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EMPIRICAL EVIDENCE ON THE RELATIONSHIP BETWEEN UNEMPLOYMENT AND ECONOMIC GROWTH IN CROATIA

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Abstract: *Okun's law is a valuable tool for understanding the relationship between economic growth and employment, but it should be adapted to the specific characteristics of the observed economy, including demographics, structural reforms, and the broader economic environment. The primary aim of this paper is to examine the relationship between unemployment and economic growth in Croatia. The analysis is based on quarterly time series data spanning from 2000Q1 to 2024Q4 and employs a range of analytical models, including first-difference and gap specifications, nonlinear autoregressive distributed lag (NARDL) models, and the Granger causality model, in order to capture the underlying complexity of the growth-unemployment nexus. Ultimately, the findings confirm that Okun's law remains a useful empirical tool, especially when applied as a gap model and during stable economic periods. However, its explanatory power weakens during times of economic turbulence, highlighting the need for flexible models capable of accommodating nonlinearities and structural breaks.*

***Keywords*:** *unemployment, Croatia, Okun law.*

JEL Classification: *F43*

INTRODUCTION

The relationship between economic growth and unemployment has been at the center of economic research for decades. Unemployment negatively affects economic growth, public finance and standard of living (Šimčević, 2025). Croatia had significant milestones in the past decade, including successful entry into the European Union (EU) and the adoption of the euro, reflecting notable advancements in both the economy and society. Between 2012 and 2022, income *per capita* rose by over 40 percent, while labor force participation also increased, reaching nearly 70 percent by 2022 (Bartolini, 2024). However, looking ahead, emerging labor shortages may pose a challenge to sustaining economic growth. Another challenge is the expected rise of the unemployment rate which is projected to reach 4.6% in 2025 and 4.5% in 2026 as employment is set to decelerate in the future period (European Commission, 2025), Similarly, after having accelerated to 3.8% in 2024, Croatia's real gross domestic product (GDP) growth is projected to slow to around 3.0% on average in 2025 and 2026 (HNB, 2025).

Okun's law is a useful tool for understanding the relationship between economic growth and employment, but it needs to be adapted to the specificities of the Croatian economy, including demographics, structural reforms and the EU environment. The law is typically expressed in two forms: the "difference model" and the "gap model", each offering a different way of relating changes in the unemployment rate to changes in real GDP. In the difference version, the causality is primarily assumed to go from economic growth to changes in unemployment, with economic growth leading to higher labour demand and lower unemployment, and *vice versa.* In the gap version of Okun's law, the causal link typically runs from economic growth to unemployment, as positive output gaps lead to lower unemployment and negative output gaps lead to higher unemployment.

The main aim of the paper is to explore the relationship between unemployment and economic growth in Croatia by using the Okun law. Scientific contribution of the paper is in employing a diverse and rigorous econometric framework. The integrated approach, which combines linear, nonlinear, and time-varying analyses, sets a precedent for the empirical modelling of macroeconomic relationships and contributes to the design of responsive and resilient economic policies. The overarching objective of this study was to examine how variations in economic output correlate with changes in unemployment, and whether this relationship exhibits asymmetry, temporal instability, or is susceptible to disruption by structural economic shocks. First-difference models were employed to analyze short-term fluctuations by differencing the time series, thereby addressing the issue of nonstationarity. In contrast, the gap models employed Hodrick-Prescott filtered data to isolate cyclical components, enabling a more nuanced investigation of deviations from potential output and natural unemployment levels. Furthermore, the nonlinear autoregressive distributed lag (NARDL) approach was utilized to explore potential asymmetries in the relationship, particularly focusing on whether unemployment responds differently to positive and negative output shocks in both the short and long term. The research also used the Bai-Perron structural break methodology and finally, static and time varying Granger causality tests to get insight into the dynamic relationship between economic growth and unemployment, as well as between the output gap and unemployment gap.

The structure of the paper is as follows. After the introduction follows the literature review regarding empirical studies testing the Okun law. Then, methodology and data used are described after which results are explained. Th paper ends with the conclusion.

LITERATURE REVIEW

Recent empirical studies employing quarterly data provide a nuanced understanding of the output–unemployment relationship as conceptualized in Okun's law, particularly emphasizing the importance of asymmetry and regional variation.

(Singh, Nurudeen, 2022) used the OLS estimator to test Okun's law, and also the generalized method of moments (GMM) estimator, incorporating the first lag of both unemployment and GDP as instrumental variables. They proved the validity of the Law. Similarly, (Soylu, Çakmak, Okur, 2018) examine the applicability of Okun's law in eight Eastern European countries over the period from 1992 to 2014, using a panel data framework. The study results show that a 1% increase in GDP leads to a 0.08% decrease in the unemployment rate.

In Serbia, (Mihajlović, 2021) applies both linear ARDL and nonlinear ARDL models using quarterly data from 2008 to 2019. The results affirm the existence of a significant long-run cointegration between GDP and unemployment and uncover pronounced asymmetries - output contractions have a stronger and more persistent impact on job losses than expansions do on job gains. These findings support asymmetric policy interventions. Similarly, (Sere and Tchereni, 2020) utilize a NARDL model with South African data from 1994 to 2019 and report strong evidence of asymmetry. They find that negative GDP shocks significantly increase unemployment, whereas positive growth has a weaker employment effect, confirming the presence of labour market rigidities and the necessity for targeted reforms.

South African studies further validate these insights but underscore regional differences (Stungwa and Siphuxolo, 2022), using the ARDL bounds testing method over the period 2000–2020, confirm Okun's law in both the short and long run but highlight that the coefficient estimates are relatively modest. This suggests that growth alone cannot sufficiently reduce unemployment without structural reforms. At the subnational level, (Omoshoro-Jones, 2021) focuses on the Free State Province and employs a NARDL model on cyclical data from 2008 to 2019. The results again point to a clear asymmetry, with unemployment rising faster in recessions than it falls during expansions. The evidence lends empirical support to "labour hoarding" u and the "loss aversion" hypothesis, strengthening the case for asymmetric modelling.

In Chile, (Navarro, 2023) also adopts the NARDL framework and examines quarterly data from 1996 to 2019. The study identifies both long-run and short-run asymmetries, revealing that unemployment reacts more severely to negative than to positive output shocks. This suggests that labour markets in Latin American economies with structural dualities may exhibit similar dynamics to their African counterparts.

Collectively, these studies demonstrate that Okun's law holds under asymmetric conditions across diverse political and economic systems, be it the emerging democracy of Serbia, the upper-middle-income economy of South Africa, or the export-oriented market economy of Chile. While traditional linear models confirm the presence of a negative relationship, the NARDL approach consistently reveals deeper insights into the asymmetric behavior of unemployment in response to economic fluctuations.

METHODOLOGY AND DATA

Data description

Quarterly data for the real gross domestic product *per capita* (GDP) and unemployment rates (UR) in Croatia are available since 2000Q1 until 2024Q4 (GDP *per capita*) and from 2002Q1 until 2024Q4 for unemployment rates. The sample consists of 92 quarterly data points. Variable acronyms and data sources are given in Table 1.

Table 1. Variables definition

Variable	Description	Source
GDP	Gross domestic product	Eurostat
LGDP	Natural logarithm of GDP	Eurostat
DLGDP	The first difference of the LGDP series.	Eurostat
UR	Unemployed persons aged 15 to 74 years	Eurostat
DUR	The first difference of the UR series	Eurostat

Source: authors

Description of the methodology

Okun's law is not a strict, deterministic rule, but rather an approximation that varies by country, time, and specific economic conditions. The relationship also depends on structural factors in the economy, including productivity levels, labour force participation, technological change, and the degree of labour market flexibility. While Okun's law is primarily observed as a short-term empirical correlation, it plays an essential role in understanding how fluctuations in the labour market might influence economic activity and vice versa.

According to the first-difference model, the relationship between the natural logarithm of output (GDP) and the unemployment rate (UR) is analysed within the framework of the following function:

$$UR_t - UR_{t-1} = \alpha + \beta(GDP_t - GDP_{t-1}) + \varepsilon_t \quad (1)$$

where GDP_t is the natural logarithm of the real GDP in quarter $t = 1,2, \ldots ,T$, UR_t is the unemployment rate, α indicates the long-term unemployment rate resulting from structural characteristics of the labour markets, Okun's coefficient β represents the elasticity of the unemployment rate about output and ε_t is a white-noise disturbance term. However, as with the gap version of Okun's law, there is an alternative possibility: unemployment may affect economic growth. From a supply-side perspective, high levels of unemployment represent unused labour capacity, which can hinder potential output.

According to this version of the first-difference model, the relationship between the natural logarithm of output (GDP) and the unemployment rate (UR) is analysed within the framework of the following function:

$$GDP_t - GDP_{t-1} = \alpha + \beta(UR_t - UR_{t-1}) + \varepsilon_t \quad (2)$$

where GDP_t is the natural logarithm of the real GDP in quarter $t = 1,2, \ldots ,T$, UR_t is the unemployment rate and ε_t is a white-noise disturbance term.

In terms of Okun's law, economic growth and changes in employment are tightly linked because both are driven by aggregate demand. When economic activity picks up, firms increase their output in response to growing demand, which requires more labour. This positive relationship between output and labour demand leads to lower unemployment. As such, economic growth is considered the main driver of employment changes in this model. Standard version of Okun's law is a gap equation which is given by:

$$UR_t - UR_t^* = \beta(GDP_t - GDP_t^*) + \varepsilon_t, \; t = 1,2, \dots, T \quad (3)$$

where GDP_t is a natural logarithm of the real GDP in quarter $t = 1,2, \dots, T$, UR_t is the unemployment rate, GDP_t^* and UR_t^* are the corresponding potential values and ε_t is a white-noise disturbance term. The parameter β ($\beta < 0$) is known as the Okun coefficient and indicates changes in unemployment rate caused by changes in real output. Potential values of real GDP and equilibrium values of unemployment, i.e. natural rate of unemployment, are not directly observable. While the gap version of Okun's law typically emphasises, the causality running from economic growth to unemployment, there are theoretical grounds to consider the possibility that the reverse causality could occur, with changes in unemployment affecting economic growth. The reverse causality argument posits that high unemployment may negatively impact economic growth. High unemployment reduces overall income levels, which, in turn, reduces aggregate demand in the economy. As the unemployed population spends less due to a lack of income, firms experience lower sales, which can dampen economic growth. This mechanism suggests that changes in the labour market can influence the overall economy, thereby affecting future output.

From this viewpoint, high unemployment could also represent structural issues in the labour market (such as skill mismatches or wage rigidities), which can hamper the growth potential of the economy. This would indicate that unemployment acts as a drag on growth by reducing labour market efficiency and inhibiting optimal utilisation of resources.

A gap equation in this version of Okun's law is given by:

$$GDP_t - GDP_t^* = \beta(UR_t - UR_t^*) + \varepsilon_t, \; t = 1,2, \dots, T \quad (4)$$

As stated before, GDP_t is a natural logarithm of the real GDP in quarter $t = 1,2, \dots, T$, UR_t is the unemployment rate, GDP_t^* and UR_t^* are the corresponding potential values and ε_t is a white-noise disturbance term. The parameter β ($\beta < 0$) is known as the Okun coefficient and indicates changes in real output caused by changes in unemployment rate. Potential values of real GDP and equilibrium values of unemployment, i.e. natural rate of unemployment, are not directly observable.

Overall, the research methodology was structured to encompass both linear and nonlinear dynamics. Seasonally adjusted series were used to ensure the GDP and unemployment data reflect true economic signals, not just calendar effects. As explained, first-difference models were deployed to analyze short-term fluctuations by differencing the time series, thereby addressing the issue of nonstationary, which is frequently encountered in macroeconomic datasets. In contrast, the gap models employed Hodrick-Prescott (HP) filtered data to isolate cyclical components, enabling a more nuanced investigation of deviations from potential output and natural unemployment levels. Furthermore, the NARDL approach was utilized to explore potential asymmetries in the relationship, particularly focusing on whether unemployment responds differently to positive and negative output shocks in both the short and long term. To decide on the appropriate NARDL model the so-called general-to specific approach was used, which is grounded in the principle of starting with a statistically and theoretically rich general model and then simplifying it through systematic testing (Hendry, Doornik, 2014). The study also adopted Bai-Perron structural break methodology, which allowed the identification and estimation of Okun's coefficients within distinct macroeconomic regimes. This segmentation was critical in assessing how economic crises and recoveries influenced the empirical validity of Okun's law.

A battery of statistical techniques supported the analytical framework. Unit root tests including Elliot, Rothenberg and Stock Point Optimal test (DF-GLS) (Elliott, Rothenberg, Stock, 1996), KKPS (Kwiatkowski, Phillips, Schmidt, Shin, 1992), ZA test (Zivot, Andrews, 1992) and Clemente–Montañés–Reyes test (CMR) (Clemente, Montañés, Reyes, 1998) were conducted to ascertain the integration properties of the variables. Cointegration was assessed using Engle-Granger test (Engle, Granger, 1987), Johansen test (Johansen, 1988), Gregory-Hansen (Gregory, Hansen, 1996) test with breaks, Bayer-Hanck meta-tests (Bayer, Hanck, 2013), and ARDL-based bounds testing approach. Diagnostic evaluations such as the Breusch-Godfrey serial correlation LM test, heteroscedasticity tests, Jarque-Bera test for normality, Ramsey RESET test for functional form, and CUSUM and CUSUMSQ tests for model stability were conducted to validate the reliability of the estimated models. Dummy variables representing structural disruptions such as the 2009 global financial crisis and the COVID-19 pandemic in 2020 were incorporated to control for the effects of extreme economic events. The main results are discussed in the following section, however, additional tables with detailed results are in the Appendix. Empirical analysis was conducted in Stata 15, EViews 10 and R4.4.3.

EMPIRICAL RESULTS

Unit root tests

The comprehensive battery of unit root and structural break tests is used, including DF-GLS, KPSS, ZA, CMR, the Bai & Perron (BP) and Ditzen-Karavias-Westerlund (DKW) procedures, as it provides a nuanced and robust understanding of the time series properties of the core macroeconomic variables relevant to Okun's law: real GDP (log-transformed), the unemployment rate, the output gap, and the unemployment gap. These tests, applied in both levels and first differences, along with models that allow for structural breaks, collectively help determine the most appropriate specification for modelling the dynamic relationship between economic growth and unemployment.

Table 2. Summary of the unit root tests outcomes

Variable	DF-GLS Result	KPSS Result	Conclusion
LGDP	Non-stationary	Reject level & trend	I(1)
DLGDP	Stationary	Accept stationarity	I(0)
UR	Non-stationary	Reject level & trend	I(1)
DUR	Stationary	Accept stationarity	I(0)
Output Gap	Stationary	Accept stationarity	I(0)
DOutput Gap	Stationary	Accept stationarity	I(0)
Unemployment Gap	Stationary	Accept stationarity	I(0)
DUnemployment Gap	Stationary	Accept stationarity	I(0)

Source: authors. Note: "D" indicates the first difference of the time series.

Overall, the evidence strongly supports the use of first-difference models and gap models in the empirical analysis of Okun's law. The first-difference model captures short-run movements and avoids nonstationarity-related misspecification, while the gap model leverages stationary measures of cyclical deviations from potential output and the natural unemployment rate. If later analysis identifies a cointegrating relationship between GDP and unemployment, an error correction model (ECM) or vector error correction model (VECM) may also be appropriate to capture both the long-run equilibrium and short-run adjustments.

The KPSS test, which reverses the null hypothesis by assuming stationarity, complements the DF-GLS results. For LGDP and UR in level form, KPSS test statistics exceed critical values, especially under the no-trend (drift) specification indicating a rejection of stationarity and thus supporting the $I(1)$ classification. Conversely, the first-differenced series have test statistics well below critical values, consistent with stationarity. For the output gap and unemployment gap, the KPSS test provides strong support for stationarity in both drift and trend specifications, which aligns well with the DF-GLS outcomes.

Traditional unit root tests, such as the DF-GLS and KPSS tests, assume a constant mean and variance over time. However, real-world economic time series often exhibit structural breaks, abrupt changes in the data-generating process due to events like policy shifts or economic crises. Ignoring these breaks can lead to misleading conclusions about the stationarity of a series. To address this issue, several unit root tests have been developed to account for structural breaks (see Appendix)

Under ZA tests, LGDP and UR still fail to reject the unit root null even when allowing for breaks, with test statistics not surpassing 10% critical values in any specification. This indicates that these series remain non-stationary even when accounting for potential structural shifts. In contrast, first-differenced LGDP and UR show strong stationarity with statistically significant breakpoints, often around 2008–2015, coinciding with the global financial crisis and its aftermath. For the gap series, ZA tests reveal borderline outcomes: while output and unemployment gaps show some signs of stationarity, break-adjusted models still tend to classify them as $I(0)$, particularly in first-differences, indicating robustness.

CMR test allows two structural breaks in the intercept and trend (Table 9). Using both the additive outlier (AO) and innovative outlier (IO) models, the CMR tests overwhelmingly reject the unit root null for all series in first differences, and for the gap series in levels. For LGDP and UR in levels, the IO model provides critical insight: breaks identified in 2008–2020 represent meaningful economic shifts that alter the statistical properties of these variables. Importantly, the AO model, which captures sudden, transitory shocks (such as financial crises or pandemics), also indicates non-stationarity in level LGDP and UR, reinforcing the idea that these variables evolve through distinct regimes or structural phases. The gap variables: output gap and unemployment gap, are confirmed to be stationary under both the AO and IO specifications, with structural breaks often located around crisis episodes. This is consistent with their construction as deviations from trend and their sensitivity to macroeconomic cycles.

The structural break analysis is reinforced and expanded through the Bai-Perron (Bai, Perron, 1998) and DKW sequential procedures. These tests detect multiple breakpoints in the time series relationships between variables (Tables 7, 8). The

LGDP–UR system is found to have at least three and possibly up to five structural breaks. Estimated breakpoints occur in 2005Q1, 2011Q1, and 2021Q3, coinciding with significant economic events such as the pre-GFC build-up, post-crisis recovery, and the COVID-19 pandemic. The sequential F-statistics support multiple structural breaks at high significance levels, indicating instability in the Okun's law relationship when specified using level variables. Conversely, the model using gap variables shows fewer and less significant structural breaks, especially when the output gap is the dependent variable. This suggests that the gap model specification is more stable over time, and potentially more suitable for long-run macroeconomic modelling.

The integration of unit root and structural break tests highlights that stationarity and structural stability are more likely when Okun's law is modelled using gap specifications rather than levels. This supports the preference for gap models in empirical applications, especially when dealing with small samples or macroeconomic data prone to shocks. However, if level models are used, it is essential to incorporate structural breaks explicitly to avoid misleading inferences. Combining filtered data (e.g., HP-filtered gaps) with robust structural break tests enhances both the explanatory power and the empirical validity of Okun's law in modern macroeconomic analysis.

Cointegration tests

Cointegration is a crucial concept in time series analysis, particularly when dealing with economic variables that exhibit long-term equilibrium relationships. The analysis of the long-run relationship between output and unemployment within the framework of Okun's law was carried out using a comprehensive suite of cointegration tests, including the Engle-Granger two-step procedure, the Gregory-Hansen test for structural breaks, the Johansen maximum likelihood approach, and the Bayer-Hanck combined cointegration framework. This multifaceted strategy allowed for a robust assessment of cointegration dynamics, accounting for both structural shifts and varying lag structures.

Evidence strongly favors the presence of a cointegration relationship between output gap and unemployment gap, while the results for first-differences of the series LGDP and UR are more mixed and specification-dependent. The Bayer-Hanck tests point to a likely cointegrating relationship in the level model, especially when appropriate lag length and structural breaks are accounted for (Table 3). In contrast, the Engle-Granger and Johansen tests remain non supportive, likely due to their lower power in finite samples and structural instability (Table 4).

Table 3. Bayer-Hanck cointegration test

Model	**Test**		
	EG-JOH	**EG-JOH-BO-BDM**	**Cointegration**
	With constant		
LGDP = f(UR)	5.24	5.49	No
UR = f(LGDP)	7.01	22.18	Yes
Output gap = f(Unemployment gap)	19.17	39.98	Yes
Unemployment gap = f(Output gap)	14.37	34.23	Yes

	With constant and trend		
LGDP = f(UR)	4.20	4.87	No
UR = f(LGDP)	4.85	15.51	No
Output gap = f(Unemployment gap)	14.10	28.52	Yes
Unemployment gap = f(Output gap)	10.27	24.68	No | Yes

Source: authors. Note: Critical values for the 5% significance level for the model with a constant: EG-JOH: 11.229 and EG-JOH-BO-BDM: 21.931, and for the model with a constant and trend: EG-JOH: 11.269 and EG-JOH-BO-BDM: 22.215. The model was expanded with 8 lags.

Eagle-Granger test results (Table 4) show Z-statistics and tau-statistics for both variables fail to exceed the critical thresholds at the 5% significance level, with values such as -6.33 and -1.86 for LGDP and -6.40 and -1.85 for UR under the constant-only specification, and similarly non-significant outcomes under the trend-inclusive version. These results suggest that GDP and unemployment in levels do not share a stable long-run equilibrium relationship over the sample period. In contrast, strong evidence of cointegration is found for the output gap and unemployment gap pairs, regardless of the deterministic components included. The Z-statistics for the output gap (-57.90) and unemployment gap (-19.95), along with their respective tau-statistics (-5.32 and -3.32), decisively reject the null hypothesis of no cointegration. These findings support the presence of a stable long-run relationship in the gap formulation of Okun's law, aligning with theoretical expectations and affirming the usefulness of filtered series in capturing equilibrium dynamics.

Table 4. Engle-Granger cointegration tests

Dependent variable	Z-statistic	Decision	tau-statistic	Decision
With a constant as an additional regressor				
LGDP	-6.33	Not cointegrated	-1.86	Not cointegrated
UR	-6.40	Not cointegrated	-1.85	Not cointegrated
Output gap	-57.90	Cointegrated	-5.32	Cointegrated
Unemployment gap	-19.95	Cointegrated	-3.32	Cointegrated
With trend as an additional regressor				
LGDP	-15.70	Not cointegrated	-2.88	Not cointegrated
UR	-13.11	Not cointegrated	-2.66	Not cointegrated
Output gap	-57.98	Cointegrated	-5.32	Cointegrated
Unemployment gap	-19.96	Cointegrated	-3.32	Cointegrated

Source: authors. Note: Number of lags in the Augmented Engle-Granger cointegration test is decided based on an automatic lags specification based on Schwarz criterion. "Decision" means a decision about cointegration relationship made at the 5% significance level. Critical values from MacKinnon (1996).

For the first-difference models (LGDP and UR), the absence of cointegration implies that changes in GDP and unemployment are not linked through a long-term equilibrium mechanism (Table 12), and as such, ARDL or NARDL models estimated in levels may suffer from spurious regression risks. Instead, the modeling should focus on short-run dynamics e.g., estimating dynamic OLS or standard autoregressive distributed lag models in first differences without imposing error correction structures.

In contrast, the gap model version of Okun's law is supported by strong statistical evidence of cointegration. Comparative analysis of ARDL models of Okun's law in gap form (Table 13) reveals that while both the output gap and unemployment gap specifications yield valid long-run relationships, the unemployment gap models are generally more robust and statistically significant. This validates the use of VECM or error-correction-based ARDL and NARDL models to capture both short- and long-run dynamics between the cyclical components of GDP and unemployment. The presence of a cointegrating relationship suggests that deviations between output and unemployment gaps are mean-reverting over time, in line with theoretical expectations of macroeconomic equilibrium.

The NARDL model is grounded in the cointegration theory and is particularly useful when modelling relationships between economic variables that may exhibit nonlinearities. Based on the results of estimated NARDL models (Tables 14, 15) an extensive evaluation and comparison were conducted to assess the robustness, asymmetries, and theoretical consistency of the empirical relationships between unemployment and GDP in Croatia.

As was the case with the linear ARDL models where LGDP was specified as the dependent variable, the NARDL estimation results also failed to provide evidence of cointegration in most specifications. In these models, the *F*-statistics and *t*-statistics from the bounds tests consistently fell below the lower critical values at standard significance levels, indicating the absence of a long-run equilibrium relationship. Moreover, all NARDL models with economic growth as the dependent variable exhibited signs of model instability. Residual diagnostics revealed violations of key assumptions, including non-normality and misspecification of the functional form. The in-sample explanatory power of these models was also extremely weak, with adjusted R^2 values ranging only from 0.02 to 0.14, suggesting poor model fit. Even attempts to improve model performance by increasing the number of lags included in the specification did not yield meaningful improvements. Given these deficiencies, the results for these models were not reported.

The comparative analysis of the four NARDL models underscores the superiority of the first-difference specification in modelling the empirical relationship between GDP and unemployment. These models not only provide stronger evidence for cointegration and dynamic adjustment but also validate the presence of asymmetric responses that carry important policy implications. The gap models, while theoretically appealing, fall short in capturing these nuances and appear to be more sensitive to measurement issues and structural model limitations. Thus, for empirical testing of Okun's law and associated labor market hypotheses, the first-difference NARDL models offer a more robust and interpretable framework (Table 14).

Granger causality tests

Toda–Yamamoto procedure (Toda, Yamamoto, 1995) is applied to both the levels and first-differences of the series related to Okun's law: LGDP and UR, as well as output gap and unemployment gap. This dual approach allows us to examine both the original variables and their cyclical components for directional predictability, while mitigating the risk of spurious results due to nonstationarity or omitted structural breaks. While traditional static Granger causality tests provide a method to assess whether one variable helps to predict another, these approaches assume that the relationship is stable over time. Economic relationships often evolve due to structural changes, regime shifts, and shocks such as financial crises or pandemics. To address this limitation, (Shi, Phillips, Hurn, 2018) introduced a novel class of Time-Varying Granger Causality (TVGC) tests, based on moving and recursive Wald test statistics.

Firstly, the results of the static Granger causality test based on the Toda-Yamamoto approach are shown in Table 5.

Table 5. Granger causality tests – Toda-Yamamoto approach

Causality direction	Chi-square statistic	P-value	Causality
LGDP → UR	18.71	<.01	Yes
UR → LGDP	0.91	.92	No
Output gap → Unemployment gap	22.71	<.01	Yes
Unemployment gap → Output gap	2.23	.69	No

Source: authors. Note: The VAR(4) model was used.

The conventional VAR-based Granger causality tests provide evidence of a unidirectional causal relationship between economic growth and unemployment. When the dependent variable is LGDP, the test fails to reject the null hypothesis that UR does not Granger-cause LGDP, with a *P*-value of .92. This suggests no evidence that changes in the unemployment rate help predict GDP in the linear VAR framework. However, when the dependent variable is UR, the results are quite the opposite: the null hypothesis that LGDP does not Granger-cause UR is strongly rejected with a Chi-squared statistic of 18.71 and a *P*-value of <.01. This indicates that GDP is a significant predictor of unemployment.

Similarly, in the gap version using the output gap and unemployment gap derived from the HP filter, the pattern holds. The output gap does not appear to be Granger-caused by the unemployment gap (*P*-value = .69), but the unemployment gap is strongly Granger-caused by the output gap (Chi-squared = 22.71, *P*-value = <.01). These findings are fully consistent with the traditional formulation of Okun’s law, which posits that changes in GDP (or output gap) lead to changes in the unemployment rate (or unemployment gap), not the other way around.

The time-varying Granger causality tests provide a more flexible framework (Table 6). For the pair LGDP → UR, all three test statistics exceed the 99th percentile critical values from bootstrap replications, strongly rejecting the null hypothesis of no Granger causality throughout the sample. This reinforces the earlier finding with static Granger causality test that GDP Granger-causes unemployment, but importantly, confirms that this causality is robust even under time variation and structural uncertainty.

Table 6. Time-varying LA-VAR Granger causality test

Causality direction	Max Wald forward	Max Wald rolling	Max Wald recursive	Causality
LGDP → UR	21.98	141.52	141.52	Yes
90th percentile	12.33	11.69	13.05	
95th percentile	13.54	14.69	15.21	
99th percentile	18.39	19.56	19.72	
UR → LGDP	8.92	158.09	158.09	No (1) | Yes (2)
90th percentile	10.24	10.60	11.04	
95th percentile	13.01	12.22	14.00	
99th percentile	21.25	21.79	21.86	
Output gap → Unemployment gap	41.80	163.02	163.02	Yes
90th percentile	16.30	15.55	16.47	
95th percentile	21.43	20.97	21.43	
99th percentile	34.46	35.41	35.41	
Unemployment gap → Output gap	15.17	142.37	142.37	Margin | Yes (2)
90th percentile	8.47	8.23	8.54	
95th percentile	10.58	10.43	10.58	
99th percentile	15.35	14.63	15.35	

Source: authors. Note: 90th, 95th and 99th percentiles of test statistics (199 replication in the bootstrap procedure)

Based on the Granger causality test results and the time-varying Granger causality tests, several key insights can be derived on the dynamic relationship between economic growth (as measured by the log of seasonally adjusted GDP, LGDP) and unemployment (UR), as well as between the output gap and unemployment gap. These insights are critical for understanding the validity of Okun's law and the directionality of influence between these macroeconomic indicators.

Both test frameworks consistently show unidirectional Granger causality from GDP or output gap to unemployment or unemployment gap. This lends strong empirical support to Okun's law in its predictive form, where output dynamics lead labour market changes. The time-varying tests enhance the interpretation by confirming that this relationship is not merely a full-sample artifact but persists even when allowing for changes in the underlying structure of the data.

These findings are not only consistent with Okun's law but also provide deeper insights into its temporal behaviour. By confirming that GDP leads unemployment across multiple test frameworks and under time-varying conditions, we gain greater confidence in using output as a predictor for labour market outcomes. This has important implications for macroeconomic forecasting and policy evaluation, particularly in times of economic upheaval. Additionally, the robustness of the gap-based relationship underscores the value of filtering techniques (such as the HP filter) in enhancing signal extraction for business cycle analysis.

CONCLUSION

This paper researched the applicability and dynamics of Okun's law in Croatia by employing a diverse and rigorous econometric framework. The overarching objective was to examine how variations in economic output correlate with changes in unemployment and whether this relationship exhibits characteristics of asymmetry, temporal instability, or is subject to disruption by structural economic shocks. The study utilised quarterly data from 2000 to 2024.

The empirical findings revealed a complex and nuanced relationship between GDP and unemployment. The Bayer-Hanck tests point to a likely cointegrating relationship in the level model, especially when appropriate lag length and structural breaks are accounted for. In contrast, the Engle-Granger and Johansen tests remain non supportive, even when structural breaks and dummy variables were accounted for. This absence of a long-run equilibrium relationship suggests that Okun's law may be more appropriately interpreted as a short-run association within this context.

First-difference models offered partial support for the Okun's law, with some specifications yielding statistically significant negative coefficients, indicative of the inverse relationship expected by theory. However, the explanatory power of these models was modest, with adjusted R-squared values around 0.04. Interestingly, the reverse model, where unemployment drove GDP changes, demonstrated stronger statistical properties with an adjusted R-squared of approximately 0.70, though this direction of causality contradicts the theoretical underpinnings of the law.

The gap models provided more robust and consistent evidence in support of Okun's law. The presence of a cointegrating relationship suggests that deviations between output and unemployment gaps are mean-reverting over time, in line with theoretical expectations of macroeconomic equilibrium. In these models, the coefficient linking the unemployment gap to the output gap was statistically significant and negative, with values around -0.85, suggesting a strong inverse relationship. The adjusted R-squared values for these models were substantially higher, approximating 0.65, indicating a better overall model fit. Furthermore, incorporating dummy variables for the pandemic quarters in 2020 effectively controlled for the transitory shocks introduced by COVID-19, thereby improving model stability and interpretability. These results affirm that the gap model specification is superior for capturing the cyclical dimensions of the Okun relationship in the Croatian economy.

The NARDL models illuminated critical asymmetries in the output-unemployment relationship. Specifically, the models revealed that negative output gaps had a more pronounced effect in increasing unemployment than positive output gaps had in reducing it. The combination of static and time-varying Granger causality tests offered a comprehensive assessment of the GDP and unemployment dynamic. While static tests confirm the basic predictive structure proposed by Okun, the time-varying methods validate its resilience across changing economic environments. Together, they make a strong case for the directionality of Okun's law and highlight the utility of modern time series tools in validating macroeconomic theory under real-world conditions.

From a policy standpoint, these findings offer several important implications. First, the output gap should be employed as a leading indicator in economic surveillance to anticipate movements in the labour market. Policymakers should design and implement counter-cyclical employment measures that respond proactively to downturns by preserving jobs and stimulating hiring. During recessions, wage subsidies, temporary tax relief for employers, and public infrastructure projects can help stabilise employment. Conversely, in expansionary periods, investments in workforce skills (e.g. in vocational education to fill skill gaps) and mobility can ensure that labour supply keeps pace with demand, preventing inflationary bottlenecks and skill mismatches. Policymakers should also consider automatic stabilisers (e.g., progressive unemployment insurance, emergency re-employment support) that adjust without delay in response to changing economic conditions. The gap models' superior performance reinforces the importance of distinguishing between trend and cyclical components of economic activity. This understanding is crucial in designing effective fiscal and labour market policies. For instance, a temporary output gap may not warrant structural policy changes, while a persistent unemployment gap might necessitate long-term interventions in education, training, or regional development. Policymakers and economists must interpret Okun's coefficients with caution and supplement them with broader macroeconomic indicators and contextual knowledge.

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Appendix - Table 7. Ditzen, Karavias & Westerlund break points procedure

Test	Test statistic				Bai & Perron critical values		
	(1)	(2)	(3)	(4)	1%	5%	10%
UDmax	203.82	99.17	5.60	31.41	12.37	8.88	7.46
F(1|0)	141.29	70.53	5.54	22.74	12.29	8.58	7.04
F(2|1)	100.75	16.81	4.43	16.13	13.89	10.13	8.51
F(3|2)	17.44	15.55	8.98	34.76	14.80	11.14	9.41
F(4|3)	7.12	9.92	3.69	6.51	15.28	11.83	10.04
F(5|4)	20.88	8.14	3.94	14.33	15.76	12.25	10.58
Number of breaks:							
(min)	3 (all)	3 (all	na	3 (all)			
(max)	5 (all)	3 (all)	na	5 (all)			
Break points	2005Q1	2011Q1	na	2008Q4			
	2011Q1	2017Q2		2012Q1			
	2021Q3	2020Q4		2019Q4			
95% *CI*	[2001, 2024]	[2010Q1, 2012Q1]	na	[2008Q3, 2009Q1]			
	[2001, 2024]	[2016Q2, 2018Q2]		[2011Q4, 2012Q2]			
		[2014Q4, 2026Q4		[2019Q3, 2020Q1]			

Source: authors. Note: UDmax test for multiple breaks at unknown breakdates (Bai & Perron, 1998), H0: no break(s) vs. H1: 1 <= s <= 5 break(s); DKW test: The detected number of breaks indicates the highest number of breaks for which the null hypothesis is rejected. (1) LGDP, UR; (2) UR, LGDP; (3) Output gap, Unemployment gap; (4) Unemployment gap, Output gap.

Table 8. Zivot-Andrews unit root tests with one endogenous break

Series	Intercept			Trend			Both		
	stat	TB	Decision	stat	TB	Decision	stat	TB	Decision
				Level					
LGDP	-3.79 (>.10)	2009Q1	I(1)	-2.74 (>.10)	2016Q1	I(1)	-3.25 (>.10)	2009Q1	I(1)
UR	-3.61 (>.10)	2010Q1	I(1)	-2.68 (>.10)	2013Q1	I(1)	-3.51 (>.10)	2010Q1	I(1)
Output gap	-5.59 (<.05)	2009Q1	I(0)	-5.15 (>.10)	2020Q3	I(0)	-5.93 (<.01)	2020Q1	I(0)
Unemployment gap	-3.56 (>.10)	2015Q4	I(1)	-2.83 (>.10)	2013Q3	I(1)	-3.54 (>.10)	2015Q4	I(1)
				First-difference					
LGDP	-9.33 (<.01)	2020Q3	I(0)	-8.87 (<.01)	2009Q2	I(0)	-9.57 (<.01)	2020Q3	I(0)
UR	-4.60 (>.10)	2013Q4	I(1)	-3.84 (>.10)	2010Q3	I(1)	-4.70 (>.10)	2013Q4	I(1)
Output gap	-8.71 (<.01)	2020Q4	I(0)	-8.41 (<.01)	2009Q2	I(0)	-9.17 (<.01)	2020Q4	I(0)
Unemployment gap	-6.53 (<.01)	2015Q4	I(0)	-6.18 (<.01)	2006Q4	I(0)	-6.94 (<.01)	2020Q2	I(0)

Source: authors. Note: TB is the breakpoint. "Decision" means a decision made at the 5% significance level. The Schwarz information criterion was used to select the increment for the ZA test. The minimised Dickey-Fuller t-statistic was used to select the breakpoint in these tests. The critical values for the ZA are for model with intercept: 1% -5.34, 5% -4.80, 10% -4.58; for model with trend: 1% -4.93, 5% -4.42, 10% -4.11; for model with intercept and trend: 1% -5.57, 5% -5.08, 10% -4.82.

Table 9. Clemente-Montañés-Reyes unit root tests with two endogenous breaks

Series	IO				AO			
	t-stat	TB_1	TB_2	Decision	t-stat	TB_1	TB_2	Decision
				Level				
LGDP	-6.23 (<.01)	2015Q3 (<.01)	2020Q1 (<.01)	I(0)	-4.08 (<.01)	2005Q1 (<.01)	2019Q4 (<.01)	I(0)
UR	-4.72 (<.01)	2009Q3 (<.01)	2015Q2 (<.01)	I(0)	-3.16 (>.05)	2011Q2 (<.01)	2016Q4 (<.01)	I(1)
Output gap	-7.10 (<.01)	2015Q3 (>.05)	2020Q1 (>.05)	I(0)	-2.61 (>.05)	2018Q1 (<.01)	2019Q4 (<.01)	I(1)
Unemployment gap	-5.32 (<.01)	2011Q3 (<.01)	2015Q2 (<.01)	I(0)	-2.71 (>.05)	2011Q4 (<.01)	2015Q1 (<.01)	I(1)
				First difference				
LGDP	-13.70 (<.01)	2008Q4 (<.01)	2020Q1 (<.01)	I(0)	-3.45 (>.05)	2008Q3 (>.05)	2019Q4 (>.05)	I(1)
UR	-4.48 (<.01)	2008Q2 (<.01)	2013Q2 (<.01)	I(0)	-2.18 (>.05)	2009Q1 (<.01)	2013Q1 (<.01)	I(1)
Output gap	-8.74 (<.01)	2008Q4 (>.05)	2020Q1 (>.05)	I(0)	-4.27 (<.01)	2008Q3 (>.05)	2019Q4 (>.05)	I(0)
Unemployment gap	-3.01 (>.05)	2020Q1 (<.01)	2020Q4 (<.01)	I(1)	-3.68 (<.01)	2019Q3 (<.01)	2021Q1 (<.01)	I(0)

Source: authors. Note: TB1 and TB2 are the breakpoints. "Decision" means a decision made at the 5% significance level. The critical value for the Clemente-Montañés-Reyes unit root test with two structural breaks for IO and AO is -5.49 at the 5% significance level.

Table 10. Gregory-Hansen cointegration test (first-difference model)

Dependent	Break type	ADF	Z_t	Z_a	Break point			5% asymptotic critical values			Cointegration (Yes/No)
					ADF	Z_t	Z_a	ADF	Z_t	Z_a	
LGDP	Level	-3.31	-3.43	-18.15	2009Q2	2009Q3	2009Q3	-4.61	-4.61	-40.48	No (ADF, Z_t, Z_a)
	Trend	-4.56	-5.05	-35.20	2019Q2	2019Q1	2019Q1	-4.99	-4.99	-47.96	No (ADF, Z_a) Yes (Z_t)
	Regime	-3.67	-3.86	-21.26	2018Q1	2018Q1	2018Q1	-4.95	-4.95	-47.04	No (ADF, Z_t, Z_a)
	Regime trend	-4.62	-5.09	-34.96	2019Q1	2019Q1	2019Q1	-5.50	-5.50	-58.58	No (ADF, Z_t, Z_a)
UR	Level	-2.97	-3.11	-16.60	2008Q3	2008Q3	2008Q3	-4.61	-4.61	-40.48	No (ADF, Z_t, Z_a)
	Trend	-3.50	-3.91	-23.87	2019Q2	2014Q3	2014Q3	-4.99	-4.99	-47.96	No (ADF, Z_t, Z_a)
	Regime	-2.93	-3.13	-16.99	2008Q3	2009Q2	2009Q2	-4.95	-4.95	-47.04	No (ADF, Z_t, Z_a)
	Regime trend	-4.21	-3.95	-26.69	2018Q2	2018Q2	2018Q2	-5.50	-5.50	-58.58	No (ADF, Z_t, Z_a)

Source: authors. Note: The modified Schwarz information criterion was used to select the degree of increase in the test equation.

Table 11. Gregory-Hansen cointegration test (gap model)

Dependent	Break type	ADF	Z_t	Z_a	Break point			5% asymptotic critical values			Cointegration (Yes/No)
					ADF	Z_t	Z_a	ADF	Z_t	Z_a	
Output gap	Level	-5.45	-5.26	-40.01	2007Q2	2006Q3	2006Q3	-4.61	-4.61	-40.48	Yes(ADF, Z_t) No(Z_a)
	Trend	-5.61	-5.37	-41.81	2007Q2	2006Q3	2006Q3	-4.99	-4.99	-47.96	Yes(ADF, Z_t,) No(Z_a)
	Regime	-5.64	-5.51	-43.64	2006Q2	2006Q3	2006Q3	-4.95	-4.95	-47.04	Yes(ADF, Z_t,) No(Z_a)
	Regime trend	-5.88	-5.66	-45.88	2006Q2	2006Q3	2006Q3	-5.50	-5.50	-58.58	Yes(ADF, Z_t,) No(Z_a)
Unemployment gap	Level	-3.41	-3.52	-21.79	2014Q3	2019Q1	2019Q1	-4.61	-4.61	-40.48	No (ADF, Z_t, Z_a)
	Trend	-3.80	-3.96	-26.29	2009Q2	2009Q2	2009Q2	-4.99	-4.99	-47.96	No (ADF, Z_t, Z_a)
	Regime	-4.14	-3.95	-28.13	2017Q4	2017Q4	2017Q4	-4.95	-4.95	-47.04	No (ADF, Z_t, Z_a)
	Regime trend	-4.24	-4.03	-28.97	2017Q4	2017Q4	2017Q4	-5.50	-5.50	-58.58	No (ADF, Z_t, Z_a)

Source: authors. Note: The modified Schwarz information criterion was used to select the degree of increase in the test equatio

Table 12. ARDL models summary (first-difference models)

Model	ARDL Lag order	F-stat (Bounds test)	Cointegration (F-test)	t-stat (Bounds test)	Cointegration (t-test)
			Model: LGDP = f(UR)		
C	(1, 0)	0.247	No	-0.695	No
C + T	(1, 0)	2.135	No	-2.063	No
C + Dummy	(1, 0)	1.033	No	-1.022	No
C + T + Dummy	(1, 0)	2.204	No	-1.837	No
			Model: UR = f(LGDP)		
C	(6, 0)	6.128	Yes	-3.398	Yes
C + T	(11, 1)	22.943	Yes	-6.762	Yes
C + Dummy	(6, 0)	4.156	No	-2.783	No
C + T + Dummy	(12, 1)	20.281	Yes	-6.358	Yes

Source: authors. Note: C = model with constant; C+Dummy = model with constant and dummies (D200Q1, D2020Q2, D2020Q3, D2020Q4); C+T = model with constant and trend; C+T+Dummy = model with constant, trend and dummies. Schwarz (SIC) criterion was used as a model selection method, or to determine the optimal length of the delay, i.e. order of the ARDL model.

Table 13. ARDL models summary (gap models)

Model	ARDL Lag order	F-stat (Bounds test)	Cointegration (F-test)	t-stat (Bounds test)	Cointegration (t-test)	CointEq(-1) coefficient	CointEq(-1) significance
				Model: Output gap = f(Unemployment gap)			
C	(2, 0)	12.77	Yes	-4.69	Yes	-0.4540	<.01
C+T	(2, 0)	12.65	Yes	-4.67	Yes	-0.4544	<.01
C+Dummy	(1, 0)	19.46	Yes	-5.90	Yes	-0.4307	<.01
C+T+Dummy	(1, 0)	19.95	Yes	-5.98	Yes	-0.4376	<.01
				Model: Unemployment gap = f(Output gap)			
C	(5, 1)	13.10	Yes	-2.54	Inconclusive	-0.1536	<.01
C+T	(5, 1)	13.02	Yes	-2.53	No	-0.1535	<.01
C+Dummy	(5, 1)	8.98	Yes	-2.72	Inconclusive	-0.1744	<.01
C+T+Dummy	(5, 1)	8.03	Yes	-2.53	No	-0.1686	<.01

Source: authors. Note: C = model with constant; C+Dummy = model with constant and dummies (D2020Q2 and D2020Q3); C+T = model with constant and trend; C+T+Dummy = model with constant, trend and dummies. Schwarz (SIC) criterion was used as a model selection method, or to determine the optimal length of the delay, i.e. order of the ARDL model.

Table 14. NARDL first-difference models for Unemployment rate dependent variable (General-to-specific approach)

Variable	Model 1	Model 2
Intercept	2.753 (<.01)	2.891 (<.01)
Trend		-0.024 (.10)
Short-run dynamics		
UR_{t-1}	-0.149 (<.01)	-0.140 (<.01)
$LGDP^{+}_{t-1}$	-0.050 (<.01)	-0.042 (<.01)
$LGDP^{-}_{t-1}$	-0.073 (<.01)	-0.102 (<.01)
ΔUR_{t-2}	-0.203 (.04)	-0.248 (.02)
ΔUR_{t-3}	0.357 (<.01)	0.303 (<.01)
ΔUR_{t-4}	-0.093 (.33)	-0.146 (.14)
ΔUR_{t-5}	0.341 (<.01)	0.297 (<.01)
$\Delta LGDP^{+}_{t-3}$	0.162 (<.01)	-0.169 (<.01)
$\Delta LGDP^{+}_{t-4}$	-0.085 (.11)	-0.092 (.08)
Long-run relation $LGDP^{+}_{t-1}$	-0.337 (<.01)	-0.299 (<.01)
Long-run relation $LGDP^{-}_{t-1}$	-0.487 (<.01)	-0.728 (<.01)
Long-run asymmetric Wald test	5.680 (.02)	6.143 (.02)
Short-run asymmetric Wald test	15.000 (<.01)	16.924 (<.01)
F-bounds cointegration test	F-statistic | Lower bound | Upper bound	
10% critical value	6.730 | 4.04 | 4.78	5.883 | 4.05 | 4.49
5% critical value	6.730 | 4.94 | 5.73	5.883 | 4.68 | 5.15
1% critical value	6.73 | 6.84 | 7.84	5.883 | 6.10 | 6.73
t-bounds cointegration test	t-statistic | Lower bound | Upper bound	
10% critical value	-4.448 | -2.57 | -2.91	na
5% critical value	-4.448 | -2.86 | -3.22	na
1% critical value	-4.448 | -3.43 | -3.82	na
Adjusted R^2	0.372	0.388
Jarque-Bera normality test	0.537 (.76)	0.717 (.70)
Breusch-Godfrey serial correlation LM test	11.519 (.17)	11.393 (.18)
Engle ARCH test for heteroscedasticity	6.890 (.55)	(.98)
Ramsey RESET test	0.764 (.38)	1.989 (.16)
CUSUM test	Stable	Stable
CUSUM of squares test	Stable	Stable

Source: authors

Table 15. NARDL gap models for Unemployment gap dependent variable (General-to-specific approach)

Variable	Model 3	Model 4
Intercept	0.031 (.79)	0.146 (.42)
Trend		-0.010 (.38)
Short-run dynamics		
$Unemployment\ gap_{t-1}$	-0.168 (<.01)	-0.207 (<.01)
$Output\ gap^{+}_{t-1}$	-0.088 (<.01)	-0.083 (<.01)
$Output\ gap^{-}_{t-1}$	-0.091 (<.01)	-0.100 (<.01)
$\Delta Unemployment\ gap_{t-2}$	-0.321 (<.01)	-0.295 (.01)
$\Delta Unemployment\ gap_{t-3}$	0.170 (.09)	0.119 (.24)
$\Delta Unemployment\ gap_{t-4}$	-0.268 (.01)	-0.245 (.03)
$\Delta Unemployment\ gap_{t-5}$	0.173 (.09)	0.144 (.15)
$\Delta Unemployment\ gap_{t-6}$	-	0.118 (.29)
$\Delta Output\ gap^{+}_{t-3}$	-0.079 (.17)	-
$\Delta Output\ gap^{+}_{t-4}$	-0.060 (.30)	-0.089 (.11)
$\Delta Output\ gap^{+}_{t-5}$	0.031 (.59)	-
Long-run relation $Output\ gap^{+}_{t-1}$	-0.525 (.02)	-0.399 (.02)
Long-run relation $Output\ gap^{-}_{t-1}$	-0.538 (.01)	-0.483 (<.01)
Long-run asymmetric Wald test	0.249 (.62)	0.943 (.33)
Short-run asymmetric Wald test	1.544 (.22)	2.601 (.11)
F-bounds cointegration test	F-statistic | Lower bound | Upper bound	
10% critical value	6.631 | 4.04 | 4.78	5.998 | 4.05 | 4.49
5% critical value	6.631 | 4.94 | 5.73	5.998 | 4.68 | 5.15
1% critical value	6.631 | 6.84 | 7.84	5.998 | 6.10 | 6.73
t-bounds cointegration test	t-statistic | Lower bound | Upper bound	
10% critical value	-2.858 | -2.57 | -2.91	na
5% critical value	-2.858 | -2.86 | -3.22	na
1% critical value	-2.858 | -3.43 | -3.82	na
Adjusted R^2	0.335	0.333
Jarque-Bera normality test	0.130 (.94)	1.070 (.59)
Breusch-Godfrey serial correlation LM test	9.361 (.31)	7.921 (.44)
Engle ARCH test for heteroscedasticity	6.544 (.59)	6.217 (.62)
Ramsey RESET test	0.021 (.89)	1.269 (.26)
CUSUM test	Stable	Stable
CUSUM of squares test	Stable	Stable

Source: authors