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The Link between Unemployment and Industrial Production: The Fourier Approach with Structural Breaks

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Abstract. The purpose of this study was to investigate the long-term relationship between unemployment and industrial production during structural breaks in the United States. We used monthly data from the Industrial Production Index and the unemployment rate between January 1948 and October 2018 to analyze this relationship. We found the stationarity of the time series used using the Fourier KPSS stationarity test, which enabled a stationarity analysis, including with the existence of structural breaks. As a result of the stationarity analysis, we did not find any stationarity in either series. We then used a Fourier Shin cointegration analysis to investigate the long-term relationship between the industrial production index and the unemployment rate. This test demonstrates its difference from other cointegration tests considering the time and shape of these breaks in the presence of structural breaks. According to the cointegration analysis results, we found a long-term relationship between the U.S. unemployment rate and the industrial production index variables. These results indicate that sudden structural changes in the industrial production index have an effect on the U.S. unemployment rate in the long term. We then used the Least Squares with Breaks Bai-Perron break type method to determine the structural break periods and the coefficients of these periods. We found the years 1958, 1974, 1990, and 2007 to be when the structural changes occurred.

Key words: Fourier KPSS stationarity, Fourier SHIN cointegration, growth, structural breaks, unemployment rate, industrial production.

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Introduction

Initial contribution to growth theory includes two periods – the late 1950s and 1960s that form neoclassical growth theory. Robert Solow made the greatest contribution to neoclassical growth theory. The second period, called intrinsic growth theory and led by Robert Lucas and Paul Romer, includes the late 1980s and 1990s [1].

It is important for policy makers to know how exactly GDP growth by 1 p. p. will reduce the unemployment rate. In 1962, Arthur Okun suggested that the increase of economic growth would reduce the unemployment rate. According to this theory, known as Okun's Law, economic growth (stated as the output increase in production) has an important effect on full employment. In other words, there is an inverse relationship between the output increase of production and the unemployment rate [2]. Unemployment is a primary issue for economic managers all over the world. Increasing unemployment rates, especially during periods of economic crisis, create a serious problem for the full-employment target that is one of the macroeconomic goals of all countries. Unemployment is also considered one of the reasons of poverty and unfair distribution [3]. Most people around the world earn most of their income by working at a profession. This point indicates the importance of having opportunities for employment, business quality, high income, conditions for economic growth, and the decrease of poverty. Developing countries continue to believe that employment has an important effect on development and prioritize providing employment to reduce poverty when creating development policies [4].

After the petroleum crises in the 1970s, the United States began to deal with low-growth and high-unemployment problems. Crises such as the increase in female-labor employment, the stationarity of productivity and wages made economists think that a structural change had occurred in the relationship between economic growth and unemployment. This also led to approaching Okun's Law with suspicion. Studies have indicated that Okun's coefficient regressed from three to two [5]. Along with the United States, industrialized European countries in particular deal with high unemployment rates cyclically, sparking discussions among economists about the fact that these problems derive from structural issues, rather than cyclical situations [6].

The purpose of this study is to identify structural breaks in the relationship between unemployment and growth and examine this long-term relationship in light of these structural breaks. The reason why the industrial production index is taken as a variable representing growth is that it allows a better view of structural changes in production. The industrial production index shows the dynamics of production output and emphasizes structural developments in the economy [7]. For this reason, we used the Fourier Cointegration Approach, which allows the existence of cointegration relationship in the presence of structural breaks, in the study. Thus, the relationship between variables could be analyzed to show structural changes.

In this study, we examined the long-term relationship between the industrial production index and unemployment rate using data from January 1948 to October 2018 for the United States. This paper is organized as follows: an introduction where general information is given; the literature review, where the literature on the subject is summarized; a section in which the method is explained, the data description and results of the analysis; conclusions and the list of references.

Literature overview

Since 1962, when Arthur Okun revealed the existence of an inverse relationship between economic growth and the unemployment rate, economists have continued investigating this issue. The relationship known as Okun's Law was accepted as a structure that did not require a valid hypothesis process [2]. Beginning with Okun's article (1962), bringing forward the relationship between economic growth and unemployment, researchers reached similar findings indicating that a 2–3% increase of real gross domestic product (GDP) leads to a 1% decrease in unemployment [8].

There are various opinions which explain the dynamics of this relationship in studies dealing with unemployment and economic growth. According to Meyer and Tasci (2012), the relationships between macroeconomic variables are more complicated than the simple relationship stated by Okun's law. Researchers argue that there is no clear evidence that the relationship between output growth and the unemployment rate is stable over time. Therefore, they say that it is uncertain how the increase in real GDP will affect the unemployment rate [9]. According to Chamberlin (2011), structural changes occurring over time do not allow simply to explain the relationship between unemployment rate and economic growth. As a reason, the researcher says that the unemployment rate is affected by structural and cyclical movements [10]. Akeju and Olanipekun (2014) state that the industrial production system is shaped according to the change in total demand. Thus, changes in the labor market affect the unemployment rate. In addition, they expressed the opinion that the effect of the rate of the increase of production on unemployment is an important factor in combating inflation [11]. There are also opinions stating that changes in total output have an asymmetrical effect on the unemployment rate. According to these, the unemployment rate is more affected by shocks in the contraction periods compared to during the expansion periods of the economy [6, 12–14].

Studies analyzing the relationship between economic growth and unemployment for the United States continued to follow Okun. In his study, Blackley (1991) researched the validity of Okun's Law at the state level in the United States. He determined that this relationship was valid in 26 states. The study reveals that an average of 3.1% in economic growth is required to reduce the unemployment rate by 1% in a state. The differences in industrialization levels and fields of the states, as well as the age and gender distributions belonging to labor and taxation policies, affected differences between states in the relationship between unemployment and economic growth [15]. However, Palley (1993) reformed Okun's Law by considering the asymmetrical structure of the USA economic system. According to findings of the study, a break was identified in Okun's coefficient in 1974. At the same time, it was observed that the Okun coefficient increased [13]. Similarly, Silvapulle et al. (2004) obtained findings in support of the claim that the relationship between economic growth and unemployment, called Okun's Law, was asymmetrical. Using the data from the postwar period for the United States, the study discovered that the effect of the increase in economic growth on unemployment varied with regard to the decrease in short-term growth [14]. Guisinger et al. (2018) also estimated the Okun coefficients for each American state separately, focusing on reasons for differences in coefficients among the states. According to the study results, the rate of high education in the population, as well as the lower unionization rate and nonproduction employment, are among the main reasons for the coefficient differences among the states [16].

Using the data between 2002 and 2010 from 358 metropolitan statistics areas (MSAs) in the USA, Kuscevic (2014) tried to estimate Okun's Law by also considering the national shocks and spatial distribution effect for these cities. Because the research was carried out at a metropolitan level, not at a state level, it focused on whether there was a different spatial effect on unemployment. According to the research findings, the growth in MSAs had a small effect on its unemployment rate. These results suggest that unemployment at the city level in an integrated labor market, such as the United States, depends on changes in neighboring cities and the national labor market. The results also show that reasons for fluctuations of unemployment rates for metropolitan areas are different from reasons in other states [8].

Elshamy (2013) analyzed the Okun's coefficient for Egypt using the cointegration method with the data from the 1970–2010 period. Elshamy revealed that the Okun coefficient between unemployment and economic growth there was 2.2%. At the same time, Elshamy revealed the existence of a cointegration relationship and found a significant relationship in short and long terms [3].

Doğru (2013) researched the relationship between economic growth and unemployment in the Eurozone using annual data, including the 2000–2012 period. In the analysis, the panel cointegration method showed that Okun's Law was valid, but the calculated coefficients were below those of the United States and other developed countries. Doğru also determined that Okun coefficients of Eurozone countries differed from each other [17].

Beaton (2010) tested Okun's Law for the United States and Canada using the neutral median estimator method. According to the analysis results, the unemployment rate in both countries is highly sensitive to increases in economic growth and exhibits structural instability [18].

Lee (2000) analyzed the validity of Okun's Law for 16 Organization for Economic Co-operation and Development (OECD) countries using the data from 1955 to 1996. Lee's findings indicate that Okun's Law was statistically valid for most of the countries, but the coefficients differed among them. Okun coefficients are sensitive in terms of the first difference and gap models. Findings about the asymmetrical relationship were also reported, and the effect of the structural break that happened in the 1970s was quite strong [6].

Freeman (2000) measured the Okun coefficient using USA national and regional data. The study revealed that the value of the coefficient measuring the change in the economic growth and unemployment rate relationship was roughly 2 in all time periods and among regions [5].

Moosa (1997) tested the reactional relationship of unemployment and economic growth for G7 countries using the OLS, Rolling OLS, and SUR methods. According to Moosa's findings, the highest Okun coefficient was found for the United States and the lowest one – for Japan. Researchers appreciated that differences in markets could be the reason for the disparity [19].

Altug and Gencer (2012) examined industrial production and employment variables in their studies and investigated cyclical differences for developed and developing countries. They used Markov chains as a method. In the study, researchers examined the relationship between unemployment and change in the business cycle, considering that changes in industrial production are important in determining the turning points in a business cycle. Based on the Markov chain analysis, the researchers concluded that developed and developing countries are interdependent [20].

Akar and Sahin (2018) analyzed whether unemployment insurance is an automatic stabilizer in the business cycle in Turkey. For this purpose, the researchers used the Johansen cointegration, vector error correction model (VECM), and Granger causality methods to investigate the relationship between the industrial production index and unemployment. The researchers found a short-term causality relationship between unemployment allowance, unemployment rate, and industrial production [21].

Michael, Emeka, and Emmanuel (2016) examined the relationship between unemployment and economic growth in Nigeria. In the analysis, the researchers performed cointegration and causality analysis for real GDP, private consumption expenditures, and unemployment rate variables. The results showed a long-term relationship between the variables. According to the VECM, unemployment has an inverse and significant effect on real GDP. According to the causality analysis, there is a one-way causality from real GDP to unemployment [22].

Madito and Khumalo (2014) investigated the relationship between unemployment and economic growth in South Africa. In this study, researchers conducted a Johansen cointegration analysis with data from 1967Q1–2013Q4. For the short-term analysis, they used the VECM method. The Johansen cointegration test results revealed four cointegration vectors and showed a long-term relationship. According to the results of the study, 62% of economic growth is corrected every 3 months. In addition, there is a negative relationship between economic growth and unemployment [23].

Abbas (2014) investigated the long-term relationship between economic growth and unemployment using the ARDL boundary test. The researcher used 1990–2006 data for Pakistan. The study results showed a long-term negative relationship between economic growth and unemployment for Pakistan. The long-term coefficient, obtained in the study, showed that a 1% increase in economic growth will reduce unemployment by 1.65% in the long run. In the study, short-term coefficients were not significant [24].

Kangasharju, Tavera, and Nijkamp (2012) examined the relationship between unemployment and economic growth for Finland's regions. In this study, researchers used the hidden cointegration method, which takes into account cross-sectional dependence. The results of the study showed that, even though the coefficients are small for the regions in Finland, there is a cointegration relationship. Moreover, the long-term relationship between regional production and unemployment is asymmetrical, according to the results. The effect of GDP growth on unemployment was thus smaller in absolute value than the effect of the decrease in the GDP [25].

Kargi (2014) examined the relationship between economic growth and unemployment in OECD countries. Although there are differences in coefficients for 23 selected countries, Okun's hypothesis appears valid. The study revealed a long-term cointegration relationship between unemployment and growth. A consistent unemployment rate could not be detected in countries with high growth rates, but the unemployment rate was quite high in countries with low growth rates [26].

Palombi, Perman, and Tavéra (2015) examined the relationship between regionally based output in the U.K. and the unemployment rate. The aim of this study was to eliminate the problem of horizontal cross-sectional dependence by using a hidden cointegration method for the panel data. The results of the study show a hidden cointegration between unemployment and growth. At the same time, the relationship between economic growth and unemployment was asymmetrical in the medium term, and the impact of GDP growth on unemployment was less than the absolute value of the impact of the decrease of the GDP on unemployment. Therefore, positive and negative shocks to the GDP have a limited impact on unemployment in the medium term [27].

Vakulenko and Gurvich (2015) examined the relationship between GDP and the unemployment rate in their studies for short and long term for Russia. In the study, they determined that the effect of the decrease in production on unemployment is higher than the effect of growth in production on employment. In the study, they also showed that the Okun coefficient calculated for Russia is close to values of a developing country [28]. In another study on Russia, Yüksel (2016) analyzed the causal relationship between economic growth, unemployment rate, and inflation. In the study, Granger and Toda-Yamamoto causality analyzes were performed using 1992–2014 data. According to the results obtained in the study, it has been determined that there is causality between the unemployment rate and growth in Russia [29]. In a similar way, unemployment and output dynamics in the CIS countries (Russia, Uzbekistan, Ukraine, Belarus, Moldova and Kazakhstan) were studied in 2017. According to the analysis for Russia, it is shown that a 1% increase of Russia's quarterly growth decreased the unemployment rate by 0.06%. In this study, researchers determined that the relationship between economic growth and unemployment rate in Russia has a stable course over time [30].

Methods

Fourier KPSS Stationarity Test

The issue on the stationarity of the series was first investigated during its analysis. In the 1980s, the first developed stationarity tests [31, 32] were used for an analysis of the level state of a time series along with its stable and/or trend interactions. However, these tests ignored the structural breaks in time series. Later stationarity tests considered the structural breaks [33, 34], but these tests were also criticized because the place, number, and form of the structural breaks should have been determined beforehand and only then included in the model. By developing the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test with the Fourier function, Becker, Enders, and Lee (2006) developed the Fourier KPSS stationarity test that considers the structural breaks in series, where the determination of a location, number, and form of the break is not necessary [35]. One of the most important advantages of this developed test is that it considers not only significant structural changes but also softer ones [36].

Becker et al. [37] first formulated the data production process given in Equations (1) and (2):

$$y_t = X_t'\beta + Z_t'\gamma + r_t + \varepsilon_t. \quad (1)$$

$$r_t = r_{t-1} + u_t\ . \quad (2)$$

Here ε_t indicates the stable error term, and u_t indicates the error term distributed identically with the σ_u^2 variant. Z_t is used to identify a break that may occur in a deterministic term; the structure that damages the linearity is expressed with Equation (3) [38].

$$Z_t = \left[sin\left(\frac{2\pi kt}{T}\right), cos\left(\frac{2\pi kt}{T}\right)\right]'\ . \quad (3)$$

Z_t is the vector that expresses the Fourier expansion and includes trigonometrical terms in it. The variable k indicates the frequency value, t indicates the trend term, and T indicates the sample size. $X_t = [1]$ is defined in the stationarity test of yt at level, $X_t = [1, t]$ is defined in the stationarity test in the existence of a trend. The null hypothesis expressing the stationarity is indicated as H_0: $\sigma_u^2 = 0$, and the test statistics are calculated with waste values that would be obtained from Equations (4) or (5) to test this hypothesis [39]:

$$y_t = \alpha + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) + e_t. \quad (4)$$

$$y_t = \alpha + \beta t + \gamma_1 \sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 \cos\left(\frac{2\pi kt}{T}\right) + e_t. \quad (5)$$

Although the stationarity at a level is tested by Equation (4), the stationarity in the existence of a trend is tested through Equation (5). Where the k value indicates the frequency value, selected for the Fourier approach, γ is the measure of the substitution and width in the approach. From this point of view, the test statistics are calculated as indicated in Equation (6) below [30]:

$$\tau_\mu(k) or\ \tau_\tau(k) = \frac{1}{T^2}\frac{\sum_{t=1}^{T}\tilde{S}_t(k)^2}{\tilde{\sigma}^2}. \quad (6)$$

where $\tilde{S}_t(k) = \sum_{j=1}^{t}\tilde{e}_j$. $\tilde{e}_j$ indicates the error terms in the OLS regression obtained from Equation (4) or Equation (5). As in the KPSS test, $\tilde{\sigma}^2$, the non-parametric estimation of the variant in the long term, is obtained by Equation (7) by selecting l, the cutoff lag parameter, and $w_i, j = 1, \ldots, l$, the weighting series:

$$\tilde{\sigma}^2 = \tilde{\theta}_0 + 2\sum w_j\,\tilde{\theta}_j. \quad (7)$$

Here $\tilde{\theta}_j$ indicates the error terms — for instance, autocovariances, obtained from Equation (4) or Equation (5).

F-test statistics, given in Equation 8, are recommended for testing the null hypothesis, $H_0: \gamma_1 = \gamma_2 = 0$, indicating the nonexistence of a nonlinear trend in the data production process:

$$F_i(k) = \frac{(SSR_0 - SSR_1(k))/2}{SSR_1(k)/(T-q)} \qquad i = \mu, \tau \quad (8)$$

Here, $SSR_1(k)$ indicates the error sum of squares obtained from Equation (4) or Equation (5), SSR_0 indicates the error sum of squares obtained from the model with no trigonometrical terms, and q indicates the number of explanatory variables. The fact that the null hypothesis cannot be rejected in the F test indicates the insignificance of trigonometrical terms. Critical values for the test appeared in the Becker et al. [37] study.

Fourier Shin Cointegration Test

Differences between the series are taken to provide the stationarity in nonstable time series. However, this is criticized because it leads to information losses in the long term. Cointegration analyses became popular because they enabled an analysis of the long-term relationship between variables without information losses. The Fourier Shin (FSHIN) cointegration test included by Tsong et al. [40] can be described as the expanded form of the Fourier KPSS test for cointegration. The main hypothesis in the FSHIN cointegration test indicates the existence of cointegration. This test reveals its difference from other cointegration tests considering the location, time, and form of these breaks. The FSHIN cointegration test is in two stages. In the first stage, the model is given in Equation (9) [41]:

$$y_t = d_t + X_t'\beta + \eta_t. \quad (9)$$

Here, $\eta_t = \gamma_t + \vartheta_{1t}$ is defined as $\gamma_t = \gamma_{t-1} + u_t$, $x_t = x_{t-1} + \vartheta_{2t}$. The variable u_t indicates an i.i.d. process with σ_u^2 variance with 0 average. The variable γ_t indicates the random walk process with 0 average. Because the ϑ_{1t} scalar value and the ϑ_{2t} p dimensioned vector are stable, y_t and x_t are I(1). The deterministic term can be defined in two forms as $d_t = \delta_0 + f_t$ or $d_t = \delta_0 + \delta_1 t + f_t$, according to the fixed term or the fixed term and trending situation. The variable f_t is the Fourier function given in Equation (10):

$$f_t = \alpha_k\, sin\left(\frac{2\pi kt}{T}\right) + \beta_k\, cos\left(\frac{2\pi kt}{T}\right). \quad (10)$$

The null hypothesis indicating the existence of cointegration and the alternative hypothesis asserting the contrary are indicated in Equation (11) [40]:

$$H_0: \sigma_u^2 = 0 \text{ versus } H_0: \sigma_u^2 > 0. \quad (11)$$

Equations (9) and (10) can be obtained, as in Equation (12), under the existence of the null hypothesis:

$$y_t = \sum \delta_i t^i + \alpha_k sin\left(\frac{2\pi kt}{T}\right) + \beta_k cos\left(\frac{2\pi kt}{T}\right) + + X_t'\beta + \vartheta_{1t} . \quad (12)$$

The partial sum of OLS residues obtained from Equation (12) is calculated as $S_t = \sum_{t=1}^{T} \hat{\vartheta}_{1t}$. From this point of view, FSHIN test statistics are calculated as indicated in Equation (13):

$$CI_f^m = T^{-2}\hat{\varpi}_1^{-2} \sum_{t=1}^{T} S_t^{\,2}. \quad (13)$$

However, $\hat{\varpi}_1^{-2}$ is a consequent long-term variance estimator of ϑ_{1t}, obtained by the non-parametric Barlett-Kernel method.

Data and empirical analysis

The purpose of this study was to analyze the relationship between economic growth and employment through the Fourier approach by also considering the structural breaks. Therefore, we analyzed the unemployment rate (*unrate*) and industrial production index (*indpro*) variables of the United States.

The *indpro* is an economic indicator that measures the real output for all businesses in production, mining, electricity, and gas sectors in the United States. It measures changes occurring in production output and gives information about the structural developments in the economy. Monthly growth in the production index is an indicator of the growth in the industry sector [42]. The employment rate is calculated as the percentage of total labor that the number minus the unemployed represents. Labor data include people aged 16 and over. People in one of the 50 states or in the District of Columbia are included in this data scope, but people working in jails, mental hospitals, elderly-care centers, and the active armed forces are not included [43].

The data cover the period between 01.01.1948 and 01.10.2018 and consist of 850 observations. We obtained data from the database of the Federal Reserve Bank of St. Louis (FRED Economic Data), and we performed analyses using the EViews 9.5 program.

First, we analyzed the stationarity of the variables; *table 1* shows the results.

It is shown that test statistics for the *unrate* and *indpro* variables are larger than table critical values. Therefore, the null hypothesis of the stationarity analysis is rejected. In other words, the *unrate* and *indpro* variables are not stationary. When the stationarity analysis is redone by taking the first differences of these variables, the test statistics are smaller than critical table values. Therefore, the null hypothesis of the stationarity analysis cannot be rejected. In other words, the *unrate* and *indpro* variables are stationary at the I(1) level. Additionally, we tested the trigonometrical terms for both the *dunrate* and the *dindpro* variables for significance, and the trigonometrical terms were significant for both the *dunrate* and *dindpro* variables.

Table 1: Fourier KPSS Stationarity Test Results

Variables	Frequency	Min SSR	Fourier KPSS	Bandwidth	Fstat
Unrate	3,0	1917.71	0.48	23.0	79.35
Indpro	1.0	262923.2	1.32	23.0	802.68
Dunrate	4.0	36.76	0.051	18.0	3.08
Dindpro	3.0	178.39	0.057	18.0	3.18

Notes: Critical values for FKPSS test are 0.1295, 0.1704, and 0.2706 for k = 1; 0.3304, 0.4388, and 0.7086 for k = 3 and 0.3355, 0.4470, and 0.7163 for k = 4 at the 10%, 5%, and 1% levels, respectively. Critical values for the F test used to find the significance of trigonometrical terms are 3.935, 4.651, and 6.281 at the 10%, 5%, and 1% levels, respectively.

To support the Fourier KPSS type stationarity test, we also performed a Fourier ADF type test [44]. First, in the Fourier ADF test, $k = 2$ and $SSR = 177.13$ for the *indpro* variable. We used the Wald test to test the significance of trigonometric coefficients. The value $Fstat = 0.84$ resulted from this test. This value is compared to the F table value (7.53) in Enders and Lee [44, p. 197]. Because $Fstat < Ftable$, trigonometric terms are significant. Then, in the model where the trigonometric terms are significant, we calculated the t-stat of *indpro* (-1) as 0.25. Because the *indpro* variable contains a trend, we compared it with the t-value in Table 1a in Enders and Lee [44, p.197]. We found 0.25 is less than absolute -4.57, -3.99, and -3.67, which are 1%, 5%, and 10%, respectively. Therefore, the *indpro* has a unit root.

We also performed the Fourier ADF test for the *unrate* variable. For the *unrate* variable, $k = 4$ and $SSR = 36.58$. $Fstat = 1.96$ resulted from this test. This value is comparable to the F table (Table 1b) value (6.16) in Enders and Lee [44, p. 197]. Because $Fstat < Ftable$, trigonometric terms are significant. Then, in the model where trigonometric terms are significant, we calculated the t-stat of *unrate* (-1) as -3.14. We compared it with the t-value in Table 1a in Enders and Lee (2002, p. 197) and found -3.14 is less than absolute -3.62 for 1%. But it is more than absolute -2.97 and -2.66, which are 5% and 10%, respectively.

Therefore, the *unrate* does not contain a unit root with a 5% significance.

When *figure 1* was analyzed, it was revealed that Fourier oscillations, especially for the *unrate* variable, comply with the data. In other words, the *unrate* variable experiences the periodical cycle more than the *indpro* variable in time.

From now on, the FSHIN cointegration test can be performed to analyze the long-term relationship between the *unrate* and *indpro* variables, which were found to be stationary from the same level. *Table 2* displays a cointegration analysis of the relationship between the unemployment rate and the industrial production index for the United States.

Because Fourier Shin statistics are smaller than a 5% critical value for significance level, there is a cointegration (i.e., a long-term relationship), between the USA unemployment rate and the *indpro* variable. These results indicate that sudden structural changes in the *indpro* variable affect the USA unemployment rate in the long term.

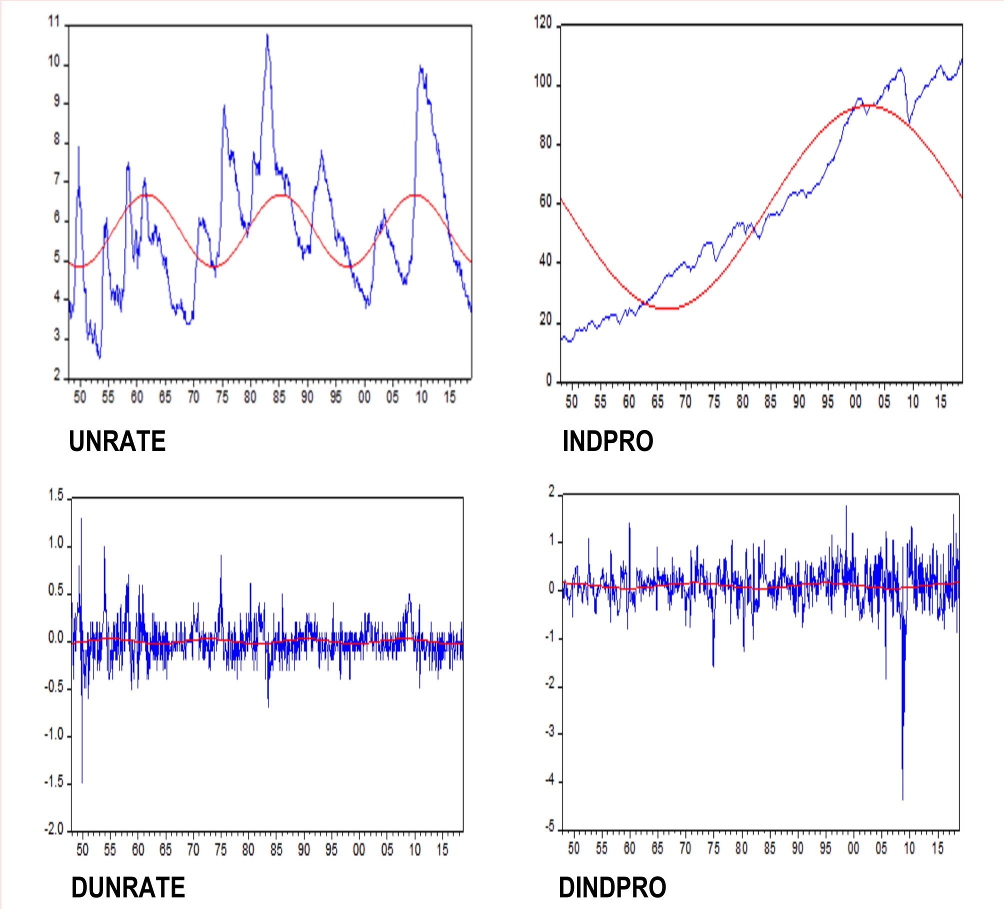
After the cointegration relationship was determined, we estimated cointegration coefficients with the FMOLS estimator developed by Phillips and Hansen [45]. *Table 3* illustrates these results.

We estimated the DOLS estimator and found that it was very close to the FMOLS. According to both FMOLS and DOLS cointegrating results, the *indpro* coefficient is statistically significant. The relationship between the *unrate* and *indpro* variables is inverse. According to this result, because it is an important variable that emphasizes the structural change in production, the increase of the variable will cause the increase in economic growth in the long term, leading to the decrease of unemployment.

To find the coefficients of the relationship between the unemployment rate and the industrial production index by periods, we used the Least Squares with Breaks method, indicating even the break dates, with the Bai-Perron break type. *Table 4* shows the results of this analysis.

1958, 1974, 1990, and 2007 are the break dates in the relationship between the industrial production index and the unemployment rate. According to the findings in the table, the effect of the increase of industrial production on reducing the unemployment in the 1958M08–1974M10 and 1990M11–2007M11 periods is

Figure 1. The Compatibility of the *unrate* and *indpro* Variables and the Fourier Function



Source: Author's own calculation.

Table 2. Fourier SHIN Cointegration Test Results

Frequency	Min SSR	Fourier SHIN Coint.	Bandwidth	F stat
2.0	1754.01	0.21	23.0	2.19
Notes: Critical values for Fourier cointegration test for k = 2 are 0.200, 0.276, and 0.473 at 10%, 5%, and 1% levels, respectively.				

Table 3. Cointegration Coefficient Estimates

Variable	Coefficient	Std. Error	t-stat	Prob.
INDPRO	-0.20	0.02	-9.29	0.000
C	6.53	0.27	23.71	0.000
@TREND	0.02	0.002	9.88	0.000

Table 4. Estimation of Coefficients Through Least Squares with Breaks Method

Period	INDPRO	Const.	t-stat	Prob.
1948M01 - 1958M07	-0.10	6.29	-3.26	0.001
1958M08 - 1974M10	-0.05	6.86	-6.03	0.000
1974M11 - 1990M10	-0.14	15.02	-13.16	0.000
1990M11 - 2007M11	-0.05	10.28	-11.14	0.000
2007M12 - 2018M10	-0.31	38.67	-19.65	0.000
Notes: R^2 = 0.66, Prob. (Fstat = 0.000) and Breaks were obtained as 1958M08, 1974M11, 1990M11, and 2007M12.				

quite weak. One of the most striking points in the coefficients is that the effect of the increase in the industrial production index on reducing unemployment was at its highest value in the 2007M12–2018M10 period. Expansionary monetary policy, implemented in the specified period in the United States, may have affected that situation.

Conclusions

In this study, in the light of the existence of structural breaks, we investigated the long-term relationship between economic growth and employment in the United States. We selected the determination of economic growth, the industrial production index, and the indicator of employment, the unemployment rate, and tested the long-term relationship between specified variables using data of 850 months between January 1948 and October 2018. We analyzed the stationarity of used time series through the Fourier KPSS stationarity test considering structural breaks, and it was not found to be stationary at the level in either series. The series were characterized as stationary at I (1). We used the Fourier Shin cointegration analysis to investigate the long-term relationship between variables. According to the cointegration analysis results, we found a long-term relationship between the U.S. unemployment rate and the industrial production index variables. These results indicate that sudden structural changes in the industrial production index have an effect on the USA unemployment rate in the long term. These results are compatible with ones presented in the economic literature, where it is indicated that unemployment will increase in cyclical contraction periods; however, unemployment will decrease in cyclical expansion periods.

After determining the long-term relationship between these two variables, we estimated coefficients through the Least Squares with Breaks method, thereby determining break periods and coefficients belonging to these periods. The years of structural changes were 1958, 1974, 1990, and 2007.

As Meltzer stated in 1991 [46], the breakpoint of 1958 could be considered the result of the continuous decline of the dollar's real exchange rate index and development of international relative prices in relation to the United States, along with the currency convertibility of the Bretton–Woods system. The break of 1974 may be related to the start of an adjustment mechanism period in the United States, along with the collapse of the Bretton–Woods system in 1973 and the transition to a floating exchange rate regime [47].

These results also indicate that unemployment will decrease along with increases of production in periods when expansionary economic policies are implemented. During the analysis of coefficients, related to break dates, especially for 2008 and 2018, it was revealed that the increase of industrial production reduced unemployment in this case more than in other periods. Fawley and Neely suggested [48] that this result could be related to the "Quantitative Easing" policy of FED, which started in November 2008. The expansionary monetary policy, which resulted from this FED policy, led to the stability of growth rates in the United States and reduced unemployment markedly.

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