Empirical Economics (1995) 20:717–725

Short Paper

Quarterly US Unemployment: Cycles, Seasons and Asymmetries

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Abstract: This paper documents three stylized facts for the quarterly unemployment rate in the United States. Firstly, unemployment is asymmetric over the business cycle, i.e. it rises sharply in recessions and it falls slowly in expansions. Secondly, its seasonal fluctuations are not constant across the two business cycle stages in the sense that there is less seasonality in recession periods. Thirdly, the effect of shocks to the unemployment rate in expansions seem transitory, while this effect is permanent in recessions. Some implications of these stylized facts for empirical macroeconomics and seasonal adjustment are discussed.

JEL Classification System-Numbers: C22, E24

1 Introduction

For the United States economy it is now widely recognized that the business cycle displays asymmetric patterns. Roughly speaking, these asymmetries in macroeconomic variables as investment and employment may concern different positive and negative growth processes in expansion and contraction periods, respectively. Given the asymmetries, and also given the fact that recessions typically cover short periods with a large impact on the time series path of economic variables, much recent research has been dedicated to describing asymmetric macroeconomic time series, see Neftçi (1984), Hamilton (1989), Durland and McCurdy (1994) and Filardo (1994). These studies mainly consider variables as GNP and unemployment in the US. The presence of asymmetric employment dynamics in the United Kingdom economy is documented in Burgess (1992). Studies on asymmetry usually consider seasonally adjusted (SA) data. Recently, there has been a growing interest in empirical macroeconomics to analyze seasonally unadjusted (NSA) time series, see Hylleberg (1994) and Miron (1994), *inter alia*. Additionally, several studies investigate possible links between seasonal and business cycle variation. For example, Barsky and Miron (1989) document that there is a seasonal cycle in the US economy which has characteristics that mirror those of the conventional business cycle, while

0377–7332/95/4/717–725 $2.50

Canova and Ghysels (1994) explore whether seasonal mean shifts in US macroeconomic time series are significantly different during expansions and contractions. The overall conclusion from these studies is that it seems useful to jointly investigate seasonal and business cycle patterns.

In the present paper we focus on seasonality and business cycles in the US unemployment rate with the purpose to document some key stylized facts of this variable. For this purpose we rely on econometric time series analysis techniques. The proposed econometric model nests the models proposed in Barsky and Miron (1989) and Canova and Ghysels (1994) in the sense that it involves a simple autoregressive distributed lag (ADL) model with output as an explanatory variable and that it allows the dynamic parameters to vary with the seasons. We document that seasonal fluctuations are not constant over the business cycle, that seasonality in contraction periods is different from that in expansion periods, and that the unemployment rate is mean-reverting in expansion stages while it contains a stochastic trend in contraction periods.

2 The Model and Hypotheses

Consider the graph of the United States unemployment rate in the period 1966.1 through 1993.4, ur_t, as it is given in Figure 1. We confine ourselves to this sample period since it includes major economic upswings and downturns. In this Figure we present the ur_t series when it is decomposed into four annually observed series $UR_{s,T}$, which contain the observations per season s in year T, $s = 1, 2, 3, 4$, $T = 1, \ldots, N = n/4$. The source of the data is the *OECD Main Economic Indicators*, and the data are not transformed using logs. Together with the $UR_{s,T}$ series, Figure 1 includes indications of the business cycles stages, i.e. expansion (e) and contraction (c). The NBER business cycle chronology is used to define the contraction and expansion periods. This means that the recessions are assumed to cover 1970.1–1970.4, 1974.1–1975.1, 1980.2–1980.3, 1981.4–1982.4 and 1990.4–1991.2. In total, there are 19 quarterly observations which correspond to a recession. For the first, second and fourth quarter data, 5 observations correspond to a recession, while for the third quarter only 4 observations do so. This small number of observations should be borne in mind when cautiously interpreting the empirical findings below.

The first conclusion from Figure 1 is that the unemployment rate shows asymmetries. In expansion periods the pattern of the ur_t series seems to differ from that in contractions in the sense that the rate of change differs. The second aspect of Figure 1 is that the series does not seem to be stationary over the entire sample. More precisely, after a recession, the mean of the time series does not always return to its value right before that recession. Although in expansion periods there seems to be a tendency towards some stable value (which is roughly 5%), any new recession abruptly ends such a tendency. This asymmetry

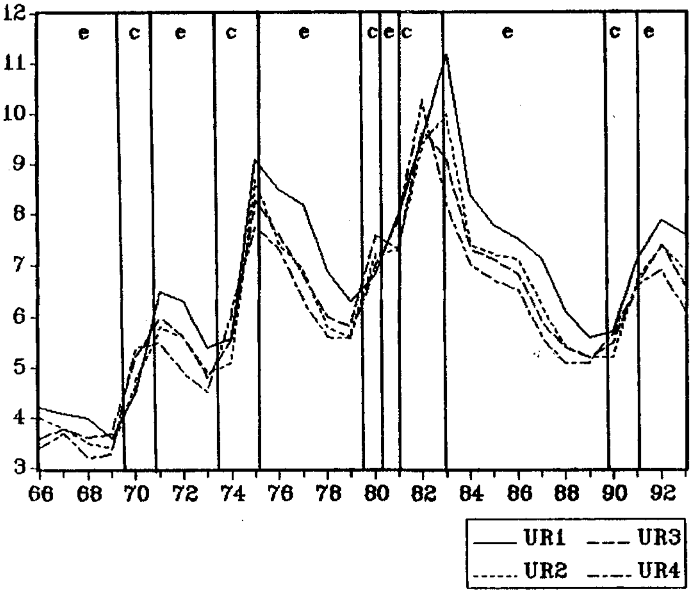

Fig. 1. Contractions (c) and expansions (e) in the US unemployment rate: 1966.1–1993.4

suggests that shocks in contractions have more impact on the time series path than shocks in expansions. Given the mean-reverting tendency in expansions, the question arises whether the ur_t series contains one or more unit roots over the whole sample. Theoretically, assuming unit roots for the entire observation period means that all shocks have permanent effects. Although Figure 1 suggests that shocks in contractions may have such permanent effects, the ur_t series should bounded between 0 and 100. Therefore, the assumption of a unit root at the zero frequency implies that in principle the series can cross these boundaries. A third and final aspect of Figure 1 is that seasonal fluctuations seem to change over the sample in that there is a marked seasonal pattern in expansions but not in contractions. It can be seen that in expansion periods the $UR_{s,T}$ series show regular patterns with the distances between the series approximately constant and that there are not many intersections. On the other hand, in contractions the $UR_{s,T}$ series seem difficult to disentangle, i.e. there seems "less seasonality" in a recession. This suggests that the dynamic behavior of the ur_t time series varies throughout the year, which implies that we wish to account for such seasonal variation in the dynamics in our econometric model.

In the present paper the framework to describe quarterly unemployment is assumed to the ADL model:

$$\Delta_1 ur_t = -\alpha ur_{t-1} + \gamma_s + \delta \Delta_1 y_t + \varepsilon_t \ , \tag{1}$$

where ε_t is a standard white noise error process, where Δ_1 is the first order differencing filter defined by $\Delta_k x_t = (1 - B^k)x_t = x_t - x_{t-k}$, where y_t denotes the log of output, and where γ_s are seasonally varying intercepts. This model corresponds to the models (for employment) in Sims (1974) and Kennan (1979), see also Nickell (1986). From an economic viewpoint, model (1) is related to dynamic labor models, which originate from the class of linear quadratic adjustment cost models, see Nickell (1986). To arrive at (1), one needs to assume non-zero adjustment costs, which are reflected by the α parameter, and the validity of static expectations. Sims (1974) and Kennan (1979) show that similar models as (1) can adequately describe employment fluctuations. The additional assumptions we make here are that the framework adopted in the aforementioned studies for labor demand carries over to the unemployment rate and that log output is a nonstationary variable that needs to be differenced once to become stationary. Of course, the simple model in (1) may not reflect the most sophisticated economic theory for the unemployment rate, but it suffices for our current purposes. In fact, it will be modified below by allowing the parameters to vary with the seasons and with the business cycle. More complicated dynamic econometric models may yield many additional parameters and hence possible estimation problems. Finally, the application of diagnostic checks to the estimated version of our model should prevent us from drawing inappropriate conclusions.

The visual evidence obtained from an inspection of Figure 1 suggests the following modifications to (1). Firstly, the adjustment parameter α may vary with expansions (e) and contractions (c), i.e that α_e may be unequal to α_c. Note that when $\alpha_c = 0$ and $\alpha_e > 0$, the ur_t process has stochastic trend behavior in recessions and mean-reverting behavior in expansions. Secondly, there may be seasonal variation in the adjustment process, i.e. α can be α_s, where the index s indicates that the parameter can take different values over the seasons. An economic motivation for this may be that seasonally varying labor supply may facilitate adjustment in some seasons more than in others. Thirdly, some or all α_s may take different values across the business cycle, i.e. α may be replaced by α_{es} and α_{cs}, and therefore the γ_s in (1) may be replaced by γ_{es} and γ_{cs}. Finally, an (unreported) scatter plot of ur_t versus y_t, where the source of the output data is the *OECD Main Economic Indicators* (NSA total industrial production), suggests that the relation between these two variables may also vary across the business cycle. For (1) this implies that δ can be replaced by δ_e and δ_c. To keep the degrees of freedom at a reasonable level, we abstain from modifying δ_e and δ_c into δ_{es} and δ_{cs}. Taking all these suggested modifications to (1) together, the econometric model that allows us to formally establish some empirical stylized facts with respect to asymmetries in seasons and business cycles for US unemployment is given by

$$\Delta_1 ur_t = -\alpha_{es} ur_{t-1} + \gamma_{es} + \delta_e \Delta_1 y_t - \alpha_{cs} ur_{t-1} + \gamma_{cs} + \delta_c \Delta_1 y_t + \varepsilon_t \ , \qquad (2)$$

In unrestricted form this model contains 18 parameters to be estimated, where the parameters α_{cs} are only estimated using 4 or 5 observations. Hence, one should account for the fact that there are not too many degrees of freedom. Note that when $\alpha_{es} = \alpha_{cs} = 0$ and $\delta_e = \delta_c = 0$, (2) reduces to a model similar to that used in Canova and Ghysels (1994), and when additionally $\gamma_{es} = \gamma_{cs}$, a similar model as in Barsky and Miron (1989) emerges.

The conjectures with respect to possible empirical stylized facts for the ur_t series can now be summarized as tests for restrictions on the parameters in (2). The first is that the adjustment process, which is reflected by α, varies with the business cycle. This hypothesis can be formulated as

$$H_{11}\colon \alpha_{es} \neq \alpha_{cs} \qquad \text{for each } s \ . \tag{3}$$

It can be tested with an F type test which follows a standard F distribution. The second hypothesis that corresponds to asymmetry over the business cycle is

$$H_{12}\colon \delta_e \neq \delta_c \qquad \text{and} \qquad |\delta_c| > |\delta_e| \ . \tag{4}$$

This hypothesis implies that when $\Delta_1 y_t$ is negative, which is often the case in recessions, the impact on the increase in ur_t exceeds the decreasing effect when $\Delta_1 y_t$ is positive, which is often the case in expansions. The second possible stylized fact for unemployment, which is that the (dynamic) seasonal fluctuations may vary over the business cycle, can be formulated as the hypothesis

$$H_2\colon \alpha_{es} \neq \alpha_e \qquad \text{and} \qquad \alpha_{cs} \neq \alpha_c \qquad \text{for all } s \ . \tag{5}$$

Again the statistical validity of this hypothesis can be checked using an F type test which follows a standard F distribution under the relevant null hypothesis.

The third possible stylized fact concerns stochastic trend behavior across the business cycle. Given H_2, it seems not useful to investigate this stylized fact via testing, e.g., $\alpha_{cs} = 0$ in (2) since one may find that in fact $\alpha_{cs} \neq \alpha_c$ via (5). Hence, one should consider an alternative method to check whether the time series has a stochastic trend in each business cycle stage. It is now important to recognize that, when abstaining from output and seasonal intercepts, the ur_t series in (2) can be described by a first order periodic autoregressive process, i.e.

$$ur_t = \phi_s ur_{t-1} + \psi_t \ , \tag{6}$$

where ϕ_s is periodically varying parameter defined by $\phi_s = (1 - \alpha_s)$. The characteristic equation for ur_t in (6) is $1 - (\phi_1\phi_2\phi_3\phi_4)z = 0$, see Osborn (1991) and Franses (1994), *inter alia.* Hence, the process ur_t is said to be periodically integrated when $\phi_1\phi_2\phi_3\phi_4 = 1$ and not all $\phi_s = \phi$. A test for a unit root in a periodic autoregression is proposed in Boswijk and Franses (1994). Here it amounts to comparing the residual sum of squares (RSS_1) of the unrestricted regression (6) with the RSS_0 of the nonlinear least squares regression with the imposed restriction $\phi_1\phi_2\phi_3\phi_4 = 1$. The relevant test statistic is $\text{BF} = [\text{sign}(\hat{\phi}_1\hat{\phi}_2\hat{\phi}_3\hat{\phi}_4) - 1)]$ $(n \log(RSS_0/RSS_1))^{1/2}$. This test follows the standard Dickey-Fuller distribution. To test for a unit root, it is useful to define $\phi_{is} = 1 - \alpha_{is}$ with $i =$ e, c in (2). The relevant hypothesis is now

$$H_3\colon \phi_{e1}\phi_{e2}\phi_{e3}\phi_{e4} < 1 \qquad \text{and} \qquad \phi_{c1}\phi_{c2}\phi_{c3}\phi_{c4} = 1 \ . \tag{7}$$

Note that the null hypothesis concerns the case where shocks to unemployment are persistent in recessions and transitory in expansions. Furthermore, notice that when $\phi_{es} \neq \phi_e$ and $\phi_{cs} \neq \phi_c$ for all s, H_3 implies that for the entire sample it is the level of unemployment that depends on output growth (since not all adjustment parameters equal zero).

3 Empirical Results

The model is estimated for the sample 1966.1 through 1993.4, where the observation in 1965.4 is used as a starting-value. Hence, the sample contains 112 observations. The number of observations in recession periods is 19, and in contraction periods it is 93. Notice that the α_{cs} parameters are estimated using either 5 or 4 data points, and hence that one should interpret the empirical results with some caution.

The γ_{es} and γ_{cs} parameters in (2) are difficult to interpret since they correspond to mixtures of intercept parameters. Therefore, we only report the results for the ϕ_{es}, ϕ_{cs}, δ_e and δ_c parameters. The OLS results are

$$\begin{aligned} ur_t = {} & D_{et}(\underset{(0.025)}{1.060}D_{1t}ur_{t-1} + \underset{(0.023)}{0.902}D_{2t}ur_{t-1} + \underset{(0.028)}{0.973}D_{3t}ur_{t-1} + \underset{(0.028)}{0.908}D_{4t}ur_{t-1}) \\ & + D_{ct}(\underset{(0.057)}{1.097}D_{1t}ur_{t-1} + \underset{(0.054)}{0.863}D_{2t}ur_{t-1} + \underset{(0.052)}{0.982}D_{3t}ur_{t-1} + \underset{(0.052)}{1.093}D_{4t}ur_{t-1}) \\ & - \underset{(1.477)}{8.188}D_{et}\Delta_1 y_t - \underset{(2.362)}{18.905}D_{ct}\Delta_1 y_t + \hat{\gamma}_{es} + \hat{\gamma}_{cs} + \hat{\varepsilon}_t \,, \end{aligned} \tag{8}$$

where $D_{1t}, \ldots, D_{4t}$ are the usual seasonal dummies, and where D_{et} and D_{ct} are dummies that take a value of 1 in expansions and recessions, respectively, and a value of zero elsewhere. Since the ϕ_{cs} and ϕ_{es} may be equal to one, the estimated standard errors in parentheses should be interpreted with care. The Box-Pierce test for residual autocorrelation until 12 lags obtains the insignificant value of 13.86, and the F versions of LM tests for ARCH of orders 1 and 4 obtain the values of 0.005 and 0.711. The $\chi^2(2)$ normality test has a value of 6.818, which is not significant at the 1% level.

The four $F(1, 94)$ test statistics for the hypotheses that α_{cs} equals α_{es} for $s = 1$, 2, 3, 4 obtain values of 0.343, 0.436, 0.022 and 9.930. A joint $F(4, 94)$ test statistic for the hypothesis that α_{cs} equals α_{es} for all s yields a value of 2.685. Except for the $F(1, 94)$ statistic in the fourth quarter, all these F test values do not exceed the 5% critical level. Hence, any asymmetry in unemployment dynamics seems mainly confined to the last quarter. This implies that only part of the hypothesis H_{11} in (3) is supported. In terms of adjustment processes, the standard error of $\hat{\phi}_{4c}$ in (8) seems to indicate that there is no adjustment in the contraction stage. However, the adjustment parameter α_{4e} is estimated as 0.092 with an absolute t ratio of 3.321. Furthermore, the $F(1, 94)$ test for the hypothesis that δ_e is equal to δ_c yields the highly significant value of 14.797. From (8) it can be observed that $|\delta_c|$ exceeds $|\delta_e|$ indeed. In sum, these results seem to confirm (part of) H_{11} and H_{12} formulated in (3) and (4), i.e. the unemployment rate displays asymmetric business cycle patterns.

With respect to asymmetries in dynamic seasonal fluctuations, the two $F(3, 94)$ test statistics for the hypotheses that the α_{is} equal α_i for i = e, c obtain values 8.831 and 4.327. Both values exceed the 5% significance level. This means that there appears to be a marked seasonal pattern in both business cycle stages. Given that the $F(3, 94)$ statistic value for the expansion periods is about twice as large as that in recessions, there is also some indication that there is "more seasonality" in expansions. The empirical evidence obtained can be summarized as that seasonal fluctuations differ across the two business cycle stages.

The remaining question is now whether unit root type behavior varies over the business cycle. Although the number of observations is not very large in our application, it is of interest to check whether a parameter restriction like $\phi_1\phi_2\phi_3\phi_4 = 1$ is valid in each of the two business cycle stages. For the contraction stage $\hat{\phi}_{e1}\hat{\phi}_{e2}\hat{\phi}_{e3}\hat{\phi}_{e4}$ equals 1.016, and for the expansion stage the similar product takes a value of 0.846. The BF tests, which are calculated for 19 and 93 observations only, obtain the values 0.068 and -3.088, respectively. The 5% critical value for the BF test, when the auxiliary regression contains seasonal constants, is about -3.00. Hence, the null hypothesis of a unit root cannot be rejected for recessions, while it is rejected at a 5% level for expansions. Given the empirical support for H_2 in (5), this implies that ur_t is periodically integrated in contraction periods and periodically stationary in expansions, and hence that there is empirical support for H_3 in.

Imposing the aforementioned parameter restrictions, the final estimation results are $\hat{\alpha}_{e1} = \hat{\alpha}_{c1} = -0.064$ (0.021), $\hat{\alpha}_{e2} = \hat{\alpha}_{c2} = 0.106$ (0.019), $\hat{\alpha}_{e3} = \hat{\alpha}_{c3} =$ 0.028 (0.022), $\hat{\alpha}_{e4} = 0.092$ (0.027), $\hat{\alpha}_{c4} = 1 - [(1 - \hat{\alpha}_{c1})(1 - \hat{\alpha}_{c2})(1 - \hat{\alpha}_{c3})]^{-1} =$ 0.075, $\hat{\delta}_c = -8.120$ (1.383) and $\hat{\delta}_c = -18.754$ (2.217), where estimated standard errors are given in parentheses. Note that α_{e3} and α_{c3} are not significantly different from zero.

In summary, a time series analysis of the quarterly unemployment rate yields the following three conclusions. The unemployment variable shows asymmetric business cycle patterns. This stylized fact has already been documented in many studies, see, e.g., Neftçi (1984). Furthermore, the seasonal fluctuations vary with the business cycle stages. Finally, in expansions the time series can be described using a stationary periodic model, while in contractions unemployment contains a unit root, implying that, in contrast to expansions, shocks in recessions have a permanent impact.

4 Implications and Concluding Remarks

There are several implications of the empirical time series results reported in this paper. One reason for variation in the seasonal fluctuations over the business cycle seems to be that in recessions there is less opportunity for employers to adjust to disequilibrium errors throughout the year than there is in expansions. Our results paper suggest that theoretical models for unemployment may be modified by incorporating parameters that vary with the seasons, and also by including some mechanism that generates changing seasonality. The second implication is that the use of seasonal adjustment techniques may not be appropriate for variables as the unemployment rate. This is because the key assumption of seasonal adjustment, i.e. that cycles, trends and seasons can be separated in some sense, is violated. A third implication is that, given that unemployment seems stationary in expansions while it contains a unit root in recessions, one may question the use of unit root tests to a sample containing all observations. Finally, the forecasts generated from the estimated model for unemployment will show different patterns according to the business cycle stage. In recessions where the series has a unit root, the effect of a shock is different, and this will be reflected by the pattern of forecasts and their error variances. In expansions where the time series appears (periodically) stationary, forecasts will converge to the seasonal means.

Acknowledgements: The author thanks the Royal Netherlands Academy of Arts and Sciences for its financial support. This paper was presented at seminars at the University of California in Berkeley and Cornell University (April 1994). Helpful comments from the seminar participants, as well as from Lourens Broersma, Fabio Canova, Marius Ooms, two anonymous referees and the Editor Baldev Raj are gratefully acknowledged.

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First version received: January 1994
Final version received: September 1995