployment-output nexus. Including lags captures the idea that firms take time to adjust employment when output changes. Using both annual and quarterly data allows us to compare estimates with varying time frequency. Estimating three different versions of OL sheds light on the issue of model specification that might play a role in obtaining heterogeneous OC estimates.

Thus, the focus is on the time dimension of OL in the European context. Knotek (2007) argues that while the contemporaneous correlation between output and unemployment movements has decreased over time, the dynamic correlation with lagged output measures has increased. Owyang and Sekhposyan (2012) also extend OL by including current and past values of output

[2] In a meta-regression analysis the authors analyse 28 studies including 269 estimates. After incorporating for study specific characteristics (e.g. econometrics techniques and data frequency) they find the fundamental 'true' value is between -0.61 when unemployment is the endogenous variable and -1.02 when output is the dependent variable. It is well-known that the reversal of the functional specification of the estimated relationship between the unemployment rate and real GDP growth does in general not hold due to econometric and theoretical assumptions (Owyang and Sekhposyan 2012; Plosser and Schwert, 1979).

growth and unemployment rates using quarterly data. Ball et al. (2017) follow this approach and include two lags of the output term. However, they assume the output-unemployment relationship to be only short-run and hence do not test for more than two lags (e.g. the gestation period of the output shock is less than one year). Most importantly, all these studies focus primarily on the U.S. context without further investigating the dynamic version of OL for the European countries[3]. Moosa (1997), however, shows that the long-run effect of cyclical output on cyclical unemployment can differ from the 'pure' short-run effects finding that the adjustment process takes longer than one year[4]. Hence, we aim to extend the analyses of the time varying aspect of OL by taking into account the importance of the lag structure in the output-unemployment relationship as well as considering dynamic effects in OL.

Furthermore, our paper is an attempt to provide an answer to the question posed in the title for the average EU15 country. It benefits from taking into account more recent revised data after the Great recession; an important issue that might have distorted previous empirical estimations of the output-unemployment relationship as pointed out in Daly et al. (2014). It attempts to shed light on possible explanations for country outliers found in the literature by estimating an extended dynamic version of OL including a mixed lag structure.

The reminder of this paper is structured as follows: In the second section we introduce three different versions of OL employed in the empirical literature. Section three introduces data and methods applied in this paper. Section four discusses the empirical results and outlines further robustness checks. Section five summarizes the main findings and concludes.

2 Three different versions of Okun's law

Okun (1962) presented two equations connecting the rate of unemployment to real output growth, which have been commonly employed in the empirical literature: The gap version and the difference version. These equations have been expanded on and modified in various ways to improve their statistical fit and give more insight on the theoretical foundations (Perman et al.

[3]Hutengs et al (2012) also consider implementing a dynamic version of OL for the Eurozone countries by introducing lags of GDP growth and unemployment rates into the difference version of OL in order to get possible additional explanatory power. However, they decide to keep the analysis simple and stick to the contemporaneous relationship between GDP growth and unemployment rates. Using annual data they argue that dynamic adjustment processes should be completed within one year and do not estimate quarterly data. Ball et al. (2017) do include 20 OECD countries in their estimation with two output lags.

[4]His analysis is based on the G7 countries including European countries. He finds a delayed response in unemployment to a shock in output for Germany and Italy.

2015). In the gap version the unemployment gap is dependent on the output gap[5]:

$$U_t - U_t^* = \beta_1(Y_t - Y_t^*) + \epsilon_t \tag{1}$$

where β_1 denotes the OC. The output gap measures the difference between natural log of actual (Y_t) and potential GDP (Y_t^*) and hence captures the cyclical component of output. Likewise, the difference between observed (U_t) and natural rate of unemployment (U_t^*) is a proxy of the cyclical rate of unemployment.

Since U^* and Y^* are unobservables, a suitable estimation method needs to be applied. Several time series approaches have been proposed in the literature involving different filtering techniques such as the HP filter (Ball et al. 2017), the Baxter-King filter (Freeman, 2001) or the Kalman filter algorithm (Hutengs et al. 2013)[6]. The idea in the gap version is that when actual output grows above its potential (e.g. long run growth trend) there is downward pressure on the unemployment gap (and vice versa). It points to the fact that shifts in aggregate demand can change output in the short run which causes unemployment to change respectively. The error term (ϵ_t) captures factors that may shift the unemployment-output relationship. These factors might be unusual changes in labour force participation or labour productivity etc. This equation thus also assumes that the growth rate of potential output and the natural rate of unemployment do not vary over time (Ball et al. 2017)[7]. In the difference version, a change in the unemployment rate depends on the change in output:

$$\triangle U_t = \alpha + \beta_1 \triangle Y_t + \epsilon_t \tag{2}$$

where $\triangle$ is the difference operator representing a percentage point change for the unemployment rate and a percent change regarding output from the previous period, α an intercept capturing the mean change in unemployment that is independent from output growth and β_1 denotes the OC, expected to have a negative sign. This equation has the advantage that it does not need to rely on unobservables such as in the gap version.

Recent research has emphasized that the unemployment-output relationship might be

[5]In alignment with Ball et al. (2017) we do not include a constant in our equation. Even though this seems theoretically like a strong restrictive assumption empirically it makes no difference, e.g. the estimated results do not change.

[6]However, results are robust when using different filter methods (Dixon et al., 2017; Lee 2001).

[7]Otherwise, the part of the error term that depends on a change in potential output is probably correlated with the regressor (actual output growth) and OLS estimates of the OC would be biased. Here, since we have a relatively short sample period (1980 – 2018) we assume potential output and the natural rate of unemployment to stay constant over time. As a robustness check, we also estimate the difference version of OL.

dynamic and that both past and current levels of output and unemployment play a vital role (Knotek, 2007; Owyang and Sekhposyan 2012; Ball et al. 2017). This extension of the simple static relationship takes into consideration the fact that the adjustment process of unemployment facing an exogenous shock in output needs time to fully materialise such as pointed out originally by Okun (1962). Okun (1962) and Oi (1962) argued that labour is a quasi-fixed factor. It is costly to adjust employment, therefore firms accommodate short-run output fluctuations in other ways: e.g. they adjust working hours or the intensity of workers' effort (which produces pro-cyclical movements in measured productivity) (Ball et al. 2017). In the short-run, labour is thus a semi-fixed factor of production (Paldam, 1987). It is thus not theoretically plausible that the relationship is only contemporaneous. Moreover, it might be empirically misspecified due to omitting significant time lags. Hence, we introduce limited dynamics to the model. The dynamic version can then be specified as:

$$U_t - U_t^* = \beta_0(Y_t - Y_t^*) + \beta_1(Y_{t-1} - Y_{t-1}^*) + \beta_2(Y_{t-2} - Y_{t-2}^*) + \delta(U_{t-1} - U_{t-1}^*) + \epsilon_t \tag{3}$$

Equation 3 is the autoregressive distributed lag model (ADL) of the gap version given in equation (1)[8]. This specification has the advantage that it allows potential serial correlation in the error terms to be eliminated (Knotek, 2007; Andonova and Petrovska, 2019). It also possibly eliminates issues of endogeneity in the contemporaneous part of the model[9]. Meyer and Tasci (2012) suggest that including lags might resolve that instability problem of OL over time. The dynamic relationship is thus more flexible allowing for different variations in the connection between real output growth and changes in the unemployment rate. Including lags of the dependent and independent variable indirectly controls for asymmetries in the relationship (e.g., asymmetric adjustment process over the business cycle) and possible misspecification by omitting variables that play a role in explaining a change in the unemployment rate. However, the simple interpretation of the original version of OL becomes more nuanced.

[8] We also estimate the difference version of OL in section 4.2. Growth rates of potential output and the natural rate of unemployment are assumed to be constant over time. Hence, one would not need to introduce a time index. We apply them to indicate the respective time period taking into account change values for actual output growth and unemployment rates.

[9] We assume the causality to run from output growth to a change in the unemployment rate but issues of simultaneity bias between the two variables might exist in the short run. Significant lags of output growth indicate that causality runs from changes in output to unemployment rates (Paldam, 1987).

3 Data and methods

The data set consists of annual real GDP data and annual unemployment rates published in the Annual-Macro-Economic Database (AMECO) of the European Commission (2018)[10]. Quarterly real GDP data and quarterly unemployment rates stem from the OECD Economic Outlook database (2018). The observation period is between 1980 and 2018 for annual data and between 1985 and 2018 for quarterly data[11]. The analysis includes the EU15 countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the UK.

Table 1 illustrates the average unemployment rates and real GDP growth rates in the EU15 countries for our annual data between 1980 and 2018. The EU 15 countries exhibited an (unweighed) average GDP growth of 2.9%. Unemployment rates were 6.4% on average. However, country trends are quite heterogeneous: While Ireland had the fastest growing economy on average (4.7%) it also shows high unemployment rates (9.3%). The lowest unemployment rates on average can be found in Luxembourg (2.4%) and Austria (3.3%). Spain had the highest unemployment rates on average (12.1%) with peaks during the crisis (26.1%).

This paper employs time series methods. Since trend GDP and the natural rate of unemployment are not directly observable we use the HP-filter to de-trend the data. It is common practice in the literature to employ the Hodrick-Prescott filter method[12] in order to estimate the unemployment gap as well as the output gap. We have used common smoothing parameters of $\lambda = 1{,}600$ for quarterly data and $\lambda = 100$ for annual data. Newey-West standard errors are estimated to produce consistent estimates of the t-statistics. We estimate OL in a dynamic version that includes current and lagged values of unemployment rates and output growth. Previous research highlights the importance of correlation between lagged values of output growth and changes of current unemployment rates (Knotek, 2007; Owyang and Sekhposyan; Ball et al. 2017). Several approaches have been proposed to test the variation of OL over time. In this paper, we apply two methods to examine the stability of our OC. First, we do simple stability tests by breaking our sample in half and estimate separate coefficients for each time

[10]The definitions and sources of the variables used in this paper can be found in appendix 2.

[11]Annual data on unemployment rates and real GDP growth is gnerally available between 1960 and 2018 for all countries. However, due to missing data before the 1980s for some countries we start our sample in 1980 for annual data and in 1985 where quarterly data is available for all countries except Denmark and Greece. This also avoids issues with low unemployment rates as well as differences in the measurement of unemployment in earlier periods as argued in Ball et al. (2017).

[12]The method has been widely applied to estimate potential output or the natural rate of unemployment. However, it can be criticized for arbitrarily choosing a certain smoothing parameter.

Table 1: Summary Statistics

	Annual Data (1980-2018)							
	GDP Growth				Unemployment Rate			
Country	Mean	SD	Min	Max	Mean	SD	Min	Max
Austria	2.7	1.9	-3.8	6.9	3.3	1.6	0.8	6
Belgium	2.6	1.9	-2.3	6.7	6.5	3	1.4	11
Denmark	2.3	2.3	-5	8.9	4.9	2.5	0.6	9.6
Finland	2.8	3.1	-8.6	9.2	6.4	4	1.1	16.6
France	2.7	2	-3	6.9	6.7	3.3	1.2	10.7
Germany	2.4	2.1	-5.8	7.2	5.5	3.3	0.5	11.2
Greece	2.7	4.7	-9.6	12.4	8.8	6.5	1.7	27.5
Ireland	4.7	3.8	-4.7	22.8	9.3	4.2	4.2	16.8
Italy	2.4	2.6	-5.6	7.9	8	2.4	3.7	12.7
Luxembourg	3.6	3.2	-6.8	9.5	2.4	2	0	6.5
Netherlands	2.7	2	-3.8	8	4.9	2.7	0.5	11.8
Portugal	3.1	3.3	-5.2	10	6.9	3.6	1.7	16.4
Spain	3.3	2.9	-3.6	11.2	12.1	7.3	1.5	26.1
Sweden	2.5	2.2	-5.3	6.6	5	2.9	1.3	11
UK	2.3	2	-4.3	6.3	5.7	3	1.1	11.2
EU15	2.9	2.8	-9.6	22.8	6.4	4.4	0	27.5

Note: Data based on annual real GDP growth (in logs) and annual unemployment rates (in levels) downloaded from AMECO database.

period. For our quarterly data specifications, however, we apply an additional Andrews test for a break at an unknown date taking into account possible non-linearity's in the relationship.

4 Empirical estimates of Okun's law

4.1 Baseline results

We tested OL in the gap version and difference version with quarterly data and annual data. We examine the period between 1980 and 2018 for annual data and 1985 to 2018 for quarterly data due to data restrictions[13]. We first test the empirical fit of our gap version by estimating

[13]Ball et al. (2017) also drop the 1960s and 1970s from their sample. Coefficients might be less significant and small in countries with low unemployment rates (Paldam 1987). For quarterly data, we thus start only in

the change in the unemployment rate with two lags of the output gap:

$$U_t - U_t^* = \beta_0(Y_t - Y_t^*) + \beta_1(Y_{t-1} - Y_{t-1}^*) + \beta_2(Y_{t-2} - Y_{t-2}^*) + \varepsilon_t \quad (4)$$

where U^* and Y^* are the long-run levels estimated with the HP filter and the $\widehat{\beta_s}$ are the estimated coefficients on the current and lagged output gaps. We do the same for the difference specification including only current output for annual data but also two lags for quarterly data:

$$\triangle U_t = \beta_0 + \beta_1 \Delta(Y_t) + \varepsilon_t \quad (5)$$

Table 2 shows our estimates for the equation in levels (gap version) given in equation (4)[14]. The fit is good for most countries with an R^2 value exceeding 0.4 for all countries but Austria, Germany, Ireland and Italy for quarterly data and for all but Austria, Italy and Luxembourg concerning annual data. On average, the fit for annual data is slightly better than with quarterly data (0.59 compared to 0.55). The OC is significant in all countries with the expected negative sign. However, the estimated coefficients differ substantially across countries. Regarding quarterly data, most coefficients lie between -0.2 and -0.5 with the average coefficient being -0.39[15]. Luxembourg has – in absolute terms – the lowest value of -0.09[16] and Spain the largest one with -0.87.

1985. A robustness check with the full sample size (1960-2018) shows that the fit of the regression is lower on average using data starting in 1960 (where available).

[14] We report Newey-West (1987) standard errors in parentheses. Applying this method leads to HAC standard errors correcting for heteroscedasticity and autocorrelation issues. For annual data we apply a HP parameter of $\lambda = 100$ and for quarterly data a HP parameter of $\lambda = 1600$.

[15] Regarding annual data the average coefficient is similar with -0.41. We have also estimated weighted average coefficients (e.g. taking into consideration the country's GDP in total EU15 GDP). The average coefficient (based on quarterly data) stays the same, but with annual data it increases slightly to -0.44.

[16] Luxembourg shows the lowest unemployment rates on average out of the EU15 country sample (see appendix 1). Hence, small OC are plausible. Also, there is almost no change in the unemployment gap over the full sample. Hence, we will drop this country in the subsequent analysis of the next sections.

Table 2. Gap version of Okun's law in the EU15 countries.

	Quaterly data (1985Q1-2018Q4)			Annual data (1980-2018)		
	$\widehat{\beta}_0 + \widehat{\beta}_1 + \widehat{\beta}_2$		Adjusted R2	$\widehat{\beta_0}$		Adjusted R2
Austria	-0.199**	(0.036)	0.342	-0.179***	(0.030)	0.392
Belgium	-0.494***	(0.057)	0.555	-0.508***	(0.100)	0.507
Denmark	-0.375***	(0.047)	0.608	-0.471***	(0.042)	0.701
Finnland	-0.436***	(0.060)	0.703	-0.478***	(0.077)	0.759
France	-0.393***	(0.039)	0.681	-0.396***	(0.035)	0.707
Germany	-0.233***	(0.047)	0.380	-0.407***	(0.122)	0.458
Greece	-0.501***	(0.071)	0.635	-0.522***	(0.071)	0.784
Ireland	-0.218***	(0.061)	0.339	-0.366***	(0.059)	0.732
Italy	-0.277***	(0.056)	0.321	-0.308***	(0.092)	0.362
Luxemburg	-0.085***	(0.011)	0.404	-0.080***	(0.020)	0.210
Netherlands	-0.466***	(0.051)	0.692	-0.490***	(0.074)	0.646
Portugal	-0.394***	(0.051)	0.543	-0.395***	(0.076)	0.633
Spain	-0.872***	(0.068)	0.725	-0.786***	(0.091)	0.715
Sweden	-0.430***	(0.064)	0.646	-0.454***	(0.084)	0.609
UK	-0.420***	(0.052)	0.724	-0.400***	(0.053)	0.625

Note: The table reports the estimated coefficients. ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively. Standard errors are reported in brackets.

Table 3 presents the results of the difference version estimated as outlined in equation (5), again both for quarterly and annual data. On average, the fit is much lower in the difference version than in the gap version. The average R^2 value for annual data is only 0.4 and for quarterly data substantially lower with 0.29. In Belgium, the fit is as low 0.09 in the quarterly specification including two lags of output. Moreover, the estimated coefficients are smaller on average in comparison to the estimated values for the gap version. For quarterly data, the estimated coefficient falls from -0.39 to only -0.29 and for annual data from -0.41 to -0.32 . However, the variation across countries show the same pattern in the gap as well as in the difference version. Spain and Luxembourg are outliers with coefficients as high as -0.70 and as low as -0.05 based on quarterly data. For annual data, again Luxembourg has a value of only -0.06 and Spain the highest value of -0.755. However, in the difference version the goodness of fit becomes better using annual data for almost all countries except in France, Luxembourg and Sweden.

Table 3. Difference version of Okun's law in the EU15 countries.

	Quaterly data (1985Q1-2018Q4)			Annual data (1980-2018)		
	Difference Version					
	$\widehat{\beta}_0 + \widehat{\beta}_1 + \widehat{\beta}_2$		Adjusted R2	$\widehat{\beta_0}$		Adjusted R2
Austria	-0.176***	(0.035)	0.104	-0.168***	(0.024)	0.354
Belgium	-0.263***	(0.079)	0.088	-0.303***	(0.066)	0.268
Denmark	-0.299***	(0.061)	0.333	-0.391***	(0.047)	0.534
Finnland	-0.367***	(0.078)	0.414	-0.346***	(0.103)	0.538
France	-0.348***	(0.041)	0.387	-0.288***	(0.043)	0.380
Germany	-0.138***	(0.051)	0.140	-0.251***	(0.105)	0.263
Greece	-0.216***	(0.076)	0.257	-0.353***	(0.096)	0.497
Ireland	-0.192***	(0.072)	0.240	-0.254***	(0.083)	0.463
Italy	-0.196***	(0.060)	0.121	-0.176***	(0.079)	0.189
Luxemburg	-0.053***	(0.019)	0.166	-0.057***	(0.013)	0.110
Netherlands	-0.312***	(0.052)	0.418	-0.395***	(0.110)	0.450
Portugal	-0.330***	(0.046)	0.179	-0.286***	(0.046)	0.402
Spain	-0.702***	(0.107)	0.496	-0.755***	(0.145)	0.551
Sweden	-0.419***	(0.080)	0.507	-0.344***	(0.096)	0.506
UK	-0.338***	(0.039)	0.486	-0.362***	(0.056)	0.478

Note: The table reports estimated coefficients. ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively. Standard errors are reported in brackets.

4.2 Accounting for delays in the response of cyclical unemployment to output

Although the literature generally supports the empirical validity of OL (e.g. finding a statistically significant negative relationship between unemployment and output) the magnitude of OC is highly sensitive to model specification, as we could see in estimating the two most common versions of OL.

This paper focuses on the dynamic nature of OL to shed light on the different results found in the literature. Hence, we further estimate an ADL model (Hendy et al., 1984) including the lagged dependent variable in the following form:

$$U_t - U_t^* = \beta_0(Y_t - Y_t^*) + \beta_1(Y_{t-1} - Y_{t-1}^*) + \beta_2(Y_{t-2} - Y_{t-2}^*) + \delta_1(U_{t-1} - U_{t-1}^*) + \delta_2(U_{t-2} - U_{t-2}^*) + \epsilon_t \quad (6)$$

The addition of lagged cyclical unemployment is necessary to remove any possible serial correlation which is known to arise if the simple static equation is used (Moosa, 1997; Andonova and Petrovska, 2019). As the dynamic specifications vary substantially across countries we use difference and gap versions of OL. This strategy permits some sensitivity analysis of the empirical results related to the maintained specification. It also avoids potential issues of obtaining empirical estimations specific to one chosen model specification (Perman and Tavera, 2007). The long-run effect of the output gap on the unemployment gap is given by:

$$\psi = \frac{\sum_{i=0}^{n} \widehat{\beta}}{1 - \sum_{i=0}^{n} \widehat{\delta}} \quad (7)$$

We aim to keep the model parsimonious by mainly including significant coefficients as well as introducing only one lag of the unemployment rate if possible. We include more lags in case that serial correlation persists. This model has two advantages over the baseline model outlined in section 2: (1) it takes into consideration the issue of serial correlation present in the previous estimates and (2) it indirectly controls for further explanatory variables[17] that might affect current unemployment with a delay. The latter one is indeed our primary concern. The empirical literature has outlined that the simple version of OL shows time variation due to different reasons. The discussion focuses around asymmetric adjustments over the business cycle (Silvapulle et al. 2004, Owyang and Sekhposyan 2012) and on integrating further explanatory

[17]The unemployment rate represents an average value blurring possible differences. Hutengs and Stadtmann (2013), Zanin (2014) and Dixon et al. (2016) for instance take into account gender and age effects in OL.

variables, e.g. changes in labour market institutions (Dixon et al. 2016) into the regression analysis.

We indirectly control for these factors by including lag effects of unemployment and output. The present issue of autocorrelation in the baseline results indicates a potential miss-specification of the model[18]. Further explanatory variables might introduce a delay into the unemployment-output relationship. Hence, taking into account these effects can enhance the explanatory power of the model. Testing for possible long-run effects can also be motivated by findings such as in Economou and Psarianos (2016) who distinguish between the transitory and the permanent effects of changes in output on unemployment in the 13 EU countries[19]. Table 4 shows the results:

[18] Omitted variable bias is an issue in a simple static specification of OL. Adding lagged effects is thus also recommendable from an econometric point of view. It solves the issue of autocorrelation in all countries except Belgium (see table 4 for results)

[19] They find that the permanent effects are quantitatively larger than the transitory effects, particularly in countries with low labour market protection.

Table 4. Autoregressive distributed lag model for 14 EU countries.

	Austria	Belgium	Denmark	Finland	France	Germany	Greece	Ireland	Italy	Netherlands	Portugal	Spain	Sweden	UK
$\widehat{\beta_0}$	-0.096***	-0.165***	-0.064**	-0.130***	-0.145***	-0.026**	-0.072**	-0.017	-0.079***	-0.051***	-0.162***	-0.114**	-0.089***	-0.094***
	(0.021)	(0.028)	(0.026)	(0.015)	(0.015)	(0.013)	(0.035)	(0.015)	(0.018)	(0.019)	(0.029)	(0.046)	(0.025)	(0.028)
$\widehat{\beta_1}$			-0.076**			-0.024*	0.008	-0.027*		-0.047*		-0.127***	-0.132***	-0.058*
			(0.029)			(0.013)	(0.031)	(0.016)		(0.025)		(0.045)	(0.027)	(0.030)
$\widehat{\beta_2}$							0.023	-0.031**		0.032			-0.034	-0.041
							(0.035)	(0.015)		(0.021)			(0.030)	(0.029)
$\widehat{\delta_1}$	0.600***	0.715***	0.753***	0.775***	0.746***	0.733***			0.827***		0.627***	0.625***	0.354***	0.456***
	(0.062)	(0.047)	(0.042)	(0.031)	(0.032)	(0.055)			(0.041)		(0.057)	(0.070)	(0.086)	(0.075)
$\widehat{\delta_2}$							0.388***	0.363***		0.166**			0.147**	
							(0.101)	(0.081)		(0.076)			(0.074)	
$\widehat{\alpha}$						0.016	0.041	0.063		0.064***		0.133***	0.147***	0.077***
						(0.013)	(0.051)	(0.050)		(0.020)		(0.049)	(0.030)	(0.022)
ψ	-0.240	-0.58	-0.567	-0.578	-0.571	-0.187	-0.350	-0.189	-0.457	-0.363	-0.434	-0.369	-0.279	-0.413
Adj R2	0.571	0.761	0.888	0.918	0.895	0.627	0.617	0.423	0.813	0.652	0.747	0.674	0.631	0.597
BG	0.535	0.018	0.294	0.285	0.085	0.771	0.138	0.281	0.816	0.457	0.385	0.997	0.311	0.111
rmse	0.244	0.287	0.888	0.315	0.148	0.129	0.390	0.391	0.221	0.144	0.415	0.345	0.228	0.156
Obs	135	135	95	135	135	135	92	134	135	134	135	135	134	134

Note: Standard errors in parenthesis; ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively. Regressions including a constant are based on the difference version outlined in equation (2) in section 2 of the paper. This relates to the following countries: Germany, Greece, Ireland, Netherlands, Spain, Sweden and the UK. Since revised model includes lagged values of the dependent variable, the Durbin–Watson test is not applicable. Instead we employ the Breusch-Godfrey test for serial correlation.

The extended model encompasses three interesting findings. First, We find that the LR coefficient (ψ) is more in alignment with the recent belief of economists that this rule-of-thumb should be closer to a two to one ratio. The average OC is -0.39 indicating a drop in unemployment of roughly 0.4%-points if output growth increases by 1%. OC only remains persistently low in Germany and Ireland (-0.19) and reaches its peak in Finland (-0.58). The range of coefficients, however, is much tighter compared to our baseline results. Second, in countries such as Italy, where the baseline results indicated a low OC, it increases to -0.46. Also, in Spain where most of the literature finds that the OC is high, taking into account a dynamic version of OL alters the coefficient down to -0.37. Hence, the new results are much closer to the generally believed size of what OC should be. Third, the fit of OL increases substantially to 0.70 on average. In countries with low R2 values such as in Italy the fit improves to 0.81.

4.3 Robustness checks

Meyer and Tasci (2012) outline possible avenues concerning the time instability of Okun's coefficient. We have already integrated one stability condition by employing a dynamic version of Okun's law. Knotek (2007) also argues that the dynamic part of OL has become more relevant than the contemporaneous part in recent years. The author uses rolling regressions showing that past values of output growth have become larger in effect after the recession in the US in the 1990s. However, as Zanin and Marra (2011) and Ball et al. (2017) point out, this method suffers from methodology problems such as the problematic window size choice[20]. We thus first do stability checks with a fixed break date splitting the sample in half for 1980-1999 and 2000 to 2018 for annual data and for 1985-2002 and 2003-2018 for quarterly data.

The general finding in the literature is that the OC has increased over time with a few exceptions (e.g. Cazes et al. 2013). However, we find that the average OC decreases from -0.39 to -0.35 (in the gap version) as well as from -0.32 to -0.30 (in the difference version) based on quarterly data. In 9 out of 14 countries OC decreases in absolute value for the gap version and in 7 out of 14 countries for the difference version. Concerning annual data the results show the same pattern: On average, OC decreases from -0.42 to -0.38 (in the gap version) and from -0.37 to -0.31 (in the difference version). It decreases in absolute value in 11 countries for the gap version and in 8 countries for the difference version. Hence, in alignment with Ball et al. (2017) we do not find that the Okun coefficient has generally risen over time. On the other hand, we can also confirm that in Spain the OC has indeed risen over the last two decades or so for most of the model specifications. Moreover, the negative short-run relationship between

[20]The amount of instability appears to depend heavily on the window width.

unemployment and output breaks down in some countries of our sample: Austria, Belgium, Greece, Germany, and Italy. In these countries, we do not find a statistically significant OC in some of the equations and the fit of the regression becomes very poor[21]. This further confirms the 'outlier role' of Austria, Belgium or Italy where the fit is below average also in the full sample.

For our Gap specification based on quarterly data, we have also performed the Andrews sup-Wald test (2003) with an unknown break date[22]. We indeed find some evidence of instability across time. We reject the stability of the OC in 13 of the 15 countries lending some support to the structural change hypothesis posed in the literature (e.g. Moosa, 1997; Lee 2000). In Belgium and Denmark we do not find a structural break. The dates vary substantially across countries: from 1996 in Austria to 2015 in Greece indicating that there is not one specific international change in OL at a particular time period. However, most structural breaks do occur in the aftermath after the Great recession (e.g. in 9 countries) lending some support to the hypothesis of a change in the correlation of the output-unemployment relationship after the Great recession (Gordon, 2010). We have also tested the ADL model presented in table 4 for structural breaks. Indeed, taking into account dynamic effects in the unemployment-output relationship appears to improve parameter stability. In addition to Belgium and Denmark we find no structural break in Austria, Italy, Netherlands, and in the UK. Hence, we have 6 out of 14 countries with no structural break in the relationship.

We further estimated a seemingly unrelated regression model (SURE) to check the robustness of our basline results given in section 4.1 [23]. Indeed, we found contemporaneous cross-correlation in the error terms for the EU15 countries to play a role. This is plausible since the EU15 represent a highly integrated economy, i.e. are affected by a common monetary policy or an oil price shock. Moreover, these countries operate in similar regulatory market environment. However, our SURE estimations (based on our gap version using quarterly data) show that we do not increase statistical significance by applying a systems approach. The estimated OC was highly significant using OLS in our baseline model. The average goodness of fit in the SURE model is 0.57, which does not indicate a major improvement compared to an average adjusted R2 value of 0.55 in the baseline model. Also the average OC is strikingly similar with -0.37 in the SURE model compared to -0.39 in our baseline model. Hence, our overall findings remain robust when estimating a SURE model, e.g. the size of the coefficients do not change much.

[21]We only focus on the sample split based on quarterly data since annual observations only include a short sample size of below 20 observations. Also, in Greece data starts only in 1995 so the sample period is very short even for quarterly data in the first half of the sample (1985-2002).

[22]In contrast to Chow breakpoint it is robust to unknown forms of heteroscedasticity.

[23]Results are available upon request.

5 Conclusion

Okun's law is a cornerstone concept in macroeconomics. The empirical analysis in this paper confirms the negative relationship between unemployment and output. In the average EU15 country the coefficients are statistically significant in all countries with the expected sign. Unemployment decreases by 0.4% points following a 1% increase in output growth. However, the dynamic version of OL point to the important issue of delays in the unemployment-output nexus.

The first aim in this paper was to employ different model specifications to compare the robustness of the results. The estimates of the gap and difference version differ substantially regarding the size of the coefficient as well as the empirical fit of the regression. While the gap version estimates confirm a strong and stable relationship between cyclical changes of unemployment and output, the difference version indicates a looser fit with the OC being considerably lower on average compared to the gap version. Both versions include substantial cross-country heterogeneity. These findings might indicate why researches have questioned the stability of the 'law'. In some countries (e.g. Austria or Italy) the fit of the regression is low indicating the need for further investigation. By the same token, countries with very high absolute values of OC (e.g. Spain) illustrate interesting country case studies for further research.

Another aim of this paper was to extend previous analysis on OL by taking into account dynamic effects and thus possibly explain cross-country and time variation of OC found in the literature. To the best of our knowledge, most of the papers that introduced a dynamic version of OL previously have focused mainly on the U.S. context. Empirical research applied lags of output in a given model, while neglecting the role of unemployment lags. The estimated ADL model pays attention to these issues integrating various dynamics in the unemployment-output relationship. We find that coefficients converge towards the more recent belief of economists, e.g. that a 1% increase in output would be associated with a 0.5% points drop in the unemployment rate. Interestingly, this is the case for previously found country 'outliers' such as Italy or Spain. The different size of the long-run coefficients and the improved fit of the regression indicates that the empirical literature needs to pay more attention to possible mixed lag structures in Okun's law. Using a dynamic approach allows for more flexible modelling and indirectly controls for variables that might affect the relationship with a delay.

Okun was quite aware that the simple empirical regularity between changes in the unemployment rate and changes in real GDP involves (at least) three other important factors: induced increases in the size of the labour force, longer weekly working hours or greater productivity.

Hence, further analysis could include further explanatory variables on labour market institutions and educational settings. An interesting avenue for future research would also include a sectoral analysis, e.g. examining structural change in different industrial sectors, to explain heterogeneous cross-country estimates. Paying attention to the lag structure more carefully, however, provides an alternative possible explanation for the variety of findings in the empirical literature.

Another goal of this paper was to test for parameter stability and analyse the length of the adjustment process following a change in output growth. While we find that non-linearity plays an important role over time, the exact time period of a structural change varies substantially across countries indicating that there was no specific international time period when the relationship broke down. Testing structural breaks in the new model (based on a mixed lag structure) indicate that the relationship becomes more stable when including dynamic lag effects. While Okun's relationship may become more stable, however, it becomes more difficult to interpret the results.

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Appendices

Appendix 1. Summary Statistics – Quarterly Data

Quaterly Data (1985-2018)								
	GDP Growth				Unemployment Rate			
Country	Mean	SD	Min	Max	Mean	SD	Min	Max
Austria	0.7	0.7	-1.9	3.2	3.6	1.4	1	6.2
Belgium	0.6	0.7	-2.6	3	6.3	3.1	0.9	11
Denmark	0.4	0.9	-2.4	2.9	5.4	2.1	0.6	9.8
Finland	0.7	1.3	-7	6.2	6.6	4.2	0.9	18.8
France	0.7	0.9	-5.2	7.4	6.6	3.3	1	10.8
Germany	0.6	1.1	-4.6	4.6	5	3.2	0.4	11.2
Greece	0.8	1.8	-3.1	5.4	6.6	8.1	0	27.9
Ireland	1.2	1.9	-4.9	20.4	10.7	4.4	4	16.1
Italy	0.6	1	-2.8	4.6	7.4	2.9	2.5	12.8
Luxembourg	0.9	1.3	-4.3	6.4	3.6	1.9	1	7.1
Netherlands	0.7	1.4	-6.1	8.8	5.1	3	0.5	12.9
Portugal	0.8	1	-2.3	5	6.7	3.3	1.9	17
Spain	0.8	0.9	-1.9	4	14.8	5.2	3.7	26.2
Sweden	0.6	0.8	-3.8	3.1	5.1	2.9	1.4	12.2
UK	0.6	0.9	-2.8	4.8	7	2.4	3.4	11.9
EU 15	0.7	1.1	-7	20.4	6.6	4.5	0	27.9

Note: Data based on quarterly real GDP growth and quarterly unemployment rates downloaded from OECD database.

Appendix 2. Data and Sources

Symbol	Variable Name	Definition	Source/variable construction	Time period
		Annual Data		
Y	Gross Domestic Product	Gross domestic product at 2010 market prices	AMECO (2018)	1980-2018
U	Unemployment rate	Unemployed persons as a share of the total active population (labour force). Unemployed persons are those aged at least 15 years, who are without work.	AMECO (2018)	1980-2018
Y*	Potential Output		HP Filter with smoothing parameters of 100	1980-2018
U*	Natural Rate of Unemployment		Calculated applying Hodrick Prescott Filter with smoothing parameters of 100	1980-2018
		Quarterly Data		
Y	Gross Domestic Product	GDP-Gross domestic product, value, market prices. Deflated by using the GDP price deflator.	OECD Economic Outlook No. 104 2018	1985-2018
U	Unemployment rate	Percentage, Quarterly	OECD Economic Outlook No. 104 2018	1985-2018
Y*	Potential Output		HP Filter with smoothing parameters of 1600	1985-2018
U*	Natural Rate of Unemployment		HP Filter with smoothing parameters of 1600	1985-2018

Notes: Unemployment rate, annual: AMECO data is between 1960 and 2018 except in Luxembourg. Here, data starts in 1975 only. We have cut off data at 1980 to avoid issues of low unemployment rates as well as differences in the measurement of unemployment rates in the 1960s and 1970s. Gross Domestic Product, quarterly: For Denmark and Greece there is no quarterly GDP data available on the OECD website. We have taken data from the Federal Reserve Database for Denmark and Greece between 1995 and 2018 instead. Unemployment rate, quarterly: We have cut off data sample at 1985 Q1 where all country data is available except Greece. In Greece data starts in 1990 Q1. For Germany and Ireland we have calculated data back using growth rates of the harmonised unemployment rates from the OECD database. For Germany growth rates are linked to West Germany before German reunification.