ECONOMIC RESEARCH REPORTS

FURTHER EVIDENCE ON THE ASYMMETRIC BEHAVIOR OF UNEMPLOYMENT RATES OVER THE BUSINESS CYCLE

by

Philip Rothman

R.R. #88-23

June 1988

C. V. STARR CENTER
FOR APPLIED ECONOMICS

NEW YORK UNIVERSITY
FACULTY OF ARTS AND SCIENCE
DEPARTMENT OF ECONOMICS
WASHINGTON SQUARE
NEW YORK, N.Y. 10003

May 20, 1988

Further Evidence on the Asymmetric Behavior of Unemployment Rates over the Business Cycle*

Philip Rothman
Economics Department
New York University
269 Mercer Street, 7th Floor
New York, N.Y. 10003

Abstract:

A modified version of Neftci's test is applied to a group of quarterly U.S. unemployment rates in an attempt to detect systematic asymmetric behavior. In particular, statistical evidence is presented which implies that it is more appropriate to assume the sample state-indicator sequence is a first-order, rather than second-order, Markov process. The subsequent results suggest that the primary source of asymmetry in the total unemployment rate is the cyclical behavior of the unemployment rate in the manufacturing sector.

---

*This paper grew out of the "Seminar in Econometrics and Non-Linear Dynamics" at New York University. Special thanks go to the seminar's coordinator, Prof. J. Ramsey, for his generous comments and suggestions. Discussions with J. Batarce and E. Goldrich were also very helpful.

I. Introduction

The idea that the business cycle is asymmetric can be traced back at least sixty years to the work of Mitchell [1927] and Keynes [1936]. It is often consequently referred to as the Mitchell-Keynes business cycle hypothesis (MKBCH). Recently, a small macroeconometrics literature has developed in which the MKBCH has been subjected to formal statistical testing.

The MKBCH is primarily twofold: economic expansions are longer but less sharp than downturns. The significance of this issue, for both theoretical and applied work, has been stressed by many authors. First, in so far as they are linear, a very wide class of models implicitly assumes that business cycles are symmetric. Hence, detection of systematic asymmetric behavior would suggest the need to develop and consider more closely non-linear theoretical models which generate this feature. Second, under the usual assumptions standard linear time series and structural econometric models are unable to produce cyclical asymmetries.

This paper stems directly from the work of Neftci [1984][1]. In his paper Nefcti tested the MKBCH by using the statistical theory of finite-state Markov chains. One purpose of the current paper is to test for Neftci-type asymmetry

---

[1] Other direct contributions to the literature include DeLong and Summers [1986], Falk [1986], Nefcti and McNevin [1986] and Sichel [1987a] and [1987b]. Two articles which touch on this issue, within the context of appropriate detrending methods of nonstationary time series, are Hamilton [1987] and Quah [1987].

in unemployment rates under an alternative, and simplified, specification of the key sample Markov process examined. The motivation for this is the practice that Neftci and other researchers have followed in generically assuming, without statistical verification, the order of this Markov process to be two. In this paper it is shown that for most of the series examined it is difficult to reject the first-order hypothesis.

The second purpose of this paper is to widen the set of data to which the test is applied. Neftci primarily focused on the cyclical behavior of the total unemployment rate. While this series is tested under the first-order assumption in this paper, the MKBCH is also tested by examination of the symmetry properties of unemployment rates across industrial sectors. The latter is done in order to isolate those sectors which are the sources of the asymmetric behavior.

Section II sets up and summarizes the test. In Section III the main results are discussed. Section IV concludes the paper. A data appendix is also included.

II. The Test

Let $\{X_t\}$ be a stationary economic time series and define the state-indicator sequence $\{I_t\}$ by:

$$I_t = \begin{cases} 1 \text{ if } \Delta X_t > 0 \\ 2 \text{ if } \Delta X_t \leq 0 \end{cases} \tag{1}$$

Further, assume the sequence $\{I_t\}$ is a stationary stochastic process. Neftci also assumed $\{I_t\}$ is a second-order Markov process. This practice was later followed by Nefcti and McNevin [1986] and Falk [1986]. As such, the steady-state log-likelihood function corresponding to a given realization S_T of $\{I_t\}$ is:

$$\begin{aligned} L(S_T, p_{111}, p_{112}, \ldots) = \quad & n_{111} \cdot \log(p_{111}) + n_{112} \cdot \log(p_{112}) + \\ & n_{121} \cdot \log(p_{121}) + n_{122} \cdot \log(p_{122}) + \\ & n_{211} \cdot \log(p_{211}) + n_{212} \cdot \log(p_{212}) + \\ & n_{221} \cdot \log(p_{221}) + n_{222} \cdot \log(p_{222}), \text{ where} \end{aligned} \tag{2}$$

$p_{ijk} = \text{Prob}(I_t = k \mid I_{t-1} = j,\ I_{t-2} = i)$,

n_{ijk} = the number of occurrences of $(I_t = k \mid I_{t-1} = j,\ I_{t-2} = i)$,

$i,j,k = 1,2$ and $t = 3, \ldots, T$. Note that $p_{ijk} = 1 - p_{ijk'}$, $k \neq k'$, because there are only two possible states.

Under the assumption that $\{I_t\}$ is a first-order Markov process, the log-likelihood function is:

$$L(S_T, p_{11}, p_{12}, p_{21}, p_{22}) = n_{11} \cdot \log(p_{11}) + n_{12} \cdot \log(p_{12}) + n_{21} \cdot \log(p_{21}) + n_{22} \cdot \log(p_{22}), \text{ where} \tag{3}$$

$p_{ij} = \text{Prob}(I_t = j \mid I_{t-1} = i)$,

n_{ij} = the number of occurrences of $(I_t = j \mid I_{t-1} = i)$,

$i,j = 1,2$ and $t = 2, \ldots, T$. Once again note that since there are only two states, $p_{ij} = 1 - p_{ij'}$, $j \neq j'$.

The specification of $L(\cdot)$ in both (2) and (3) ignores the initial state probability, i.e., $L(\cdot)$ is an approximate log-likelihood function. With respect to the potential bias introduced by the assumed asymptotic irrelevance of initial conditions, Falk [1986, p. 1105] reported that "the final point estimates are approximately the same as those that would have been attained by ... (ignoring the initial state probability)." By way of this assumption the calculations needed to obtain maximum likelihood estimates of the transition probabilities are simplified.

For the approximate likelihood technique, the estimates of the transition probabilities are:

for the second-order case:

$$\hat{p}_{ijk} = \frac{n_{ijk}}{n_{ijk} + n_{ijk'}} \quad , \; k \neq k' \text{ and } i,j,k = 1,2. \tag{4}$$

for the first-order case:

$$\hat{p}_{ij} = \frac{n_{ij}}{n_{ij} + n_{ij'}} \quad , \; j \neq j' \text{ and } i,j = 1,2. \tag{5}$$

To test the order of the state-indicator sequence, the log-likelihood functions (2) and (3) are maximized with the estimates in (4) and (5), respectively. Subtracting the maximized value of (3) from the maximized value of (2) yields a log-likelihood ratio statistic which (when multiplied by -2) is asymptotically distributed as Chi-square with two degrees of freedom[2].

The results of these tests are listed in Table 1. With the exception of the Transportation and Public Utilities and the Wholesle and Retail sectors, the null hypothesis that the order of $\{I_t\}$ is one can not be rejected at the 90 percent significance level. On the basis of these results, it seems more appropriate to assume the state-indicator sequence for these series is a first-order Markov process. One useful by-product of the first-order assumption is that the number of parameters to be estimated is halved and the number of degrees of freedom is increased.

According to the MKBCH, business cycle upturns are more persistent than downturns. Hence, given that unemployment rates are counter-cyclical series, it is expected that $\hat{p}_{22} > \hat{p}_{11}$. The null hypothesis to be tested is thus:

---

2 Anderson and Goodman [1957, p. 100].

$$H_0: \quad p_{11} = p_{22}. \tag{6}$$

The alternative against which the null is tested is:

$$H_1: \quad p_{11} < p_{22} \tag{7}$$

In order to test for symmetry, (3) is maximized twice: under the alternative hypothesis (an unconstrained maximization problem) with the first-order estimates in (4) and again subject to constraint (6). The log-likelihood ratio statistic (times -2) is asymptotically distributed as Chi-square with one degree of freedom[3].

Under the assumption that $\{I_t\}$ is a second-order Markov process, Neftci [1986] rejected the symmetry hypothesis at the 80 percent confidence level on the basis of a few quarterly unemployment rate series. At the same confidence level, though, Falk [1986] could not reject the symmetry hypothesis based on GNP, investment and productivity data.

---

3 Anderson and Goodman [1957, p. 97].

III. The Results

The point estimates of p_{11} and p_{22} and the values of the log-likelihood ratio statistics are presented in Table 2. With the exception of the agricultural sector and mining industries, all estimated transition probabilities have relative magnitudes consistent with the MKBCH, i.e., $\hat{p}_{22} > \hat{p}_{11}$. However, the statistical significance of these differences in $\hat{p}_{11}$ and $\hat{p}_{22}$ varies strongly across the series. By tracking this variation a primary source of cyclical asymmetries in the macroeconomy can be identified.

First, the test is applied to the total unemployment rate, a series Neftci also examined. Over a sample period roughly six years longers longer than Neftci's, the equality of $\hat{p}_{11}$ and $\hat{p}_{22}$ is rejected at the 80 percent level (the literature's benchmark confidence level). The marginal significance level is roughly 87 percent, suggesting that the degree of asymmetry is stronger than that initially detected by Neftci.

Next, there is a sharp contrast between the symmetry properties of the unemployment rates in the agricultural and private, non-agricultural sectors. For the agricultural sector, the null hypothesis of symmetry can not be rejected at a confidence level as low as 50 percent. On the other hand, the null is rejected for the non-agricultural sector at a marginal significance level above 90 percent.

Further, the presence of asymmetry varies strongly across components of the non-agricultural sector. In particular, the manufacturing sector is the only one for which the symmetry hypothesis is rejected at the 80 percent confidence level. For this series the marginal significance level is above 95 percent. This strong evidence of asymmetry is perhaps representative of the perceived relatively quick (and then sluggish) responsiveness of production in U.S. manufacturing industries following the significant appreciation (and then depreciation) of the dollar in the 1980's.

Finally, the result for mining industries is somewhat surprising in light of Neftci and McNevin's [1986] work on the behavior of production across industries. Specifically, while they showed that output in several mining industries exhibits asymmetry, the data in Table 2 are overwhelmingly in support of the symmetry hypothesis for the unemployment rate across all mining industries. This apparent discrepancy suggests the lack of linear relationship between output and employment in the mining sector.

IV. Conclusions

Under the first-order Markov assumption, the total unemployment rate displays asymmetric behavior. Examination of unemployment rates in the private, non-agricultural sector suggests that this asymmetry emanates primarily from the manufacturing sector.

Recently Sichel [1987a] investigated the statistical power of Neftci's test. This work led him to conclude that Neftci's test possesses extremely low power. On these grounds the evidence of asymmetric time series behavior presented in this paper should be considered particularly strong.

Table 1

Unemployment Rate	$-2(L_1 - L_2)$[a]
Total	4.23[b]
By Sectors:	
Agricultural	3.60
Private Non-Agricultural	3.97
Construction	4.44
Finance and Services	1.92
Manufacturing	1.93
Mining	3.16
Transportation and Public Utilities	6.07
Wholesale and Retail	10.59

[a]L_1 and L_2 are the values of the unconstrained log-likelihood function in the first-order and second-order cases, respectively.

[b]With 2 degrees of freedom:
$\chi^2_{.80} = 3.22$, $\chi^2_{.90} = 4.61$, $\chi^2_{.95} = 5.99$

Table 2

Unemployment Rate	$\hat{p}_{11}$	$\hat{p}_{22}$	$-2(L_C - L_U)$[a]
Total	.62 (.06)[c]	.73 (.05)	2.22[b]
By Sectors:			
Agricultural	.46 (.06)	.41 (.06)	0.38
Private Non-Agricultural	.63 (.06)	.75 (.04)	2.92
Construction	.59 (.06)	.64 (.05)	0.32
Finance and Services	.51 (.06)	.58 (.05)	0.87
Manufacturing	.58 (.06)	.74 (.05)	4.13
Mining	.48 (.06)	.47 (.06)	0.01
Transportation and Public Utilities	.47 (.06)	.52 (.06)	0.52
Wholesale and Retail	.48 (.06)	.55 (.05)	0.73

[a]LU is the value of the log-likelihood function (3) in the unconstrained case. Likewise, L_C is the value of the log-likehood function (3) under the constraint that $p_{11} = p_{22}$.

[b]With 1 degree of freedom:
$\chi^2_{.80} = 1.64$, $\chi^2_{.90} = 2.71$, $\chi^2_{.95} = 3.84$

[c]Standard errors appear in parentheses.

Data Appendix

All data cover the following sample period: 1948:Q1-1987:Q3. Each quarterly series was formed by taking quarterly averages of the monthly series found in the Citibase databank. The following are the exact Citibase variables used:

Unemployment Rate	Citibase Variable
Total	LHUR
Agricultural	LURAG
Private, Non-Agricultural	LURNA
Construction	LURC
Finance and Services	LURFS
Manufacturing	LURM
Mining	LURMI
Transportation and Public Utilities	LURTPU
Wholesale and Retail	LURWR

References

Anderson, T.W. and L.A. Goodman [1957]. "Statistical Inference About Markov Chains", Annals of Mathematical Statistics, 28:89-109.

DeLong, J.B. and L.H. Summers [1986]. "Are Business Cycles Symmetrical?", in American Business Cycle: Continuity and Change, edited by R. Gordon, NBER and University of Chicago Press.

Falk, B. [1986]. "Further Evidence on the Asymmetric Behavior of Economic Time Series Over the Business Cycle", Journal of Political Economy, 94:1096-1109

Hamilton, J.D. [1987]. "A New Approach to the Economic Analysis of Non-stationary Time Series and the Business Cycle", University of Virginia Discussion Paper No. 171.

Keynes, J.M. [1936]. The General Theory of Employment, Interest and Money, London: Macmillan.

Mitchell, W.C. [1927]. Business Cycles: The Problem and Its Setting. New York: NBER.

Neftci, S.N. [1984]. "Are Economic Time Series Asymmetric Over the Business Cycle?", Journal of Political Economy, 92:307-328.

Neftci, S.N. and B. McNevin [1986]. "Some Evidence on the Non-Linearity of Economic Time Series: 1890-1981", C.V. Starr Center Research Report No. 86-26.

Quah, D. [1987]. "What Do We Learn From Unit Roots in Macroeconomic Time Series?", NBER Working Paper No. 2450.

Sichel, D.E. [1987a]. "Business Cycle Asymmetry: A Deeper Look", Princeton Financial Research Center Memorandum No. 85.

Sichel, D.E. [1987b]. "A Reconciliation of Two Empirical Views of Business Cycle Asymmetry", Princeton University, mimeograph.