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OKUN'S LAW AND BUSINESS CYCLE ASYMMETRY

LEY DE OKUN Y ASIMETRÍAS DEL CICLO ECONÓMICO

TRABAJO DE INTEGRACIÓN CURRICULAR PRESENTADO COMO REQUISITO PARA LA OBTENCIÓN DEL TÍTULO DE ECONOMISTA

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DEDICATORIA

Para mi padre Hugo, mi madre Silvia, mi hermano David, mi hermano Alex, mi cuñada Majo y mi sobrina Darlenne.

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Agradezco sinceramente a todos los que contribuyeron a mi formación académica y profesional. Sin ellos, no habría sido posible realizar un trabajo de este nivel y exigencia, al que ellos me acostumbraron. Numerosas personas dejaron su huella en mí, pero quiero destacar especialmente a aquellas que dejaron una marca profunda. Andrea Bonilla, mi tutora y madre académica. Geovanny Romero, quien fue mi apoyo en mis primeros días en la Universidad. Javier Alvarado, por orientarme en mis primeros pasos en la vida profesional. Betzabé Zuñiga, quien me introdujo al mundo financiero en un nivel de profesionalismo excepcional. Luis Portilla, mi gran amigo durante toda la carrera. Y Alisson Alcivar, la amiga que me ayudó a ampliar mis horizontes más allá del aula.

Quiero decirles a todos que esto solo es el inicio de una larga educación y que no descansaré hasta poder tener la palabra Doctor al frente de mi nombre.

Muchas gracias

ÍNDICE DE CONTENIDO

RESUMEN

Esta investigación analiza el comportamiento asimétrico de las relaciones entre el crecimiento de la producción y la variación en la tasa de desempleo en cinco grupos de países, categorizados según sus niveles de producción, condiciones del mercado laboral y ubicación geográfica. Para ello, se emplea modelos de cambio de régimen de tipo Markov para capturar asimetrías tanto en estados de expansión como de recesión. Además, para definir los subgrupos de países, se usan métodos numéricos de agrupamiento. Los hallazgos revelan que un enfoque de cambio de régimen de tipo Markov es más efectivo que un enfoque lineal para capturar la dinámica de la Ley de Okun. El análisis de los coeficientes resultantes y las duraciones medias de los estados a través del agrupamiento indica diferentes tipos de asimetrías. Los hallazgos revelan que la relación de la Ley de Okun exhibe un comportamiento asimétrico a lo largo del ciclo económico, con algunas características comunes dentro de cada grupo de países.

PALABRAS CLAVE: Ley de Okun, asimetría, ciclo económico, agrupamiento, modelo de cambio de régimen de tipo Markov.

ABSTRACT

This research analyses the asymmetrical behavior of the relationship between output growth and the variation in the unemployment rate across five country groups of countries. Countries are grouped using data analysis techniques based on their production levels, labor market conditions, and geographical location. We employ Markov Switching Regime models to capture asymmetries in both expansion and recession states. Additionally, we use clustering methods to group countries. The findings reveal that a Markov Switching approach is more effective than a linear approach in capturing Okun's Law behavior. The analysis of the resulting coefficients and mean durations of the states through clustering indicates different types of asymmetries. We observe that the Okun's Law relationship exhibits asymmetrical behavior over the business cycle, with some common characteristics within each country group.

KEYWORDS: Okun's Law, asymmetry, business cycle, clustering, Markov switching regime model.

1 DESCRIPTION OF THE COMPONENT

For analyzing the asymmetry in the relationship between production growth and unemployment rates, the theory related to Okun's Law and the relevant empirical evidence will be thoroughly reviewed. Databases are obtained from the OECD of thirteen countries: Australia, Chile, Colombia, France, Italy, the Republic of Korea, Lithuania, Netherlands, Slovakia, Spain, the United Kingdom, and the United States. The variables obtained for the empirical exercise are real GDP growth and unemployment rate; and, for performing the clustering strategy the variables are GDP per hour worked, GDP per capita, and unemployment rate. The periods for each country are selected based on their availability.

We use Markov Switching Regime models because this approach can capture the Okun's Law relation in different states, that is in expansion and recession states. The estimations obtained from Markov Switching Regime models and linear models are compared with the LR Test and Upper bound p-values to see which is more effective in capturing the behavior of Okun's Law relationship. Also, we made the post-estimation analyses to verify the validity of the estimation results.

Using the results from the modeling and additional information from countries such as productivity, labor market conditions, and geographical locations, countries are clustered using PCA and K-means methods to identify different groups. The estimated coefficients are presented in individual tables, which allow us to compare results both within the same group and between the other groups. The mean duration of both states is analyzed to see asymmetries of Okun's Law relation in each group. This process allows for identifying key findings, concluding, and making recommendations.

1.1 General objective

To analyze the asymmetry of the relation between the variation of the unemployment rate and the output growth of five country groups with differences regarding productivity, labor market conditions, and geographical location.

1.2 Specific objectives

1. To select groups of countries based on their differences regarding productivity, labor market conditions, and geographical location.
2. To specify, estimate, and validate econometric models that describe the relationship between output growth and the variation of the unemployment rate.

3. To identify asymmetries in the relationship described by Okun's Law across different categories of countries.

1.3 Scope

The scope of this project is twofold: (i) to develop a methodological tool that allows empirical modeling of the asymmetries in the Okun's Law relationship, and (ii) to present specific empirical evidence on the asymmetry of Okun's Law in five groups of countries differentiated by productivity, labor markets, and geographical location. The project does not address the causal determination of the observed patterns between countries, the reasons behind the asymmetries among each group of countries, or the analysis of the measure of the estimated coefficients. The limitations of this project regard the availability and quality of data, the heterogeneity of countries in groups, and the impact of economic and structural changes during the studied period.

1.4 Theoretical Framework

The seminal work in the analysis of the correlation between economic growth and unemployment is the research conducted by Arthur Okun (1963). He found a negative relationship between unemployment and output in the period of 1947 to 1960 in the United States. Theoretically, as explained by Prachowny (1993), the Okun relationship may be obtained from a production function within an economy. In that sense, an important concept mentioned by Villaverde & Maza (2009) and Moosa (1997) is that Okun's law is a significant element in deriving the aggregate supply curve, together with the Phillips curve.

Okun's law is the effective lineal relation between output and unemployment. Nevertheless, empirically, the adjustment is not exactly one by one, and it is given by a coefficient. This coefficient provides an inexact adjustment that is less than one (Blanchard & Johnson, 2017, p228). Those results were developed by two models. One was worked by a "difference" model and the other was studied through a gap model (Arthur Okun, 1963).

Several authors support the empirical validity of the relationship and fund that Okun's coefficients vary for a lot of reasons. For example, seeing differences across countries, Villaverde & Maza (2009) and Moosa, (1997) obtained coefficients that can be explained in terms of differences in labor market rigidities and regional disparities in productivity growth. Adams & Coe (1989) and Knotek (2007) argued that there is no evidence to prove that Okun coefficients should be stable over time. The specification of the models is highly dependent on the existing economic conditions; hence, it is necessary to reassess the generalization of the initial model to provide a more comprehensive explanation of the

relationship between output and unemployment. Adding to this idea, Prachowny (1993) focuses on the relation that connects labor input as well as other factors of production to the output of goods and services.

In the case of Gordon & Clark (1984) and Knotek (2007), their studies focused on the limitations of the model. They explain how the results differ when the economy is in expansion compared to recession and mentioned that Okun's law should be analyzed separately due to the business cycle behavior. Thus, they review the asymmetrical way of Okun's law. Supported that, through autoregressive time series models, Harris & Silverstone (2001), Silvapulle et al. (2004), and Cuaresma (2003) explain that the differences in Okun's relationship could have not been gotten using a standard estimate with a symmetric approach.

To explain the dynamic of the business cycle in an asymmetrical form, Hamilton (1989) tested US output by a Markov Switching Regime Model. He found that the asymmetric model is better characterized by recurrent patterns than the linear one. Holmes & Silverstone (2006), Oliskevych & Lukianenko (2020), Belaire-Franch & Peiró (2015), Neftçi (1984), and others described the differences in the relationship between output and unemployment by stages. It means the authors present a regime modeling approach that separates business cycle analysis in expansion state and recession state. In the study of Okun's law with the Markov Switching Regime model, Cevik et al. (2013) show the asymmetrical behavior in the relationship between output and unemployment in a specific group of countries, which were comprised of nine transition economies. Also, that review includes the study of the mean durations of the states, which compares the asymmetries between the expansion and recession periods. That is supported by the idea of loss aversion of Kahneman et al. (2019): it is important not to ignore the responses to gains and losses in the models because of conductive bias, so capturing the asymmetries.

The remainder of this research work is organized as follows. Section 2 provides detail on the 'Data and Methodological approach' where data is presented and the used methodology from the different formulations of Okun's Law is described. Section 3 includes the 'Results, conclusions, and recommendations' where we see the resulting fit of the model, the conclusion from the analysis of the results, and the recommendations.

2 DATA AND METHODOLOGICAL APPROACH

2.1 Data

For investigating the asymmetrical relation between the variation of unemployment rate and output growth, we use real GDP growth and unemployment rates from 13 countries. The data is quarterly periodicity and is obtained from the OECD base. The variables we use are detailed in Section 2.2.1. Note that the original data sourced is already seasonally adjusted. We detail the periods of each country studied in Table 2.1 and present their Descriptive Statistics in Table 2.2.

Table 2.1. Country data information

Country	Start date	End date	Number of observations
Australia (AUS)	1966Q4	2019Q4	228
Chile (CHL)	1996Q2	2019Q4	110
Colombia (COL)	2007Q2	2019Q4	66
France (FRA)	1983Q2	2019Q4	162
Italy (ITA)	1983Q2	2019Q4	162
Japan (JPN)	1994Q2	2019Q4	118
Republic of Korea (KOR)	1990Q2	2019Q4	134
Lithuania (LTU)	1998Q3	2019Q4	101
Netherlands (NLD)	1988Q2	2019Q4	142
Slovakia (SVK)	1998Q2	2019Q4	102
Spain (SPN)	1995Q2	2019Q4	114
United Kingdom (GBR)	1983Q2	2019Q4	162
United States (USA)	1955Q2	2019Q4	274

Note: The data was obtained from the OECD Data Base.

2.2 Methodological Approach

The methodological approach includes two steps: (i) the description of the model specification and the description of the variables we use and (ii) the explanation of the complement methodology that supports our analysis of nonlinearity and differences between groups of countries. This subsection presents both steps as a whole.

Table 2.1. Descriptive statistics

	Unemployment Rate			Growth Real GDP		
Country	**count**	**mean**	**std**	**count**	**mean**	**std**
Australia (AUS)	213	0,016	0,310	213	0,816	0,971
Chile (CHL)	95	0,008	0,535	95	0,894	1,110
Colombia (COL)	51	-0,024	0,400	51	0,864	0,764
France (FRA)	147	0,001	0,229	147	0,448	0,493
Italy (ITA)	147	0,018	0,262	147	0,294	0,699
Japan (JPN)	103	-0,006	0,147	103	0,194	0,991
Republic of Korea (KOR)	119	0,009	0,376	119	1,241	1,285
Lithuania (LTU)	86	-0,081	0,839	86	0,958	1,849
Netherlands (NLD)	127	-0,024	0,258	127	0,549	0,651
Slovakia (SVK)	87	-0,074	0,575	87	0,894	1,787
Spain (SPN)	99	-0,074	0,647	99	0,532	0,650
United Kingdom (GBR)	147	-0,047	0,246	147	0,556	0,625
United States (USA)	259	-0,004	0,347	259	0,754	0,855

Note: Statistics calculated by the author using data obtained from the OECD Data Base

Model specification and estimation strategy

The selection of countries in this study is based on various factors that, according to Okun's Law (see Section 1.4), determine differences in production and employment. These factors include geographical location, population, and data availability in the OECD database. To observe the asymmetry in the relationship between output and unemployment, we selected countries from diverse continents, varying production levels and keeping differences in structural labor markets.

Now, as we see in the literature review section (Section 1.4), Artur Okun showed how is the labor market dynamic. In their study, he determined the negative relation between unemployment and production levels in the United States economy. He employed two specifications to establish his relationship. The first specification (S1) analyses the changes over time using the differences in UR and real GDP. The second specification (S2) used was the gap technique, which was the difference between the real values to the potential values of UR and real GDP (Okun, 1963). The gap model is the most common specification in academic literature about Okun's Law. However, empirical studies show that estimating Okun coefficients is challenging due to their sensibility to detrending techniques. For that

reason, there is no unique method of determining cyclical unemployment and output (Cevik et al., 2013). To avoid these complexities, we analyze Okun's Law with S1 and use the "difference" model presented by Knotek (2007) as follows:

$$\Delta UR_t = \alpha + \beta \Delta y_t + \varepsilon_t$$

Equation 2.1. Okun's Law approach

where ΔUR_t is the change in the unemployment rate and Δy_t is the real output growth, both over time. α is the intercept, β is the Okun coefficient, and ε_t is the white noise disturbance term $(0, \sigma^2)$.

We prepared the data of the selected countries to the variables we needed. Then, the use of original real GDP growth is interpreted as the changes in output data. Later, we calculate the differences in the unemployment rate. The model specification is detailed in Table 2.3 as well as the description of the variables through data.

Table 2.3. Variable descriptions

Variable	Description	Temporality	Expected effects	Source
Unemployment Rate (UR)	Continuous variable measured as the ratio between the unemployed population and the labor force as a percentage. Seasonally adjusted. $UR = \frac{Unemployed}{Labor\ Force}$	Quarterly		OCDE downloaded at May 14, 2024
UR Differences (ΔUR)	Continuous variable measured as the difference between the corresponding UR of the current date minus the UR of the previous date. (in percentage) $\Delta UR = UR_t - UR_{t-1}$	Quarterly		OCDE downloaded at May 14, 2024
Real GDP growth (Δy_t)	Continuous variable measured as the percentage change from the previous quarter of the real GDP. Seasonally adjusted. $\Delta y_t = \frac{GDP_t - GDP_{t-1}}{GDP_{t-1}}$	Quarterly	Following the theoretical Okun's Law, we expected that an increase in real GDP growth (above the growth of the labor force and labor productivity) will be associated with a decrease in the unemployment rate over time.	OCDE downloaded at May 14, 2024

Note: Variables are seasonally adjusted.

Now, we consider the specification proposed by Moosa (1997) which includes unemployment change lags. This adjustment is useful to remove serial correlation and it can be represented in Equation 2.1 as the following adaptation:

$$\Delta UR_t = \alpha + \beta \Delta y_t + \sum_{i=1}^{k} \rho_i \, \Delta UR_{t-1} + \varepsilon_t$$

Equation 2.2. Okun's Law approach with ΔUR lags

In this updated specification, ρ_k are the coefficients of the lags and k is determined by analyzing the values of the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) (Cevik et al., 2013).

Considering the earlier literature which supports analyzing data in stages (Hamilton, 1989), we proceed to reformulate our model to a nonlinearity approach. We applied in Equation 2.2 a two-state Markov regime-switching. From that inclusion we have:

$$\Delta UR_t = \alpha(s_t) + \beta(s_t)\Delta y_t + \sum_{i=1}^{k} \rho_i \, (s_t)\Delta UR_{t-1} + \varepsilon_t$$

Equation 2.3. Okun's Law approach with Δu lags and states

In Equation 2.3., s_t is the unobserved regime parameter. In the same way as Hamilton (1989), Holmes & Silverstone (2006), Oliskevych & Lukianenko (2020), and others, we worked with $s_t = 0$ as the first state and $s_t = 1$ as the second state. As mentioned by Cevik et al. (2013), we have an important issue with the identification of regimes. Previews cited studies of Okun's Law identify regimes as expansion and contraction in the economy. Following Holmes & Silverstone (2006) terminology, we use the recessionary and expansionary to describe those different stages. The 2008 crisis is used as a guide for confirming the selection of recessionary stages.

The unobserved state variable, s_t, follows the dynamic of a first-order Markov-switching process (Holmes & Silverstone, 2006). In that sense, we have:

$$P[s_t = 0 \,|s_{t-1} = 0\,] = p_{00}$$
$$P[s_t = 0 \,|s_{t-1} = 1\,] = 1 - p_{00}$$
$$P[s_t = 1 \,|s_{t-1} = 1\,] = p_{11}$$
$$P[s_t = 1 \,|s_{t-1} = 0\,] = 1 - p_{11}$$
$$0 < p_{00} < 1 \quad , \quad 0 < p_{11} < 1$$

Equation 2.4. Transition probabilities.

where p_{ij} represents the transition probabilities of being in an expansion or recession regime, respectively. Additionally, the calculation of the mean duration of staying in an expansion or recession regime, d, can be computed using $d = 1/(1 - p_{ij})$.

Equation 2.3 is estimated through the maximum likelihood method based on the Expectation-Maximization (EM) algorithm reviewed by Hamilton (1989) and (Belaire-Franch & Peiró, 2015) consisting of an iterative technique to obtain the parameters α, β, ρ_k and the transition probabilities p_{00}, p_{11} in each state. We run all our models using the `statsmodels` packages on Python. Also, Hamilton (1989) proves that the use of the EM algorithm filters allows us to estimate the smoothed probabilities of the respective states s_t and observe how both states can change over time. This is also confirmed by Cevik et al. (2013)'s empirical exercise.

Methodological complement

To complement our analysis of the asymmetry in Okun's law across different countries, we review extra methodological aspects.

Initially, we review the Augmented Dickey-Fuller (ADF) test. This is a statistical technique used to determine if a time series is stationary. This test works with the basic Dickey-Fuller test with the particularity that ADF adds lagged terms of the dependent variable and improves robustness. The rejection rule in the ADF test is that we have a unit root when do not reject the null hypothesis (Wooldridge, 2013). The results of these tests are detailed in Appendix I.

To align with our research objective, it is essential to verify the asymmetry of the relation between unemployment and output changes. We use the Likelihood Ratio (LR) test to prove if a linear model is better than a Markov regime-switching model. Following Cevik et al. (2013) testing, we defined the null hypothesis for the LR test as the absence of nonlinearity, while the alternative hypothesis is defined as the presence of the Markov regime-switching approach. We run these tests with the `statsmodels` packages on Python considering the degrees of freedom as the number of restrictions. We would have a problem when we compared regime-switching models with linear models because LR statistic does not follow well the standard $\mathcal{X}^2$ distribution as usual. For that reason, we add the upper bound p-values to help us to test twice the nonlinearity of our models (Davies, 1987). The results of these tests are detailed in Appendix II.

As a post-estimation strategy, we examine the residuals: with the Jarque-Bera test where the null hypothesis is the presence of normality, with the Breush-Godfrey test where the null

hypothesis is the no presence of serial correlation, with the Breush-Pagan test where the null hypothesis is the presence of homoscedasticity (Cevik et al., 2013). The results of these tests are detailed in Tables from 3.2 to 3.6 (in Section 3).

Finally, to analyze countries with similar structures, we use Principal Component Analysis (PCA) and K-means clustering. PCA is used to correlate the information and K-means is used to visualize the resulting country groups (Johnson & Wichern, 2007).

3 RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

3.1 Results

For identifying one or more subgroups of countries from the list detailed in Table 2.1, we apply the PCA method based on our interest variables (GDP and UR) and by incorporating labor market and productivity information which is detailed in Appendix III. Moreover, we use K-means to plot the clusters that are represented in Figures 3.1 and 3.2.

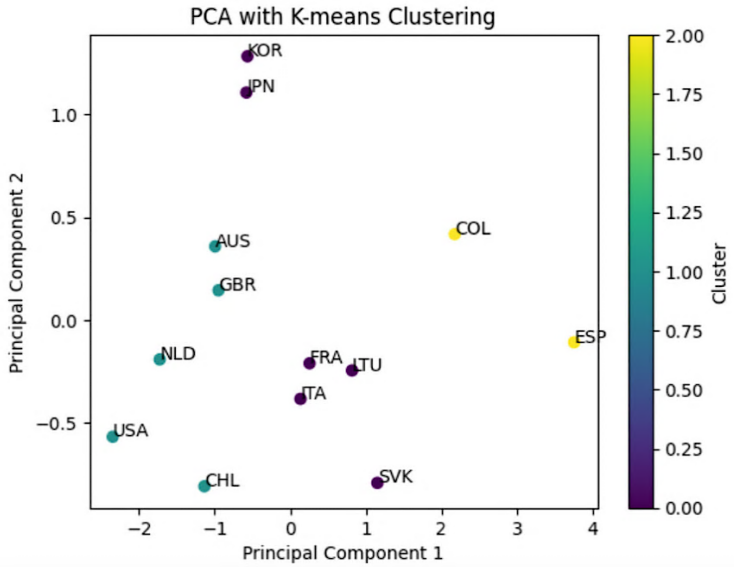

Figure 3.1. – Countries clustering made by K-means and PCA analyzing GDP per capita, productivity, and unemployment rate mean.

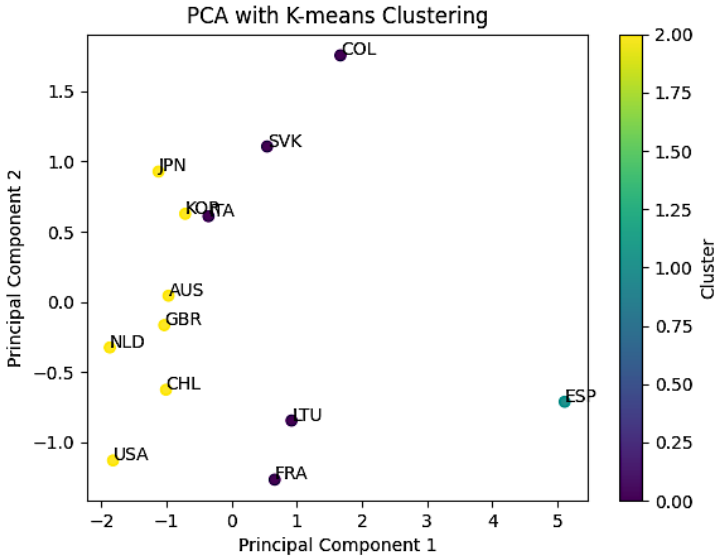

Figure 3.2. – Countries clustering made by K-means and PCA analyzing GDP per capita, productivity, unemployment rate mean, expansionary coefficients, and recessionary coefficients.

Figures 3.1 and 3.2 show a concentration of countries by productivity and geographical location, as in the case of European countries. Clusters are very similar in both plots, so we define the groups as follows in Table 3.1.

Table 3.1. Countries groups descriptions

Group	Countries	Common characteristics
1	Australia United States Chile	High level of productivity Do not be part of European and Asian countries
2	Netherland United Kingdom	European countries with high productivity Low level of the unemployment rate
3	Republic of Korea Japan	Asian countries with high productivity
4	France Italy Lituania Slovakia	European countries with low productivity High level of unemployment rate
5	España Colombia	Countries with different labor market conditions than the other OECD countries. High unemployment

Note: This clustering is an ex-ante proposal made by the author with the common characteristic criteria.

As detailed in Appendix II, using the LR test, we find that the Markov switching approach (Equation 3) is better than a linear model in all countries in their data availability (see Table 2.2). Thus, given our objective to verify the nonlinear relation between output and unemployment, these results help us to verify an asymmetry behavior in Okun's Law relation. Now, we present the results of Equation 2.3's estimation, in Tables from 3.2 to 3.6. These are separated by groups where we can see both states (expansion and recession). We focus on analyzing β which is the coefficient that represents the negative Okun's Law relation in each state.

Table 3.2. Estimated results Group 1

	Regime 0: Expansion		**Regime 1: Recession**		**Regime 0: Expansion**		**Regime 1: Recession**	
	USA				**AUS**			
α	0.044*	(0.023)	0.284***	(0.000)	0.0003	(0.023)	0.757***	(0.074)
β	-0.104***	(0.021)	-0.329***	(0.000)	-0.053***	(0.018)	-0.232***	(0.048)
ρ_1	0.257***	(0.062)	0.701***	(0.097)				
ρ_2	0.259***	(0.074)	-0.192**	(0.071)				
ρ_3	-0.046***	(0.064)	-0.075	(0.089)				
p_{ij}	0.795		0.550		0.969		0.652	
d	4.890		2.219		32.272		2.874	
$Norm$	2.167	p=0.338			1.876	p=0.391		
$Auto$	1.998	p=0.368			4.542	p=0.103		
$IHete$	9.480	p=0.049			0.742	p=0.388		
	CHL							
α	0.028	(0.069)	0.954***	(0.169)				
β	-0.140***	(0.048)	-0.202**	(0.092)				
p_{ij}	0.938		0.526					
d	16.326		2.111					
$Norm$	3.019	p=0.220						
$Auto$	3.948	p=0.138						
$Hete$	0.508	p=0.475						

Note: *, **, and *** mean rejection of the null hypothesis at 10%, 5%, and 1% respectively. Values in parentheses represent the standard error of the coefficients. All the estimations have a variance with a 1% level of significance. $Norm$ represents the Jarque Bera normality test, $Auto$ represents the Breusch-Godfrey LM autocorrelation test, and $Hete$ represents Breusch-Pagan heteroscedasticity test of the residuals. p represents the p-value.

Table 3.2 details estimations regarding the first subgrouping: the United States, Australia, and Chile, which includes countries characterized by high productivity. Results reveal that, for both states (recession and expansion), the estimated β coefficients are statistically different from zero. Specifically, during an expansion state, production increases and

unemployment decreases. On the other hand, during a recession state, production decreases, and unemployment increases. Additionally, for the three countries, the mean duration (d) of the expansionary state is longer than the mean duration of the recession state. This might reflect a higher response from agents to periods of economic deterioration, indeed, as asserted by Kahneman et al. (2019), agents are loss-averse: they do not like to lose. Because of this cognitive bias, asymmetry was expected.

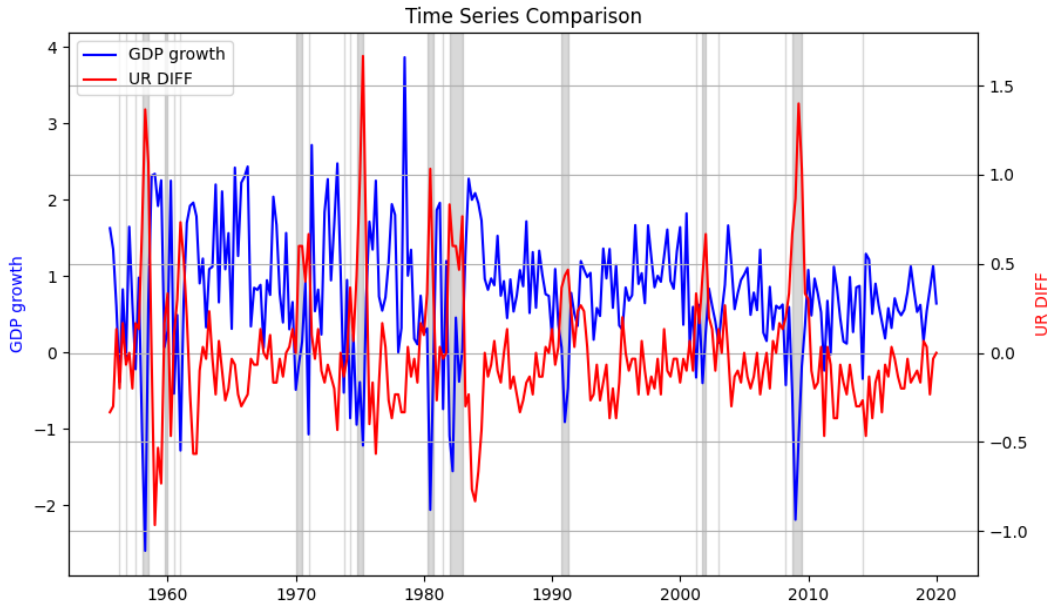

Figure 3.3. USA GDP growth versus changes in time of USA UR ($\Delta UR = UR_t - UR_{t-1}$), recession states in shadows.

Thus, we can see an asymmetry behavior in Figure 3.3 with the United States data. Shadows in Figure 3.3 represent recession states. Here, we have a clear representation of Okun's Law in both states. While the blue line is above, the red line is below, and vice versa. Also, smoothed probabilities support this asymmetry analysis (see Appendix VI).

Table 3.3. Estimated results Group 2

	Regime 0: Expansion		Regime 1: Recession		Regime 0: Expansion		Regime 1: Recession	
	NLD				GBR			
α	-0.029	(0.042)	0.078**	(0.035)	-0.031	(0.020)	0.232***	(0.032)
β	-0.075**	(0.038)	-0.079**	(0.039)	-0.147***	(0.025)	-0.122***	(0.037)
ρ_1	0.344***	(0.131)	0.955***	(0.096)	0.356***	(0.071)	0.5875***	(0.137)
ρ_2					0.123**	(0.062)	0.3633**	(0.151)
p_{ij}	0.386		0.614		0.518		0.1376	
d	1.628		2.591		2.078		1.159	
$Norm$	2032.709	p=0.000			3.820	p=0.148		
$Auto$	2.146	p=0.341			1.659	p=0.436		
$Hete$	1.359	p=0.506			6.783	p=0.079		

Note: *, **, and *** mean rejection of the null hypothesis at 10%, 5%, and 1% respectively. Values in parentheses represent the standard error of the coefficients. All the estimations have a variance with a 1% level of significance. $Norm$ represents the Jarque Bera normality test, $Auto$ represents the Breusch-Godfrey LM autocorrelation test, and $Hete$ represents Breusch-Pagan heteroscedasticity test of the residuals. p represents the p-value.

Table 3.3 presents another subgrouping: European countries with high productivity and low levels of UR. The β coefficients for these countries are highly statistically significant and asymmetric as we test. However, the difference between each state is smaller compared with Group 1 (see Table 3.2). This suggests that there is an asymmetric Okun's Law relation in these European countries, but it is less pronounced than in others. The mean duration (d) of both states is short in the two countries. In the Netherlands, the recession state is longer than the expansion state. Nevertheless, we must be cautious with the Netherlands results due to their Normality test failed.

As shown in Table 3.4, Korea and Japan, which are part of Asia, share similar levels of productivity and unemployment rates. For this reason, we sub-grouped these countries. Our analysis suggests that Okun's Law relation is present only in recession states, as the expansionary states do not exhibit statistically significant coefficients. Thus, we see that Korea and Japan have asymmetrical behavior. While Okun's Law is evidenced in a recession state, we do not have evidence to prove this relation in an expansionary state.

Table 3.4. Estimated results Group 3

	Regime 0: Expansion		Regime 1: Recession		Regime 0: Expansion		Regime 1: Recession	
	KOR				JPN			
α	0.019	(0.031)	0.370***	(0.065)	-0.082***	(0.017)	0.052*	(0.026)
β	-0.028	(0.019)	-0.207***	(0.024)	0.017	(0.016)	-0.048***	(0.016)
ρ_1	-0.153	(0.088)	0.737***	(0.063)	-0.175	(0.108)	0.794***	(0.182)
ρ_2	0.188	(0.093)	-0.264***	(0.094)	-0.036	(0.091)	-0.195	(0.207)
p_{ij}	0.933		0.578		0.935		0.851	
d	89.314		13.467		15.477		6.735	
$Norm$	4.816	p=0.089			0.821	p=0.663		
$Auto$	7.037	p=0.029			1.266	p=0.530		
$Hete$	4.479	p=0.214			1.565	p=0.667		

Note: *, **, and *** mean rejection of the null hypothesis at 10%, 5%, and 1% respectively. Values in parentheses represent the standard error of the coefficients. All the estimations have a variance with a 1% level of significance. $Norm$ represents the Jarque Bera normality test, $Auto$ represents the Breusch-Godfrey LM autocorrelation test, and $Hete$ represents Breusch-Pagan heteroscedasticity test of the residuals. p represents the p-value. Consider that Korea has Autocorrelation, and their results should be analyzed with caution.

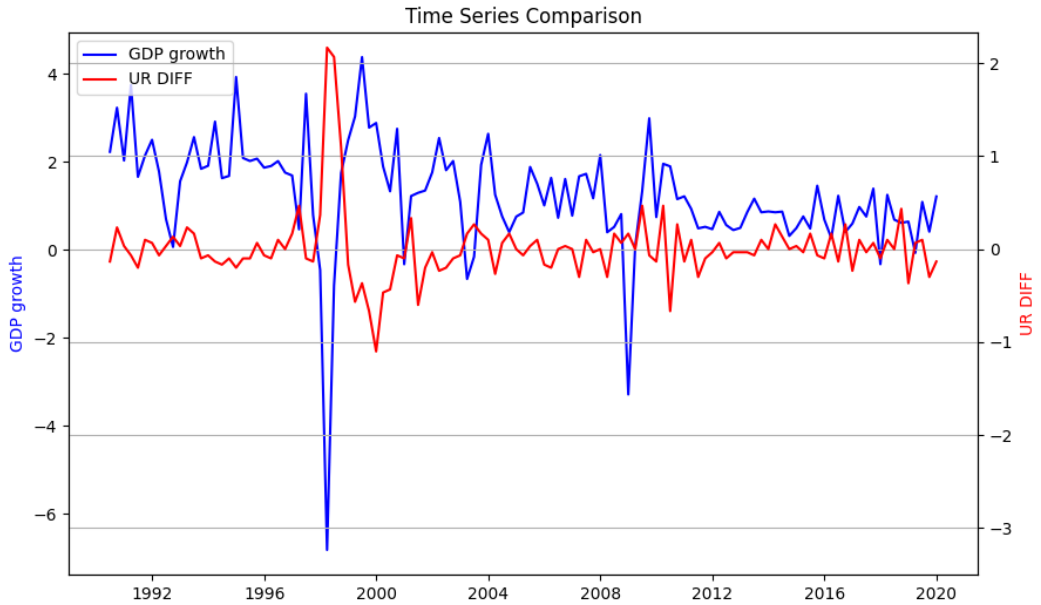

Figure 3.4. Korea GDP growth versus changes in time of Korea UR ($\Delta UR = UR_t - UR_{t-1}$).

We can see Korean series illustrated in Figure 3.4. Since 2005, GDP growth has been positive in most periods, while unemployment rates present a high variability around zero (taking positive and negative values). So, Okun's Law relation is not clearly presented, this might be attributed to Korean labor market conditions, but this assertion needs another study which is out of the scope of this work. As in the Group 1 analysis, these countries' mean durations (d) of states are longer in expansion states than in recession states.

Table 3.5. Estimated results Group 4

	Regime 0: Expansion		Regime 1: Recession		Regime 0: Expansion		Regime 1: Recession	
	FRA				ITA			
α	-0.232	(0.043)	0.078***	(0.029)	-0.103***	(0.033)	0.207***	(0.040)
β	-0.016	(0.065)	-0.146***	(0.037)	-0.024	(0.054)	-0.079**	(0.032)
ρ_1	-0.577***	(0.178)	0.548***	(0.065)				
p_{ij}	0.892		0.963		0.957		0.945	
d	9.223		44.182		23.458		18.232	
$Norm$	0.876	p=0.645			5.353	p=0.068		
$Auto$	0.817	p=0.664			0.441	p=0.801		
$Hete$	4.199	p=0.122			0.472	p=0.491		
	LTU				SVK			
α	0.615***	(0.126)	-0.036	(0.077)	-0.245**	(0.104)	0.124***	(0.043)
β	-0.552***	(0.088)	-0.057*	(0.032)	0.049	(0.045)	-0.140***	(0.021)
ρ_1	0.554***	(0.127)	0.156	(0.130)	0.113	(0.132)	0.848***	(0.070)
ρ_2	-0.096	(0.112)	0.568***	(0.131)				
ρ_3	-0.158	(0.158)	0.441***	(0.108)				
ρ_4	0.188	(0.116)	-0.554***	(0.118)				
p_{ij}	0.233		0.397		0,000		0.695	
d	1.304		1.66		1.000		3.275	
$Norm$	0.817	p=0.664			0.223	p=0.894		
$Auto$	0.363	p=0.834			0.781	p=0.676		
$Hete$	2.355	p=0.798			0.330	p=0.565		

Note: *, **, and *** mean rejection of the null hypothesis at 10%, 5%, and 1% respectively. Values in parentheses represent the standard error of the coefficients. All the estimations have a variance with a 1% level of significance. $Norm$ represents the Jarque Bera normality test, $Auto$ represents the Breusch-Godfrey LM autocorrelation test, and $Hete$ represents Breusch-Pagan heteroscedasticity test of the residuals. p represents the p-value.

Group 4 results are presented in Table 3.5. This group is characterized by low productivity and high level of unemployment rates. Also, the geographical location of these countries is concentrated in Europe. France, Italy, and Slovakia show statistically significant β coefficients only in the recession state, similar to Group 3. Lithuania is the only country in this group where the β coefficients are statistically different from zero both in the recession and expansion states.

Note that the mean durations (d) in the recession state are longer than in the expansion state, except in Italy, which contrasts Group 1's results with Group 3's results. This is possible to be related to productivity differences between countries in each group. For Slovakia, the probability of passing to the expansion state is near zero. Consequently,

based on the available data, we find that Slovakia seems to be in a continuous recession state. This assertion is better described by Slovakia´s smoothed probabilities which are graphed in Appendix VI. On many occasions, the recession state seems to change to an expansion state, but this pattern change is not statistically proven.

Thus, we found that Group 3 is more heterogeneous than other ones. Despite this, there is a relationship between output and unemployment in a recession state that is more probable and durable than in an expansion state, supporting the presence of asymmetry.

Table 3.6. Estimated results Group 5

	Regime 0: Expansion		Regime 1: Recession		Regime 0: Expansion		Regime 1: Recession	
	ESP				COL			
α	0.067	(0.043)	0.686***	(0.064)	0.128	(0.087)	0.053	(0.090)
β	-0.626***	(0.129)	-0.817***	(0.069)	0.049	(0.090)	-0.275***	(0.068)
ρ_1	0.467***	(0.131)	0.171*	(0.089)	0.081	(0.121)	-1.204***	(0.190)
ρ_2	-0.221*	(0.115)	-0.085	(0.068)				
p_{ij}	0.9118		0.8739		0.3034		0.2692	
d	11.338		7.928		1.435		1.368	
$Norm$	1.038	p=0.595			2.274	p=0.320		
$Auto$	2.626	p=0.268			3.570	p=0.167		
$Hete$	0.554	p=0.906			0.354	p=0.837		

Note: *, **, and *** mean rejection of the null hypothesis at 10%, 5%, and 1% respectively. Values in parentheses represent the standard error of the coefficients. All the estimations have a variance with a 1% level of significance. $Norm$ represents the Jarque Bera normality test, $Auto$ represents the Breusch-Godfrey LM autocorrelation test, and $Hete$ represents Breusch-Pagan heteroscedasticity test of the residuals. p represents the p-value.

Finally, Spain and Colombia's results merit a special analysis: these two economies have several structural differences but are still grouped. Spain has statistically significant β coefficients, nevertheless, their values are higher compared with other countries. Their behavior seems volatile, representing that a minimum change in output implies a considerable variation in unemployment. Even so, it is clear to see the presence of asymmetry in Okun's Law relation between expansion and recession state.

In the case of Colombia, it is difficult to establish conclusions because this country is considered to have important rates of informal employment and underemployment (García, 2019), so Equation 2.3 is not good enough to capture some form of asymmetric behavior between output and unemployment in this case.

3.2 Conclusions

This research explores the relationship between output growth and the variation in the unemployment rate. Considering the dynamic of macroeconomic data, it is worthwhile to analyze the asymmetry behavior of Okun's Law over the business cycles. Okun's Law has been widely studied. Nevertheless, this Law is generally studied as an asymmetric relation. In this research, the asymmetric behavior of this Law is explored. Specifically, we examine this asymmetry relation using a modeling strategy based on Markov Switching Regime models and, we include a regional analysis by clustering five groups of countries based on production levels, labor market conditions, and geographical location.

The main results are threefold: (i) a Markov switching regime approach is more effective than a linear approach in capturing Okun's Law behavior in the countries we analyzed; (ii) clustering analysis supports the idea of different types of asymmetries depending on the group and characteristics of countries regarding production levels, labor market conditions, and geographical location; and (iii) the mean duration analysis is useful to understand the asymmetry between expansion and recession stages which depend on the country group.

3.3 Recommendations

Based on the discussion of the results, our findings allow us to suggest the necessity of expanding the cluster analysis by exploring the reasons behind the asymmetries among each group of countries. It might be interesting, for instance, to investigate whether or not any generalization is feasible based on characteristics like productivity, labor market conditions, or geographical location. Moreover, it might be recommendable to focus on examining the country's productivity and the mean durations of its business cycles. This may lead to a study on whether there are incentives for firms to adopt different investment strategies depending on the economic conditions of each state. Finally, we suggest considering these findings about asymmetries in business cycles when planning international negotiations between country groups. Indeed, identifying asymmetry dynamics in the economy can enhance relations between countries with similar business cycle durations but differing capital and labor intensities, to establish migration politics or foreign investments.

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5 APPENDIX

APPENDIX I

p-values ADF test

Country	ΔUR	Δy
Australia	0,000	0,000
Chile	0,000	0,000
Colombia	0,200	0,003
France	0,000	0,000
Italy	0,003	0,000
Japan	0,485	0,000
Republic of Korea	0,000	0,000
Lithuania	0,015	0,001
Netherlands	0,009	0,000
Slovak	0,019	0,002
Spain	0,012	0,029
United Kingdom	0,001	0,008
United State	0,000	0,000

Note: Null hypothesis is detailed as the presence of unit root. We see that Colombia and Japan's time series are not stationary over time, so we need careful consideration of their results.

APPENDIX II

p-values LR and Upper bound tests

Country	LR test	Upper bound test
Australia	0,000	0,000
Chile	0,000	0,000
Colombia	0,000	0,000
France	0,000	0,000
Italy	0,000	0,000
Japan	0,000	0,000
Republic of Korea	0,000	0,000
Lithuania	0,000	0,000
Netherlands	0,000	0,000
Slovak	0,000	0,000
Spain	0,000	0,000
United Kingdom	0,000	0,000
United State	0,000	0,000

Note: The Null hypothesis for both the LR test and Upper bound test is that a Linear approach is better than a Markov Switching approach.

APPENDIX III

Variable	Description	Source
GDP per capita	Value measured as GDP in US dollars per person in 2023, PPP converted, and constant prices of 2015.	OCDE downloaded at May 14, 2024
Productivity	Value measured as GDP in US dollars per hour in 2022, PPP converted, and constant prices of 2015.	OCDE downloaded at May 14, 2024
Unemployment rates mean (last 100 quarterlies)	Value measured as the mean of the ratio between the unemployed population and the labor force as a percentage for the last 100 quarterlies (except for Colombia).	OCDE downloaded at May 14, 2024
Expansionary coefficients	Estimated coefficient from Equation 3 in the expansionary state.	
Recessionary coefficients	Estimated coefficient from Equation 3 in the recessionary state.	

Note: The data was obtained from the OECD Data Base. Figure 3.1 is made by GDP per capita, productivity, and unemployment rate mean. Figure 3.2 is made by