State of Persistence: Unemployment Hysteresis in Ten U.S. States: Bootstrap Nonlinear Unit Root Tests in Regional Labor Markets

Ayca Doganer
East Texas A&M University

Asli Ogunc
East Texas A&M University

This study examines the extent to which the hypothesis of hysteresis holds across different U.S. states by analyzing unemployment data. Implementing advanced nonlinear unit root tests, in combination with bootstrap techniques, the analysis investigates whether temporary shocks—such as recessions or the COVID-19 pandemic—can result in permanent changes in unemployment and other labor market outcomes.

Our results reveal mixed outcomes consistent with recent literature on the hysteresis hypothesis in the U.S. The LNV and Sollis tests generally support the natural rate hypothesis. In contrast, the KSS and Kruse tests provide evidence of permanent effects in several states.

Keywords: unemployment hysteresis, nonlinear unit root tests, bootstrap methods, state-level labor markets, regional unemployment, persistence, labor market dynamics, macroeconomic shocks, asymmetric adjustment, time series analysis

INTRODUCTION

Macroeconomics analyzes key indicators like output, price levels, employment, and economic growth to understand how an economy functions as a whole in any given country. Economic growth and price stability are essential for long-term well-being for the country. However, unemployment is the key indicator that is very sensitive to economic fluctuations.

It is essential to monitor the impact of supply shocks on unemployment levels. Equally important is assessing whether economic shocks have only temporary effects or leave lasting scars on the labor market" - unemployment hysteresis." This concept has gained increasing popularity in the economic literature, as it suggests that temporary shocks can have long-term effects on unemployment rates. The persistence of elevated unemployment levels even after economic recovery in recent years lends strong support to this view.

The dominance of the Natural Rate Hypothesis (NRU), introduced by Friedman (1968), is well established. This theory posits that each economy has an inherent unemployment rate, determined by its structural characteristics, such as labor market institutions, productivity, and demographics. Phelps (1967) similarly argued that while unemployment can be temporarily affected by economic shocks, it ultimately converges to a long-term equilibrium—referred to as the natural unemployment rate. This steady-state reflects labor market dynamics without cyclical disturbances, representing full employment conditions. Phelps (1967) and Friedman (1968) both underscored the importance of inflation expectations in shaping labor market dynamics. They argued that while a short-run trade-off between inflation and unemployment may be observed—captured by the downward-sloping Phillips Curve—this relationship breaks down in the long run. Over time, as expectations adjust, the Phillips Curve becomes vertical at the natural unemployment rate. This implies that any attempt to reduce unemployment below its natural rate through expansionary demand-side policies would result in rising inflation, with no lasting improvement in employment levels.

Blanchard and Summers (1986) added the unemployment hysteresis hypothesis to the literature and argued that shocks can permanently affect unemployment rates. They stated that there is rigidity in labor markets, that the new balance that will be formed by the effect of the shock increasing unemployment rates will remain in the long term, and that shocks will permanently affect the series and create a new balance point.

According to the hysteresis hypothesis, unemployment levels are highly persistent following shocks like recessions, preventing the unemployment rate from returning to its previous equilibrium. In contrast, the natural rate of unemployment theory suggests that there is always an equilibrium unemployment rate due to factors like minimum wage legislation pushing real wages above market-clearing levels. While the actual unemployment rate fluctuates around this natural level due to inflationary expectations, any short-term decline in unemployment caused by higher-than-expected inflation is temporary, as unemployment eventually reverts to its natural rate once expectations adjust. This theory also encompasses the concept of the “non-accelerating inflation rate of unemployment” (NAIRU), which assumes static inflation expectations. Empirical research has linked the hysteresis hypothesis to unemployment as a unit root process. Rejecting the unit root hypothesis aligns with the natural rate theory. However, the structuralist perspective posits that unemployment is stationary around a natural or structural level. Advances in unit root testing methods have fueled extensive empirical investigations into these competing hypotheses.

Several theoretical approaches attempt to explain the persistence of high unemployment rates over time. From an economic theory standpoint, this issue is often examined through two main hypotheses related to the dynamics of unemployment, both of which have implications for economic growth (Røed, 1997; Murray and Papell, 2000). The first is the ‘natural rate of unemployment’ hypothesis—also known as the non-accelerating inflation rate of unemployment (NAIRU)—which views unemployment as a mean-reverting process consistent with a stable rate of inflation. The second is the hysteresis hypothesis, originally proposed by Blanchard and Summers (1986), which argues that cyclical economic downturns can have lasting impacts on unemployment due to labor market rigidities.

A typical method for testing the hysteresis hypothesis involves applying unit root tests to assess whether the unemployment rate reverts to its mean over time. According to the traditional natural rate theory, the unemployment rate should exhibit stationarity, whereas the hysteresis hypothesis suggests that the unemployment rate follows a unit root process, meaning that shocks have lasting effects.

This study investigates whether the unemployment hysteresis hypothesis holds true across the individual states of the United States of America (USA). Both the hysteresis hypothesis and the natural rate of unemployment hypothesis explore how economic shocks influence unemployment trends. When an unemployment series displays unit root behavior—meaning it is non-stationary—it indicates the presence of hysteresis. In such cases, the impact of an economic shock persists even after the shock itself has dissipated, suggesting a long-lasting influence on unemployment. Conversely, suppose the series is stationary (i.e., does not have a unit root). In that case, the effects of an economic shock are temporary, and unemployment tends to revert to its previous level once the shock subsides. According to the natural rate hypothesis, unemployment returns to its initial state over time following a disturbance. In contrast, the hysteresis hypothesis suggests that unemployment remains elevated and does not revert post-shock. This paper tests for the presence of unemployment hysteresis in U.S. states using the bootstrap method, employing non-linear unit root tests for the analysis.

The empirical analysis employs Leybourne et al. (LNV), Kapetanios, Shin and Snell (KSS), Sollis, and Kruse tests to distinguish between stationary and non-stationary unemployment processes.

LITERATURE REVIEW

There are numerous studies in the literature on unemployment hysteresis and the natural rate hypothesis. Unit root tests have been widely used to examine these hypotheses, and over time, both linear and non-linear unit root tests and panel data tests have been applied to various countries.

Phelps (1968) analyzed the dynamic relationship between unemployment and inflation within the Phillips Curve framework, predicting that unemployment fluctuates around the natural rate but converges to it in the long run. However, empirical evidence has been limited, leading to the concept of hysteresis, where current unemployment levels are influenced by past levels (Oskooee, Chang, and Ranjbar, 2018).

Blanchard and Summers (1986) tested the unemployment hysteresis hypothesis for the USA, France, Germany, and the UK, finding evidence of hysteresis in the US. Brunello (1990) found similar results for Japan using the Dickey-Fuller unit root test. Mitchell (1993) extended this to 15 OECD countries, confirming unemployment hysteresis for most.

Song and Wu (1997) tested the hypothesis for 48 US states, finding evidence supporting the weak version of the natural rate hypothesis. Røed (1997) examined unemployment dynamics in OECD countries and argued that long-term unemployment is influenced by cyclical shocks and labor market institutions. The study highlighted that structural features can reinforce the hysteresis effect.

Arestis and Mariscal (2000) applied Perron's (1997) unit root test to 22 OECD countries and found no evidence of hysteresis in nine of them. Ledesma (2002) used panel unit root tests for 51 US states and 12 EU countries, concluding that hysteresis is more plausible for the EU.

Camarero et al. (2006) studied 19 OECD countries, finding the natural rate hypothesis most valid. Lee and Chang (2008) examined 14 OECD countries and rejected hysteresis, finding that unemployment rates were stationary. Lee (2010) used the Ucar and Omay (2009) nonlinear panel test for 29 OECD countries, showing evidence of the natural rate hypothesis in 23 countries, with only 17 countries showing stationary unemployment in a linear test. Gustavsson and Österholm (2010) conducted unit root tests for 17 OECD countries to examine the stationarity of unemployment series. Their findings suggest that unemployment follows a unit root process in several countries, providing empirical support for hysteresis.

Furuoka (2015) found that Estonian regions followed a stationary process. Yagan (2017) employed a panel data framework to study the long-term effects of the 2007–2009 financial crisis on unemployment across U.S. states. His results indicate that the shocks to unemployment had lasting effects up to 2015, confirming hysteresis for the U.S. Oskooee, Chang, and Ranjbar (2018) investigated 52 US states, finding hysteresis in some states, especially during recessions. Plotnikov (2019) used a general equilibrium model to demonstrate that unemployment shocks can become persistent through confidence channels. Simulation results supported the view that labor market rigidity amplifies the impact of shocks, leading to long-term unemployment.

Omay, Ozcan, and Shahbaz (2020) confirmed the natural rate hypothesis for most US states, except for a few outliers. Ball and Onken (2021) analyzed unemployment rates across 29 OECD countries and concluded that natural unemployment rates vary over time, with shocks having persistent effects. Using time series analysis, they found strong evidence supporting the hysteresis hypothesis.

David Arenas and Suarez (2024) analyzed Colombia from 2010-2021, emphasizing the impact of remittances and non-labor income on long-term unemployment. They found remittances played a crucial role in alleviating long-term unemployment during crises.

METHODOLOGY

In time series analysis, identifying the underlying properties of the series is essential. These characteristics must be carefully considered during model specification and analysis. Economic time series often exhibit generalizable patterns such as trends, cyclical fluctuations, and seasonal effects. Broadly, time series properties can be classified as either deterministic or stochastic. Deterministic components capture elements like trends, and seasonality, while stochastic properties relate to the stationarity of the variables—determining whether shocks to the series have temporary or permanent effects. A variety of unit root tests are widely used to determine the stocastic natüre of different series including unemployment.

This research examines the existence of unemployment hysteresis in ten U.S. states, with a particular emphasis on those contributing the most to the national Gross Domestic Product (GDP). The primary objective is to test the hysteresis hypothesis to assess whether shocks to unemployment rates have permanent effects—and whether these effects vary across states. To achieve this, both linear and nonlinear unit root tests are employed, each offering distinct methodologies for evaluating the stationarity of the series. Conducting multiple tests allows for comparative analysis and helps identify the most reliable results. Importantly, the critical values for the unit root tests are derived using bootstrap techniques to enhance robustness. Based on these bootstrap-adjusted tests, the unemployment rate series for the selected states exhibited stationarity in several cases, indicating the potential rejection of the hysteresis hypothesis in certain regions.

In 2024, U.S. states can be ranked by Gross Domestic Product (GDP), with California leading as the largest state economy at approximately $4 trillion. Texas follows it with a GDP of approxitately $2.7 trillion and New York at $2.1 trillion. The toher states included in the study are, Florida ($1.4 trillion), Illinois ($1 trillion), and Pennsylvania ($900 billion). Rounding out the top ten are Ohio ($800 billion), Georgia ($750 billion), North Carolina ($730 billion), and New Jersey ($700 billion).

Non-Linear Unit Root Tests

The nonlinear unit root tests employed in this study include those developed by Leybourne, Newbold, and Vougas (1998), Kapetanios, Shin, and Snell (2003), Sollis (2009), Kruse (2011), and Cuestas and Ordonez (2014).

Leybourne, Newbold and Vougas (1998) (LNV) Unit Root Test

Leybourne et al. (1998) (LNV) unit root test employs three regression models with smooth transitions with single smooth breaks.

Model A: $$y_t = \alpha_1 + \alpha_2 S_t(\gamma,\tau) + v_t \tag{1}$$

Model B: $$y_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma,\tau) + v_t \tag{2}$$

Model C: $$y_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma,\tau) + \beta_2 S_t(\gamma,\tau) + v_t \tag{3}$$

In the equation; v_t is the I(0) process with zero mean, $S_t(\gamma,\tau)$ is the logistic smooth transition function, γ is the transition speed, τ is the transition midpoint time, t is the number of observations.

In Model A, y_t is a stationary process around the mean that changes from the initial value α_1 to its final value α1+α2. It is a process that includes a smooth break in the constant term. In Model B, it changes from α_1 to its final value α1+α2 and also includes the fixed slope term. It is a process that includes a smooth break in the constant with a deterministic trend. In Model C, it changes from α_1 to its final value α1+α2 and the slope changes from β1 to β1+β2. It is a process that includes a smooth break in both the trend and the constant.

$$S_t(\lambda,\tau) = [1 + exp\{-\lambda(t-\tau T)\}]^{-1} \qquad \hat{v}_t = y_t - \hat{\alpha}_1 - \hat{\alpha}_2 S_t(\hat{\lambda},\hat{\tau}) \tag{4}$$

$$\hat{v}_t = y_t - \hat{\alpha}_1 - \hat{\beta}_1 t - \hat{\alpha}_2 S_t(\hat{\lambda},\hat{\tau}) \qquad \hat{v}_t = y_t - \hat{\alpha}_1 - \hat{\beta}_1 t - \hat{\alpha}_2 S_t(\hat{\lambda},\hat{\tau}) \tag{5}$$

$$\Delta\hat{v}_t = \delta\hat{v}_{t-1} + \sum_{i=1}^{p}\psi_i \Delta\hat{v}_{t-i} + \varepsilon_t \qquad H_0\colon \delta = 0 \qquad H_1\colon \delta < 0 \tag{6}$$

In the unit root test study of Leybourne et al. (1998), the test statistic is preferred using the nonlinear least squares method. Thus, the deterministic component of the model is estimated and the residuals of the model are calculated according to the nonlinear least squares method. There is a softer structural break.

Kapetanios, Shin and Snell (2003) (KSS) Unit Root Test

In their study, Kapetanios, Shin, and Snell (2003) applied a unit root test based on the Exponential Smooth Transition Autoregressive (ESTAR) model. This approach assumes symmetric mean reversion, meaning that positive and negative deviations from the equilibrium have identical effects on the adjustment process.

$$y_t = \beta y_{t-1} + \gamma y_{t-1}\left[1 - exp\left(-\theta(y_{t-1}^2 - c)\right)\right] + \varepsilon_t \tag{7}$$

$$\Delta y_t = \emptyset y_{t-1} + \gamma y_{t-1}[1 - exp(-\theta y_{t-1}^2)] + \varepsilon_t \tag{8}$$

$$\Delta y_t = \gamma y_{t-1}[1 - exp(-\theta y_{t-1}^2)] + \varepsilon_t \qquad \Delta y_t = \delta y_{t-1}^3 + \varepsilon_t \qquad H_0\colon \delta = 0 \qquad H_1\colon \delta < 0 \tag{9}$$

In the ESTAR model, c represents the location parameter, γ denotes the transition speed between regimes, and θ is the smoothing parameter. By incorporating the ESTAR structure, a linear random walk process can be transformed into a nonlinear process. Assuming the location parameter (c) equals zero simplifies the model, leading to the final form of the test regression.

Since the original nonlinear model cannot directly test the unit root, a first-order Taylor expansion is applied to the ESTAR test equation. This approximation yields a linearized test regression in which the presence of a unit root can be directly assessed. In this framework, the null hypothesis represents the existence of a unit root (non-stationarity), while the alternative hypothesis indicates nonlinear ESTAR-type stationarity.

Importantly, no deterministic components—such as a constant or trend—are included in the final test regression used to evaluate the unit root. Instead, the analysis can be conducted using raw data (without a constant or trend), demeaned data, or detrended data, depending on the characteristics of the time series.

Sollis (2009) Unit Root Test

The unit root test proposed by Sollis (2009) incorporates an asymmetric ESTAR structure. In their test, the asymmetric ESTAR model and the creation of this asymmetric ESTAR model are based blending elements from both the ESTAR (Exponential Smooth Transition Autoregressive) and LSTAR (Logistic Smooth Transition Autoregressive) processes to allow for asymmetric adjustments toward equilibrium.. A key feature is that θ_1 and θ_2 parameters are different to capture the asymmetry in how positive and negative deviations from the equilibrium influence the adjustment dynamics.

$$\Delta y_t = [1 - exp(-\theta_1 y_{t-1}^2)]\{[1 + exp(-\theta_2 y_{t-1})]^{-1}\gamma_1(1 - [1 + exp(-\theta_2 y_{t-1})]^{-1})\gamma_2\}y_{t-1} + \varepsilon_t \tag{10}$$

$$\theta_1 \geq 0, \quad \theta_2 \geq 0 \tag{11}$$

$$\Delta y_t = \delta_1 y_{t-1}^3 + \delta_2 y_{t-1}^4 + \varepsilon_t \qquad H_0\colon \delta_1 = \delta_2 = 0 \qquad H_1\colon \delta_1 \neq \delta_2 \neq 0 \tag{12}$$

As in the KSS test, it is not possible to test these hypotheses directly. Therefore, Sollis obtained a test regression in which the unit root can be directly tested by applying the first-order Taylor expansion to this test regression. There are both cubed and fourth power in the test regression. It is estimated with the classical OLS method.

While the null hypothesis expresses the existence of a unit root, the alternative hypothesis expresses symmetric or asymmetric stationarity.

No deterministic component can be added to the final test regression. As in the KSS, it can be worked with either raw data (constant and no trend), or demeaned data (presence of constant), or detrended data.

Kruse (2011) Unit Root Test

Kruse (2011) developed a new specification in the unit root test by improving the expression that the location parameter c is assumed to be o by KSS and assuming this parameter to be different from zero. This model is also based on the ESTAR model.

$$\Delta \gamma y_{t-1}\left[1-exp\left(-\theta(y_{t-1}^{2}-c)\right)\right]+\varepsilon_t \tag{13}$$

$$\Delta y_t=\delta_1 y_{t-1}^{3}+\delta_2 y_{t-1}^{2}+\sum_{i=1}^{k}\Delta y_{t-i}+\varepsilon_t \qquad H_0\colon \delta_1=\delta_2=0 \quad H_1\colon \delta_1<0,\ \delta_2\neq 0 \tag{14}$$

In this test, as in the KSS test, it is not possible to test the hypotheses directly. By applying the first-order Taylor expansion, a test regression was obtained in which the unit root could be directly tested. Since the C parameter is assumed to be different from zero, the final models obtained differ. It is estimated with the classical EKK method.

While the null hypothesis expresses the existence of a unit root, the alternative hypothesis ESTAR expresses stationarity. The alternative hypothesis has both one-sided and two-sided structures. A variance-covariance matrix was created by multiplying the estimated regression's standard error with the independent variables' coefficient matrix. The test statistic was obtained using the elements of the matrix.

In this test, no deterministic component is added to the regression, and as in the KSS, it can be worked with either raw data (constant and no trend), or demeaned data (presence of constant), or detrended data (detrended data).

Bootstrap Method

The task of constructing tests for the null hypothesis of an autoregressive unit root in the presence of weakly dependent innovations has been widely explored in the literature, resulting in the development of several testing approaches. However, comprehensive simulation analyses have demonstrated that conventional asymptotic approximations to the null distribution of many unit root tests may not perform reliably, especially when dealing with innovation processes such as moving-average structures that possess nearly unit negative roots. Consequently, in many practical applications, the true significance levels of unit root tests often deviate substantially from the nominal levels predicted by asymptotic theory. In such scenarios, employing bootstrap methods is a logical approach to enhance the reliability of finite-sample inferences (Psaradakis, 2001).

Bootstrap methods provide a flexible framework to incorporate factors like limited sample size, differing initial condition specifications, and the underlying error distribution. As a result, they often yield more precise finite-sample properties compared to traditional approaches based on asymptotic theory, which generally overlook these aspects.

Different-Based DF Sieve Bootstrap Test

Parametric (Residual Based) bootstrapping is more widely applied in the presence of a model that can be used to transform the raw data into something else that is assumed to be close to independent. After obtaining the residuals, a new bootstrapped dataset is created using the parametric model, taking them into account.

Step 1. The residuals of the traditional unit root test regression are obtained.

$$\hat{\varepsilon}_t \tag{15}$$

Step 2.

$$\hat{\varepsilon}_t - (n-p)^{-1}\sum_{t=p+1}^{n}\hat{\varepsilon}_t \rightarrow \varepsilon_t^* \qquad (16)$$

using it, a random i.i.d. ε_t^* sample is created based on the residuals.

Step 3. Bootstrap errors are obtained by repeating the following representation repeatedly:

$$u_t^* = \sum_{j=1}^{p}\widehat{\emptyset}_j u_{t-j}^* + \varepsilon_t^* \qquad (17)$$

Step 4. Bootstrap sample of the time series used in the unit root test is obtained:

$$y_t^* = y_{t-1}^* + u_t^* \rightarrow \Delta y_t^* \qquad (18)$$

Step 5. The coefficient and test statistics of the relevant unit root test are calculated with Bootstrap sampling.

Step 6. Steps 2 to 5 are repeated N times (Number of iterations, for example 10000) to obtain the Bootstrap distribution and hence the test statistics and critical values.

DATA AND EMPIRICAL RESULTS

In this study, unemployment rates of the 10 states with the largest share of GDP in 2024 from the USA are examined in the periods of 1976-2023 to investigate whether there is unemployment hysteresis. For this purpose, the total unemployment rates in the USA states are used in annual periods to determine the stationarity of the unemployment series. The data were obtained from the Bureau of Labor Statistics website database.

Non-linear unit root tests were applied to the series using Leybourne et al. (1998) (LNV), Harvey and Mills (2002) (HM), Kapetanios, Shin and Snell (KSS) (2003), Sollis (2009) and Kruse (2011) unit root tests.

TABLE 1
BOOTSTRAP LNV (1998) NONLINEAR UNIT ROOT TEST

States	LNV-A Statistics	LNV-B Statistics	LNV-C Statistics
California	-7.06**	-6.95**	-5.24*
Florida	-5.46**	-5.43**	-5.14*
Georgia	-5.27**	-6.56**	-4.27*
İllinois	-5.57**	-5.22**	-4.55*
New Jersey	-6.79**	-6.16**	-5.09*
New York	-7.03**	-7.19**	-6.03*
North Carolina	-4.85**	-6.97**	-4.40*
Ohio	-6.17**	-6.12**	-4.67*
Pennsylvania	-5.68**	-5.56*	-4.57*
Texas	-5.61**	-5.71**	-7.01**

Note: H_0 acceptance is expressed with * and H_1 acceptance is expressed with **.
H_0 = Series has unit root.
H_1 = Series is stationary with soft break.

As seen in Table 1, according to the non-linear unit root test of Leybourne et al. (2008), all state series were stationary. According to the unit root test, only the Texas series is stationary in all models.

TABLE 2
BOOTSTRAP KSS (2003) NONLINEAR UNIT ROOT TEST

States	**KSS-Raw Statistics**	**KSS-Demeaned Statistics**	**KSS-Detrended Statistics**
California	-1.68*	-2.97*	-2.41*
Florida	-2.01*	-3.08*	-5.23*
Georgia	-1.33*	-3.29*	-3.70*
İllinois	-1.52*	-3.39*	-3.79*
New Jersey	-1.80*	-6.32**	-4.28*
New York	-1.64*	-8.87*	-5.24*
North Carolina	-1.81*	-2.21*	-2.26*
Ohio	-1.90*	-2.79*	-3.59*
Pennsylvania	-2.33*	-3.69*	-2.42*
Texas	-1.77*	-6.30**	-5.23*

Note: H_0 acceptance is expressed with * and H_1 acceptance is expressed with **.
H_0 = Series is unit rooted.
H_1 = Series is nonlinear ESTAR type stationary.

As seen in Table 2, according to the nonlinear unit root test of Kapetanios, Shin and Snell (2003), California, Florida, Georgia, Illinois, New York, North Carolina, Ohio and Pennsylvania series were found to have unit roots.

TABLE 3
BOOTSTRAP SOLLIS (2009) NONLINEAR UNIT ROOT TEST

States	**Sollis-Raw Statistics**	**Sollis-Demeaned Statistics**	**Sollis-Detrended Statistics**
California	124.04**	189.26**	209.83**
Florida	113.30**	133.87**	131.28**
Georgia	127.01**	153.15**	141.08**
İllinois	127.31**	179.00**	171.85**
New Jersey	140.18**	212.91**	166.40**
New York	149.95**	238.42**	151.17**
North Carolina	127.39**	160.56**	160.94**
Ohio	129.86**	144.35**	158.01**
Pennsylvania	118.85**	175.42**	158.04**
Texas	145.04**	210.17**	186.64**

Note: H_0 acceptance is expressed with * and H_1 acceptance is expressed with **.
H_0 = Series has unit root.
H_1 = Series is symmetric or asymmetric ESTAR is stationary.

As seen in Table 3, according to the nonlinear unit root test of Sollis (2009), all series were found to be symmetric or asymmetric ESTAR stationary in all models.

TABLE 4
BOOTSTRAP KRUSE (2011) NONLINEAR UNIT ROOT TEST

States	Kruse-Raw Statistics	Kruse-Demeaned Statistics	Kruse-Detrended Statistics
California	12.45*	14.31*	10.03*
Florida	9.46*	10.76*	6.45*
Georgia	8.28*	13.52*	13.65*
İllinois	11.47**	21.28**	29.17**
New Jersey	22.86*	48.17**	23.57*
New York	43.78*	79.79*	31.91*
North Carolina	7.35*	10.27*	11.07*
Ohio	10.17*	14.79*	17.68*
Pennsylvania	12.03*	14.29*	7.20*
Texas	28.65**	35.92**	25.71*

Note: H_0 acceptance is expressed with * and H_1 acceptance is expressed with **.
H_0 = Series has unit root.
H_1 = Series ESTAR is stationary.

As seen in Table 4, according to Kruse (2011) nonlinear unit root test, California, Florida, Georgia, New York, North Carolina, Ohio and Pennsylvania series were found to have unit roots in all models. According to the unit root test, Illinois and Texas series is stationary in all models.

CONCLUSION

This study uses bootstrap nonlinear unit root tests to investigate whether unemployment hysteresis exists in selected U.S. states. We use data from 1976 to 2023 to analyze each state individually to determine the presence of long-term effects following economic shocks.

In the nonlinear unit root tests, the Leybourne et al. (LNV) test finds all series to be stationary across Model A – Sα, Model B – Sα(β), and Model C – Sαβ. According to the Kapetanios, Shin, and Snell (KSS) test, the unemployment series for California, Florida, Georgia, Illinois, New York, North Carolina, Ohio, and Pennsylvania exhibit unit roots in all model specifications. The Sollis test indicates that all states are stationary under the FAE, FAE, μ, and FAE, t models. In the Kruse test, California, Florida, Georgia, New York, North Carolina, Ohio, and Pennsylvania are found to have unit roots in all specifications, including dt = 0 (raw data), dt = 1 (demeaned data), and dt = [1 t]′ (detrended data).

Our findings show that the unemployment rate series for the states are stationary in some models while exhibiting unit roots in others. However, when considering all models collectively, the results from the Leybourne et al. (LNV) and Sollis tests—which both indicate stationarity across all states—suggest that the top 10 states, which play a significant role in the U.S. economy, tend to have natural rates of unemployment.

According to both the Kapetanios, Shin and Snell test and the Kruse test, it can be said that the unemployment rates in the 10 states of the United States of America, California, Florida, Georgia, New York, North Carolina, Ohio and Pennsylvania have unemployment hysteria. The unit root test by Kruse is the most recent test in this study. In the literature review, Blanchard and Summers (1986) introduced the unemployment hysteresis hypothesis to the literature and found stationarity in the US. Song and Wu (1997) found that the weak version of the natural rate hypothesis may be valid for the US. Ledesma (2002) shows that the natural rate hypothesis is valid for 51 states in the state-based studies. This study contains similar results with this paper. Oskooee, Chang, and Ranjbar (2018) found that 19 of the 52 states of the US showed unemployment hysteresis effect, while 33 states showed unemployment hysteresis, some during recession and some during expansion. Omay, Ozcan and Shahbaz (2020) analyzed data from 50 states and found that 47 out of 50 US states have stationary unemployment series while Arkansas, Iowa and North Carolina have unemployment hysteresis. This study obtained a similar result with the result that unemployment hysteresis was detected in the state of North Carolina as a result of the tests conducted in this article.

In economies affected by unemployment hysteresis, the impact of economic shocks becomes long-lasting rather than temporary, leading to persistent unemployment. This underscores the need for different policy interventions to absorb the effects of such shocks and manage unemployment effectively. When a shock leaves unemployment far from its long-term average, strategic policy responses may become essential to address the problem. Enhancing this resilience requires comprehensive economic reforms, sound employment policies, and programs that support sustainable growth. In addition, long-term planning is essential to increase labor market flexibility and reduce the lasting impact of shocks. Promoting economic stability will lower unemployment and help preserve broader macroeconomic equilibrium.

REFERENCES

Arestis, P., & Mariscal, Iris B., (2000). OECD Unemployment: Structural Breaks And Stationary. *Applied Economics*, *32*, 399–403.

Bahmani-Oskooee, M., Chang, T., & Ranjbar, O. (2018). Testing Hysteresis Effect in U.S. State Unemployment: New Evidence Using a Nonlinear Quantile Unit Root Test. *Applied Economics Letters*, *25*(4), 249–253.

Blanchard, O.J., & Summers, L.H. (1986). Hysteresis and the European Unemployment Problem. *NBER Macroeconomics Annual*, *1*, 15–78.

Brunello, G. (1990). Hysteresis and the Japanese Experience:A Preliminary Investigation. *Oxford Economic Papers*, *42*, 483–500.

Camarero, M., Carrión-i-Silvestre, L.J., & Tamarit, C. (2006). Testing For Hysteresis in Unemployment in OECD Countries. New Evidence Using Stationarity Panel Tests With Breaks. *Oxford Bulletin of Economics and Statistics*, *68*, 167–182.

Cardona-Arenas, C.D., & Sierra-Suarez, L.P. (2024). Remittances, Nonlabor Income as a Source of Hysteresis in Unemployment in Colombia, 2010–2020. *Latin American Research Review*, *59*, 315–340.

Harvey, D., Leybourne, I., & Stephen J. (2007). Testing for Time Series Linearity. *Econometrics Journal*, *10*, 149–165.

Harvey, D., Leybourne, I., Stephen, J., & Xiao, B. (2008). A Powerful Test for Linearity When The Order Of Integration is Unknown. *Studies in Nonlinear Dynamics & Econometrics*, *12*(3).

Friedman, M. (1968). The Role of Monetary Policy. *American Economic Review*, *58*, 1–17.

Furuoka, F. (2015). Unemployment Hysteresis in the “Nordic Kitten”: Evidence from Five Estonian Regions. *Panoeconomicus*, *62*(5), 631–642.

Gustavsson, M., & Österholm, P. (2010). The Presence of Unemployment Hysteresis in The OECD: What Can We Learn From Out-Of-Sample Forecasts?. *Empirical economics*, *38*(3), 779–792.

Kapetanios, G., Shin, Y., & Snell, A. (2003). Testing for a Unit Root in the Nonlinear STAR Framework. *Journal of Econometrics*, *112*, 359–379.

Kruse, R. (2011). A New Unit Root Test Against ESTAR Based on a Class of Modified Statistics. *Statistical Papers*, *52*, 71–85.

Lee, C.-F. (2010). Testing for Unemployment Hysteresis in Nonlinear Heterogeneous Panels: Internetional Evidence. *Economic Modelling*, 27, 1097–1102.

Lee, C.-C., & Chang, C.-P. (2008). Unemployment Hysteresis in OECD Countries: Centurial Time Series Evidence with Structural Breaks. *Economic Modelling*, *25*, 312–325.

Leybourne, S., Newbold, P., & Vougas, D. (1998). Unit Roots and Smooth Transitions. *Journal of Time Series Analysis*, *19*(1), 83–97.

León–Ledesma, M.A. (2002), Unemployment Hysteresis in the US States and the EU: A Panel Approach. *Bulletin of Economic Research*, *54*, 95–103.

Mitchell, W.F. (1993). Testing for Unit Roots and Persistence in OECD Unemployment Rates. *Applied Econometrics*, *25*, 1489–1501.

Murray, C.J., & Papell, D.H. (2000). Testing For Unit Roots in Panels in the Presence of Structural Change with an Application to OECD Unemployment. In B.H. Baltagi (Ed.), *Nonstationary Panels, Panel Cointegration and Dynamic Panels*. JAI Press.

Omay, T., Ozcan, B., & Shahbaz, M. (2020) Testing the Hysteresis Effect in The US State-Level Unemployment Series. *Journal of Applied Economics*, *23*(1), 329–348.

Phelps, E.S. (1967). Phillips Curves, Expectations of Inflation and Optimal Unemployment over Time. *Economica*, *34*, 254–281.

Plotnikov. (2019). Hysteresis in Unemployment: a Confidence Channel. *International Journal of Economic Theory*, *15*(1), 109–127.

Psaradakis, Z. (2001). Bootstrap Tests for an Autoregressive Unit Root in the Presence of Weakly Dependent Errors. *Journal of Time Series Analysis*, *22*, 577–594.

Røed, K. (1997). Hysteresis in Unemployment. *Journal of Economic Surveys*, *11*, 389–418.

Sollis, R. (2009). A Simple Unit Root Test Against Asymmetric STAR Nonlinearity with an Application to Real Exchange Rates in Nordic Countries. *Economic Modelling*, *26*(1), 118–125.

Song, F.M., & Yangru, W. (1997), Hysteresis in Unemployment Evidence From 48 U.S. States. *Economic Inquiry*, *35*, 235–243.

Yagan, D. (2017). Employment Hysteresis from the Great Recession. *NBER Working Paper Series*, *23844*.

APPENDIX

LNV (1998) NONLINEAR UNIT ROOT TEST BOOTSTAPPED VALUES

States	LNV-A			LNV-B			LNV-C		
	Bootstapped 10% critical value	Bootstapped 5% critical value	Bootstapped 1% critical value	Bootstapped 10% critical value	Bootstapped 5% critical value	Bootstapped 1% critical value	Bootstapped 10% critical value	Bootstapped 5% critical value	Bootstapped 1% critical value
California	-5.76	-6.27	-7.38	-5.98	-6.52	-7.58	-6.97	-7.53	-8.62
Florida	-5.36	-5.89	-6.96	-5.37	-5.90	-6.98	-7.17	-7.80	-8.89
Georgia	-5.19	-5.67	-6.62	-6.38	-6.91	-8.02	-5.18	-5.64	-6.53
İllinois	-4.91	-5.32	-6.19	-5.01	-5.47	-6.44	-5.55	-6.07	-7.11
New Jersey	-5.62	-6.10	-7.03	-5.99	-6.44	-7.39	-6.74	-7.30	-8.52
New York	-6.34	-6.87	-7.93	-6.85	-7.43	-8.52	-7.98	-8.68	-10.09
North Carolina	-4.52	-4.91	-5.68	-6.15	-6.71	-7.84	-5.69	-6.19	-7.10
Ohio	-5.17	-5.68	-6.61	-6.12	-6.74	-8.06	-5.37	-5.87	-6.84
Pennsylvania	-5.34	-5.78	-6.59	-6.11	-6.57	-7.49	-5.75	-6.19	-7.05
Texas	-5.84	-6.27	-7.23	-5.81	-6.26	-7.17	-6.58	-7.06	-8.00

KSS (2003) NONLINEAR UNIT ROOT TEST BOOTSTAPPED VALUES

States	KSS-Raw Statistics			KSS-Demeaned Statistics			KSS-Detrended Statistics		
	Bootstapped 10% critical value	Bootstapped 5% critical value	Bootstapped 1% critical value	Bootstapped 10% critical value	Bootstapped 5% critical value	Bootstapped 1% critical value	Bootstapped 10% critical value	Bootstapped 5% critical value	Bootstapped 1% critical value
California	-2.76	-3.24	-4.17	-3.86	-4.36	-5.31	-3.55	-4.03	-4.97
Florida	-2.95	-3.42	-4.48	-4.14	-4.71	-5.98	-5.48	-5.96	-6.97
Georgia	-2.95	-3.41	-4.37	-4.08	-4.59	-5.44	-4.38	-4.90	-5.83
İllinois	-2.43	-2.88	-3.77	-3.82	-4.28	-5.17	-4.18	-4.47	-5.59
New Jersey	-2.87	-3.31	-4.25	-5.90	-6.42	-7.41	-5.11	-5.64	-6.54
New York	-2.87	-3.36	-4.25	-10.59	-11.41	-13.05	-9.93	-10.76	-12.31
North Carolina	-2.85	-3.33	-4.28	-3.38	-3.80	-4.73	-3.43	-3.84	-4.78
Ohio	-2.66	-3.08	-3.92	-3.55	-4.02	-5.15	-4.42	-4.96	-6.03
Pennsylvania	-2.62	-3.04	-3.84	-3.69	-4.07	-4.79	-2.96	-3.32	-4.00
Texas	-2.14	-2.60	-3.42	-5.42	-5.87	-6.77	-5.48	-5.96	-6.97

SOLLIS (2009) NONLINEAR UNIT ROOT TEST BOOTSTAPPED VALUES

	Sollis-Raw Statistics			Sollis-Demeaned Statistics			Sollis-Detrended Statistics		
States	Bootstapped 10% critical value	Bootstapped 5% critical value	Bootstapped 1% critical value	Bootstapped 10% critical value	Bootstapped 5% critical value	Bootstapped 1% critical value	Bootstapped 10% critical value	Bootstapped 5% critical value	Bootstapped 1% critical value
California	6.44	12.57	26.17	23.18	27.41	37.09	25.07	29.40	38.75
Florida	6.59	8.56	14.57	11.76	14.71	22.71	11.17	14.20	21.86
Georgia	7.09	8.79	13.47	10.39	12.53	17.73	10.84	13.43	19.40
İllinois	6.34	8.05	11.76	12.94	15.23	20.38	12.33	14.55	19.56
New Jersey	9.66	11.93	16.92	22.05	25.74	33.84	14.54	17.24	22.92
New York	25.37	30.52	40.73	52.70	60.83	79.17	48.95	57.26	73.93
North Carolina	6.25	7.77	11.98	9.95	11.85	15.99	10.08	12.05	16.03
Ohio	6.70	8.42	13.15	8.88	10.80	15.58	12.09	14.72	20.96
Pennsylvania	5.02	6.31	9.29	10.01	11.93	16.10	9.22	11.17	15.31
Texas	9.32	11.23	16.05	20.06	23.29	30.87	17.57	20.71	27.68

KRUSE (2011) NONLINEAR UNIT ROOT TEST BOOTSTAPPED VALUES

	Kruse-Detrended Statistics			Kruse-Demeaned Statistics			Kruse-Detrended Statistics		
States	Bootstapped 10% critical value	Bootstapped 5% critical value	Bootstapped 1% critical value	Bootstapped 10% critical value	Bootstapped 5% critical value	Bootstapped 1% critical value	Bootstapped 10% critical value	Bootstapped 5% critical value	Bootstapped 1% critical value
California	18.14	22.26	32.66	21.61	26.37	36.72	18.47	22.48	32.22
Florida	17.43	22.21	35.18	19.91	25.09	39.12	15.74	20.11	33.48
Georgia	16.85	20.49	29.83	20.54	25.05	35.20	21.60	26.75	38.40
İllinois	15.25	18.93	26.93	19.95	24.24	33.53	23.77	28.07	39.05
New Jersey	22.89	27.81	38.67	40.38	47.03	60.95	29.68	35.02	46.74
New York	44.82	53.92	71.73	109.86	127.12	163.46	99.53	115.24	148.33
North Carolina	16.03	19.43	28.50	14.30	17.46	26.07	14.71	17.98	26.96
Ohio	15.37	19.24	28.55	16.28	19.94	30.11	23.00	28.31	42.01
Pennsylvania	13.92	16.77	24.09	16.43	19.71	26.19	12.16	15.05	20.76
Texas	21.67	25.74	35.92	33.75	39.09	51.64	34.01	39.69	53.01