Persistence and non-linearity in US unemployment: A regime-switching approach

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This article examines persistence and nonlinearity in the US unemployment rate in the post-war period by using a regime-switching unit root test. The empirical results indicate that a regime-switching unit root test outperforms conventional unit root tests and describes unemployment behavior better over the business cycle in the sample. While shocks to US unemployment dissipate in expansions, shocks to the unemployment rate seem to be persistent in recessions, supporting the hysteresis hypothesis. This is consistent with the usual explanation of hysteresis that workers may lose valuable job skills in protracted recessions.

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1. Introduction

The time series behavior of unemployment has wide implications for the conduct of macroeconomic policy. The natural rate hypothesis formulated by Phelps (1967) and Friedman (1968) implies that the unemployment rate should converge to a “natural rate” in the long run, as such deviations from the natural rate are temporary and the unemployment rate follows a mean-reverting process. On the other hand, high and persistent unemployment (particularly in European countries) has cast a doubt on the natural rate hypothesis and a competing hysteresis hypothesis was suggested by Blanchard and Summers (1987) to explain the high and persistent unemployment rates observed in some countries. In the hysteresis hypothesis, unemployed workers may lose valuable job skills over
time and recessions may have everlasting effects. In this case, shocks that affect unemployment may have permanent effects and hence unemployment is likely to exhibit a non-mean reverting process. From an empirical standpoint, evidence in favor of the unit root process indicates the existence of hysteresis while stationarity would support the natural rate hypothesis in unemployment.

There have been numerous studies that have examined the time series behavior of the US unemployment rate in the empirical literature. These studies can be classified into four groups. The first group generally employed univariate linear unit root tests. However, univariate linear unit root tests have been criticized for having low power to reject the null hypothesis of nonstationary when the span of data is not long enough. Hence the second group uses panel unit root tests to overcome the size problem in univariate unit root tests (Camarero and Tamarit, 2011; Mohan et al., 2008; Dregger and Reimers, 2009; Cheng et al., 2012). The third group of studies has focused on possible structural breaks in the US unemployment rate in testing for stationarity (Ewing and Wunnavsa, 2001; Gil-Alana, 2002; Clemente et al., 2005; Romero-Avila and Usabiaga, 2007; Lee and Chang, 2008; Lee et al., 2009).

Amable et al. (1995) and Cross (1995) emphasized that hysteresis in unemployment is essentially a feature of nonlinear models; as such, linear unit root tests are not adequate in ascertaining the presence of hysteresis in unemployment (van Dijk et al., 2002). In addition, Franchi and Ordonez (2008) noted that aggregate behavior of economic agents in labor markets is not simultaneous and nonlinear unit root tests would better capture the behavior of unemployment. Hence, the last group of studies examines the time series behavior of unemployment using nonlinear unit root tests (Caner and Hansen, 2001; van Dijk et al., 2002; Leon-Ledesma and McAdam, 2004; Caporale and Gil-Alana, 2007; Franchi and Ordonez, 2008; Lin et al., 2008).

Two important features of US unemployment that have been widely discussed in the empirical literature are persistence (van Dijk et al., 2002; Valetta and Kuang, 2012) and the asymmetric behavior of unemployment over the business cycle. The latter implies that the unemployment rate tends to increase sharply during recessions as compared to declining during expansions (Neftci, 1984; Koop and Potter, 1999; van Dijk et al., 2002; Caporale and Gil-Alana, 2008). While persistence in the unemployment rate can be examined using conventional unit root tests and other univariate methods, these tests fail to account for asymmetry. Hence nonlinear models must be employed to study the asymmetric behavior of unemployment. In this paper, we combine unit root tests and regime switching models to examine these two features of US unemployment in the post-war period.

US unemployment has increased dramatically due to the 2007–2009 global financial crisis, reaching 10.1 percent in October 2009. Even the recovery that followed thereafter did not create adequate jobs and the unemployment rate still stands at 8.3 percent as of January 2012. The high level of unemployment is one pressing problem for the US economy and understanding its behavior over the business cycle is important for formulating the policy response.

The aim of our study is to contribute to the literature by introducing the time series behavior of US unemployment by testing for the presence of unit root and regime-switching properties. In the empirical literature, the presence of a hysteresis effect for US unemployment has been examined by using some specific nonlinear unit root test (particularly threshold unit root tests). However, Maitland-Smith and Brooks (1999) showed that a Markov switching model outperforms the threshold autoregressive model particularly when the data series exhibit non-stationary properties. In addition, to the best of our knowledge, persistence and non-linearity in the US unemployment rate has not been examined using a Markov regime-switching unit root test. Toward that end, we use Markov Switching unit root tests to analyze persistence and the possibility of changing equilibrium unemployment due to breaks and business-cycle fluctuations. More importantly, we take into account regime-dependent hysteresis as multiple equilibria in the US labor market.

2. Econometric framework

We first examine the time series behavior of the US unemployment rate using the augmented Dickey and Fuller (ADF) unit root test proposed by Dickey and Fuller (1979) as follows:

$$\Delta u_t = a + \alpha u_{t-1} + \sum_{k=1}^{p} \rho_k \Delta u_{t-k} + \varepsilon_t$$ \hspace{1cm} (1)
where, $u_t$ is the unemployment rate, $a$ is the constant term, and $\varepsilon_t$ is an iid $N(0, \sigma^2)$. In Eq. (1), the null hypothesis of a unit root ($H_0$: $\alpha=0$) against the alternative of a stationary process ($H_1$: $\alpha < 0$) can be tested using the conventional $t$-ratio for $\alpha$. However, the conventional $t$-ratio for $\alpha$ cannot be used for testing the null hypothesis because the critical values are non-standard (MacKinnon, 1991).

On the other hand, conventional unit root tests have been widely criticized in the literature for having low power to reject the null hypothesis of nonstationary. Perron (1989) showed that the presence of structural breaks in the series lead to a bias against rejecting a false unit root null hypothesis and hence modified the ADF test by adding dummy variables to account for structural breaks. Zivot and Andrews (1992) indicated that structural breaks in the series may be endogenous and extended Perron’s methodology in which a structural break is determined endogenously. Lumdsdaine and Pappell (1997) and Lee and Strazicich (2003) developed unit root tests for two structural breaks in the series. Moreover, these authors showed that conventional unit root tests suffer from size distortions in the presence of a structural break in the series.

However, Nelson et al. (2001) argued that the number of regime changes in economic and financial time series might be better modeled in a probabilistic fashion rather than presuming a fixed number of structural breaks. In this context, Hall et al. (1999) employed a Markov Switching ADF (MS-ADF) test for detecting periodically collapsing bubbles. After the seminal paper of Hall et al. (1999), the MS-ADF test has been widely used for several economic and financial variables in the literature such as real exchange rates (Kanas and Genius, 2005; Kanas, 2006, 2009; Holmes, 2008, 2010), stock prices (Chen, 2008), interest rates (Chua and Suardi, 2007; Holmes, 2008), external debt (Takeuchi, 2010), inflation rate (Chen, 2010), current account deficits (Chen, 2011), and real GDP (Camacho, 2011). The general finding of these studies is that conventional unit root tests lack power substantially in the presence of a regime switch in the trend component of the series.

The regime-switching unit root test proposed by Hall et al. (1999) has the following form:

$$\Delta u_t = a(s_t) + \alpha(s_t) u_{t-1} + \sum_{k=1}^{p} \rho_k(s_t) \Delta u_{t-1} + \varepsilon_t \sim NID(0, \sum(s_t))$$

where $\Delta u_t$ is the first difference of the unemployment rate, $s_t$ is the unobservable regime, $a(s_t)$, $\alpha(s_t)$ and $\rho(s_t)$ are regime varying parameters and $\varepsilon_t$ is the innovation process. In this paper, we assume that the unemployment rate follows a two-regime Markov process and the unobserved state variable, $s_t$, evolves according to a first order Markov-switching process described in Hamilton (1994):

$$P[s_t = 1|s_{t-1} = 1] = p,$$

$$P[s_t = 0|s_{t-1} = 1] = 1 - p,$$

$$P[s_t = 0|s_{t-1} = 0] = q,$$

$$P[s_t = 1|s_{t-1} = 0] = 1 - q,$$

$$0 < p < 1, \quad 0 < q < 1$$

where $p$ and $q$ are the constant transition probabilities of being in state 0 or state 1, respectively. Note that the mean duration of staying in a state 0 or state 1 can also be calculated by $d=1/(1-p_0)$.

In the MS-ADF test, the stationarity of US unemployment can be tested according to the regimes as follows:

$H_0$: \(\alpha\) (for \(s_t=0\) and \(1\))=0

$H_{1A}$: \(\alpha\) (for \(s_t=0\) and \(1\)<0 (In this case, US unemployment is stationary in both regimes)

$H_{1B}$: \(\alpha\) (\(s_t=0\))=0 and \(\alpha\) (\(s_t=1\))=0 (In this case, US unemployment is stationary only in state 0)

$H_{1C}$: \(\alpha\) (\(s_t=0\))=0 and \(\alpha\) (\(s_t=1\)<0 (In this case, US unemployment is stationary only in state 1)

Eq. (2) can be estimated by using the maximum likelihood method based on the Expectation-Maximization (EM) algorithm discussed in Hamilton (1994) and Krolzig (1997).

The EM algorithm is an iterative maximum likelihood estimation technique designed for a general class of models where the observed time series depends on some unobservable stochastic variables. Iterations in the EM algorithm consist of two steps: In the expectation step (E), the unobserved states \(s_t\) are estimated by using their smoothed probabilities. The conditional probabilities are calculated with the BHLK (Baum–Hamilton–Lee–Kim) filter and smoother by using the estimated parameter vector \(\hat{\lambda}(J^{(1)})\) of the last maximization step instead of the unknown true parameter vector \(\lambda\). In the maximization step (M), an estimate of \(\lambda\) is derived as a solution \(\hat{\lambda}\) of the first order conditions, where
conditional regime probabilities are replaced with the smoothed probabilities of the last expectation step (Krolzig, 1997).

As in Hall et al. (1999) and Kanas and Genius (2005), we conduct Monte Carlo simulations to determine the critical values because the distribution under the null hypothesis is not standard in the MS-ADF test. Monte Carlo simulations consist of four steps:

The first step of Monte Carlo simulations is to determine the p-values associated with the t-tests of the null hypotheses against the respective one-sided alternatives by estimating Eq. (2) under the null \( \alpha(s_t)=0, s_t=0, 1 \). In the second step, we simulate a single series \( s_t \) by generating samples of size 241 (which is equal to the number of observations in our sample) that follow this estimated Data Generating Process (DGP) and the estimate transition probabilities. Then we generate 10,000 pseudo random numbers for the \( \varepsilon_t \) series from a \( N(0, \sum(s_t)) \) and simulate data for \( \Delta u_t \) with the aforementioned estimates of the parameters under the null hypothesis. In the third step, we fit Eq. (2) to each realization of \( \Delta u_t \), thus obtaining two series of t-statistics for the parameter \( \alpha \), one for state 0 and the other for state 1. Finally, the simulated p-values are calculated as the percentage of the generated t-ratios that are below the t-values from the estimated model (Kanas and Genius, 2005).

3. Data and empirical results

We use quarterly seasonally adjusted unemployment rates for the US. The data is obtained from the Federal Reserve Bank of Saint Louis from 1948:1 through 2011:3. The unemployment rate series is presented in Fig. 1. Two important features of the US unemployment rate can be seen in Fig. 1. The first is the asymmetric behavior of unemployment over the business cycle. It is noteworthy that the US unemployment rate increases sharply during recessions and decreases slowly during expansions. The second feature of the US unemployment rate is its high degree of persistence. These two features of US unemployment are consistent with theoretical expectations because several theories from labor economics such as the insider-outsider theory where insiders have more privileged positions, asymmetries in job creation and destruction, and asymmetric labor adjustment costs imply the presence of asymmetric behavior in unemployment over the business cycle.

As a first step, we implement a linear ADF test with a constant term in order to determine the order of integration of US unemployment. We select the optimum lag via the Akaike information criterion (AIC). The AIC indicates that 13 lags are sufficient to render residuals white noise in the ADF test. The ADF test statistic is –2.216 (p-value: 0.201), which is higher than McKinnon critical values, and hence we cannot reject the null hypothesis of a unit root.

\footnote{Camacho (2011) employed both Monte Carlo simulations and the bootstrap procedure to determine the critical values for the MS-ADF test and found that both methods provide similar results.}
The ADF test results suggest that the unemployment rate is an I(1) process and this is in line with the empirical literature. An important implication is that any shocks to unemployment are persistent and hence the unemployment rate does not have mean reverting properties. However, the ADF unit root test may have low power if the data generating process in question has non-linear properties. Also, it is well known that linear unit root tests suffer from size distortions in the presence of structural breaks in the series when the estimation period is sufficiently large. Therefore, we employ the MS-ADF test to examine whether unemployment has regime-switching unit root properties.

The first step of the MS-ADF test is to determine the optimal lag length. The Akaike information criterion indicates that 13 lags is sufficient to render residuals white noise. We then calculate the LR statistics to determine the fit of the linear versus the non-linear regime-switching test and which testing procedure better captures unemployment behavior over the sample. Since the linear model is a special case of the non-linear model, the LR statistics is appropriate. In this case the LR statistic is 125.81 ($p$-value is 0.000), indicating the linear model is soundly rejected in favor of a nonlinear (regime-switching) model even if the Davies (1987) $p$-value is considered. This shows that US unemployment exhibits non-linear properties and a linear test is misspecified.

The next step of the MS-ADF test is to identify the regimes. Therefore, we calculate the estimated transition probabilities from the MS-ADF test to compare with NBER recessions. The estimated smoothed probabilities for state 1 in Fig. 2 clearly correspond to the NBER recessions and hence state 1 can be identified as recessions.

We present the estimated coefficients of the MS-ADF test in Table 1. Based on the estimated transition probabilities, the expansion regime is more persistent than the recession regime. In this context, the probability of remaining in an expansion at time $t$ when the series is also in an expansion regime at time $t−1$ is 91.3%, whereas the probability of remaining in a recession at time $t$ when the series is also in a recession regime at time $t−1$ is 87.7%. According to transition probabilities, the mean duration of expansion and recession regimes is 13.55 and 8.36 quarters respectively. The estimated mean duration of expansion is found to be very close to the historical average duration of NBER expansion (59 months or 14.75 quarters).

On the other hand, the estimated mean duration for recession is found to be more than three times the historical average duration of NBER recession (11 months or 2.75 quarters). This finding is

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2 The maximum lag length was set to 15 in the ADF and MS-ADF tests. We also consider the Modified Akaike information criterion (MAIC) proposed by Ng and Perron (2001) for the ADF test and we cannot reject the null hypothesis of unit root.

3 We also compute the Sup-Wald test proposed by Caner and Hansen (2001) to determine whether or not there is a threshold effect in US unemployment. The test statistics is found to be 52.4 ($p$-value=0.000) and this supports the presence of nonlinearity.
consistent with a priori expectations because several studies in the literature emphasize the high persistence in US unemployment rates. Therefore, the mean duration of recessions for US unemployment may be higher than that when output is considered.

The estimated autoregressive parameters ($\alpha$) in the MS-ADF test suggest that US unemployment is stationary only in the expansion regime at the 1% significance level. This result indicates that the unemployment rate has mean-reverting properties in an expansion regime. On the other hand, there is evidence of the presence of hysteresis in recessions because the null hypothesis of unit root cannot be rejected (simulated $p$-values are 0.000 and 1.000 for the expansion and recession regimes respectively).\footnote{In order to examine the robustness of MS-ADF test results, we employ the threshold unit root test suggested by Caner and Hansen (2001). $p$-Values for the null hypothesis of unit root are 0.111 and 0.731 for expansion and recession regimes respectively. This is consistent with MS-ADF results because the rejection level of the null hypothesis for the expansion regime significantly decreases in the threshold unit root test.} An important implication is that any shocks to unemployment are not transitory and hence unemployment does not have mean-reverting properties in recessions. This implies that unemployment rates might affect the level of frictional unemployment. A common explanation is that employed workers lose valuable job skills and find it harder to get jobs during recessions when the unemployment rate is high. Also, employed workers might lose some of their desire to work, and hence do not search as hard for a job. Finally, past unemployment rates might affect the level of wait unemployment and hence create path dependence in the unemployment rate, particularly in recessions.

### 4. Conclusions

The time series behavior of unemployment is important for the conduct of effective economic policy. This article studies the behavior of the US unemployment rate over the post-war period. We analyze the behavior of unemployment using linear and regime-switching unit root tests. The empirical results suggest that unemployment has regime-dependent properties and the Markov Switching-ADF test captures unemployment behavior better than a linear ADF test. We also find a

#### Table 1

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Expansion regime</th>
<th>Recession regime</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficients</td>
<td>Std. error</td>
</tr>
<tr>
<td>$A$</td>
<td>0.075</td>
<td>(0.006)</td>
</tr>
<tr>
<td>$\alpha$ [p-value]</td>
<td>$-0.040$</td>
<td>(0.012)</td>
</tr>
<tr>
<td>$\rho_1$</td>
<td>0.207</td>
<td>(0.083)</td>
</tr>
<tr>
<td>$\rho_2$</td>
<td>$-0.101$</td>
<td>(0.066)</td>
</tr>
<tr>
<td>$\rho_3$</td>
<td>$-0.002$</td>
<td>(0.072)</td>
</tr>
<tr>
<td>$\rho_4$</td>
<td>$-0.232$</td>
<td>(0.065)</td>
</tr>
<tr>
<td>$\rho_5$</td>
<td>$-0.045$</td>
<td>(0.064)</td>
</tr>
<tr>
<td>$\rho_6$</td>
<td>$-0.101$</td>
<td>(0.063)</td>
</tr>
<tr>
<td>$\rho_7$</td>
<td>0.201</td>
<td>(0.053)</td>
</tr>
<tr>
<td>$\rho_8$</td>
<td>$-0.163$</td>
<td>(0.055)</td>
</tr>
<tr>
<td>$\rho_9$</td>
<td>0.012</td>
<td>(0.053)</td>
</tr>
<tr>
<td>$\rho_{10}$</td>
<td>$-0.074$</td>
<td>(0.052)</td>
</tr>
<tr>
<td>$\rho_{11}$</td>
<td>0.143</td>
<td>(0.047)</td>
</tr>
<tr>
<td>$\rho_{12}$</td>
<td>$-0.175$</td>
<td>(0.050)</td>
</tr>
<tr>
<td>$\rho_{13}$</td>
<td>0.075</td>
<td>(0.047)</td>
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<tr>
<td>$\Sigma$</td>
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<tr>
<td>$\rho_{00}$</td>
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<td></td>
</tr>
<tr>
<td>$\rho_{11}$</td>
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<td></td>
</tr>
<tr>
<td>$\chi^2$</td>
<td>125.81 [0.000]</td>
<td></td>
</tr>
</tbody>
</table>

Note: The simulated $p$-value is in square brackets. $\sigma$ shows the standard error of regression. $p_j$ indicate transition probabilities. $\chi^2$ is the LR test that null hypothesis of no regime switching. Davies $p$-value is the upper bond $p$-value of the LR test.
regime-dependent nonstationarity in the unemployment rate. Although unemployment has mean-reverting properties in expansion regimes, the null hypothesis of unit root cannot be rejected in recession regimes, which is consistent with hysteresis in unemployment. This has some important policy implications. If unemployment is not addressed by policymakers, it may persist and pose serious social and economic problems. Particularly if the spells of unemployment are long and protracted, unemployed workers lose valuable job skills and therefore remain unemployable. From a policy standpoint, the presence of hysteresis in recessions implies that Keynesian demand-driven policies are relevant in combating unemployment in the long run. Since there is path dependence in unemployment, measures reducing the unemployment rate are likely to be effective. Therefore, a combination of demand-driven and structural policies must be implemented to reduce unemployment in protracted recessions.

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