WAGE GROWTH AND INFLATION IN THE UNITED STATES: FURTHER EVIDENCE FROM JOHANSEN'S COINTEGRATION APPROACH

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Abstract

This paper examines the relationship between wage growth and inflation in the United States. It has been hypothesized that an autonomous wage change represent a significant component of inflation determination. We adopted the recent technique of unit-root testing and Johansen's maximum likelihood procedure to show that, although, wage growth has some long-run impact on inflation pressures, it represents an insignificant determinant of inflation.

1. Introduction

There has been considerable disagreement among economists about the inflationary impact of increased wage rates. A standard hypothesis is that autonomous wage changes are a significant component of inflation determination. This is basically the wage-push hypothesis of the Phillips curve. As wages move in one direction, it is expected that the price level would move in the same direction in the long-run.

Several empirical studies, based on the implicit assumption that their time series data are stationary and integrated of order I(0), have examined the relationship between wage growth and inflation [see, Gordon (1988); Zeira (1989); Helpman and Leiderman (1990); Nymeon (1991); Mehra (1977); Tanner (1993)]. Some researchers have presented evidence in support of the hypothesis that wages and prices are correlated. [See, Zeira (1989); Helpman and Leiderman (1990); Nymeon (1991); Tanner (1993)]. Other authors, however, have suggested that wage growth and prices are not related [see, Gordon (1988); Mehra (1977)].

We suggest that these mixed results may be attributed to the implicit assumption of the various studies that the variable series used in their models are stationary. However, many macroeconomic time series data have been shown to be nonstationary in their levels but stationary after first differencing, thus integrated of order one, I(1). [see, Nelson and Plosser (1982)]. As a result, the use of such nonstationary series in an ordinary least squares (OLS) regression model would lead to spurious results, unless a linear combination of the series are shown to be cointegrated. The use of cointegration analysis would allow for the avoidance of such spurious regression results [see, Granger and Newbold (1974); and Engle and Granger (1987)]. Where there is evidence to support cointegration, the indication is that a long-run economic equilibrium relationship exists among the relevant variables. But, we first, examine the time-series properties of the macroeconomic data used in the model to ascertain whether the variables series in our model are integrated of same order. This is because cointegration requires that all variable series in a model be integrated of the same order [see, Engle and Granger (1987); Dickey and Fuller (1979) and (1981); Murthy, Ukpolo and Mbaku (1994)].

The two-step cointegration technique developed by Engle and Granger (1987) was adopted by Mehra (1991) to examine the relationship between wages and prices, using quarterly data of the United States for the period 1959:1 to 1989:3. Evidence was presented to support long-run movements between changes in the growth rates of wages and prices. However, it has been shown that this two-step cointegration technique is weak in testing and estimating cointegrating relationship where there are more than one explanatory variable in the model. Instead, the use of Johansen's maximum likelihood cointegrating technique is recommended because it is more powerful in estimating parameters of a model where the possibility of multiple cointegrating vectors exist [see, Jo-

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hansen (1988); Hall (1989); Johansen and Juselius (1990); Orden and Fisher (1993); and Banerjee et al., (1993)]. No study can be found that has adopted Johansen's maximum likelihood procedure in testing for the relationship between wages and prices.

This paper uses Johansen's maximum likelihood cointegration technique to examine the relationship between wage growth and inflation in the United States during the period 1975:1-1994:3. First, a unit root testing procedure is conducted, using the augmented Dickey-Fuller (ADF) test, to ascertain the stationarity of the relevant series. [see, Fuller (1976); Dickey and Fuller (1981)]. But, it has been shown that the number of lags chosen in an ADF test could cloud the power of a test [Gordon, (1995)]. As a result, following Gordon (1995), we test for stationarity by looking at the behavior of the ADF statistic over different lag lengths. The Akaike Information Criterion (AIC) and the Schwartz Criterion (SC) are used to determine optimal lag lengths. Second, because we found the variables to be non-stationary in their levels but stationary after first differencing, we conducted cointegration analysis using Johansen's maximum likelihood procedure. This allows us to determine if a long-run relationship exist between changes in growth rates of wages and inflation in the United States for the period under study. Finally, an error-correction model (ECM) was investigated for the purpose of reconciling the short run and long-run behavior.

2. Methodology and Data

Based on the theoretical argument that changes in growth rates of wages and inflation have a long-run relationship, the wage-price dynamics can be represented by the following cointegrating regression model [see, Gordon (1985) and Mehra (1991)]:

$$\pi_t = \alpha_0 + \alpha_1 w_t + \alpha_2 g_t + \epsilon_t \qquad (1)$$

where π_t is the rate of inflation, represented by percentage change in the general price level, which is taken to be the implicit price deflator for GDP. The percentage change of the productivity-adjusted wage, w_t, is measured by the index of unit labor costs of the nonfarm business sector. The productivity-adjusted wage measures the cost-push component of inflationary impact on an economy, where wages represent a significant cost in the production processes. The demand-pull component of inflation is represented by g_t, which is measured by the ratio of real gross domestic product (RGDP) in 1987 dollars and the potential real gross domestic product (PRGDP) in 1987 dollars. The stochastic disturbance term in equation (1) is ϵ_t. The PRGDP was estimated by the use of Okun's law which, according to recent data, suggests that there is a two and half percentage point loss of real GDP for every percentage point by which the unemployment rate exceeds the natural rate of unemployment. It is assumed that this natural rate is 6 percent for the United States. [see, Gordon (1988)].

Before estimating the cointegrating regression model in equation (1) it is important to verify whether the relevant variable series are stationary in their levels individually or are together cointegrated. Therefore, we use the unit-roots tests procedure to evaluate the null-hypothesis that a variable is non-stationary, I(1), versus the alternative hypothesis that it is stationary, I(0). Failure to reject the presence of a unit root in a variable series implies that the series is I(1). It is important to point out that the presence of unit root in macroeconomic data is potentially damaging to policy effectiveness, because random shocks would produce permanent departure from the long-run equilibrium values. However, if the linear combination of the non-stationary variable series are cointegrated, it can then be concluded that the relevant variable series in the cointegrating regression model are related in the long-ruin. Therefore, the regression estimates are considered to be consistent and efficient estimators of the long-run equilibrium parameters [Murthy and Ukpolo (1994)].

As indicated earlier, since equation (1) contains more than one explanatory variable, and hence the possible existence of multiple cointegrating vectors, Johansen's maximum-likelihood (ML) procedure represents the proper technique to estimate the parameters in equation (1). Unlike the Engle-Granger technique, the Johansen's ML procedure provides a unified approach for estimation and testing of cointegrating relations in the framework of vector autoregressive (VAR) error correction models [for details, see Johansen (1988); Johansen and

Juselius (1990); Hall (1989); and Orden and Fisher (1993)]. The ECM examined, in this study, is as follows:

$$\Delta\pi_t = \beta 0 + \beta_1 \Delta Z_t + \beta_2 EC_{t-1} + \mu_t \quad (2)$$

where Z_t is a vector of variable series that is stationary, thus integrated of the order zero, I(0). The variable EC_{t-1} represents the error-correction term and Δ is the first-difference operator. Statistical significance of EC_{t-1} implies that there is long-run equilibrium relationship among the variables in equation (1). The ECM expressed in equation (2) has, since, come to be known as the restricted ECM [see, Arize (1994)].

3. *Empirical Results*

The unit roots test results for twelve lag lengths and the optimal lag lengths determined by the AIC and SC are presented in Table 1. The DF and ADF test results fail to reject the null hypothesis of the presence of a unit root for all the relevant variables in Equation (1) at the 5% level for the optimal lag lengths chosen by the summary statistics. Table 2 shows that, after first differencing, the null hypothesis was rejected at the 5% level, indicating that the variables are stationary, and integrated of the order I(1) for the optimal lag lengths chosen by the summary statistics. Johansen's cointegrating regressions results for Equation (1) is presented in Table 3. The null hypothesis that there is no cointegrating vector is rejected at the 5% level. However, the null hypothesis that there is only one cointegrating vector cannot be rejected at the 5% level. Thus, the results seem to support the hypothesis that there is a long-run relationship between wage growth and inflation. But, the estimated cointegrating normalized coefficient of the wage growth variable in equation (1) is not statistically significant at the 5% level, according to the chi-square test results reported in Table 4. The implication, therefore, is that wage growth is not a major determinant of inflation in the United States during the period under study. Wage growth and prices are unrelated to each other, and that both prices and wages tend to live separate lives [Gordon (1988)]. Nonetheless, the existence of a unique long-run equilibrium relationship among the variables in our model allows for the use of the error-correction term EC_{t-1} to capture the short run adjustment necessary for reconciliation with long-run equilibrium. Table 5 presents the results of the error-correction model, with the computed t-values in parentheses. The significance of EC_{t-1} term confirms the existence of a long-run equilibrium relationship between wage growth and inflation in the United States during the period under study. But, Johansen's cointegrating regression results reveal that such a relationship is weak.

TABLE 1
Unit Root Tests[a]

	Variables (Level Series)		
Lags	π	w	g
1	−3.0294	−1.0836	−1.2798
2	−2.3129	−0.8261*,**	−2.6497*,**
3	−2.2017*,**	−1.3645	−2.5673
4	−2.5192	−1.4735	−2.5280
5	−2.5036	−1.7613	−2.4133
6	−2.6381	−1.8235	−2.4527
7	−2.7736	−2.0094	−2.8778
8	−2.4010	−2.1928	−2.6273
9	−2.5733	−1.9644	−2.4815
10	−2.1459	−2.1640	−2.7972
11	−2.0630	−2.4076	−2.8477
12	−2.1832	−2.2479	−2.9307

The number of lags in brackets above. * and ** represent the optimal lag lengths set by the AIC and SC respectively. The critical values at the 5% level of significance is −3.47. n = 79; [a] = with trend.

TABLE 2
Unit Root Tests[a]

	Variables (First Difference Series)		
Lags	π	w	g
1	−9.7075	−6.7295*,**	−3.7592
2	−7.3013*,**	−4.0276	−3.5458*,**
3	−4.9609	−3.6763	−3.4672
4	−4.5862	−3.0123	−3.1217
5	3.6820	−2.8988	−2.5692
6	−3.1009	−2.5129	−2.6917
7	−3.1503	−2.4559	−2.7270
8	2.8776	−2.4825	−2.3572
9	−3.2863	−2.5599	−2.3391
10	−3.1882	−2.2745	−2.2545
11	2.5018	−2.2362	2.7864
12	−1.9882	−2.2090	−2.4647

The number of lags in brackets above. *, ** and *** represent the optimal lag lengths set by the AIC, SC and ACF respectively. The critical values at the 5% level of significance are −3.47. n = 79; [a] = with trend.

4. *Conclusion*

This paper examined the long-run relationship between wage growth and inflation in the United States during the period 1975:1–1994:3. Cointegration allows for such investigation even with variable series that are nonstationary and thus, integrated of the order one. The unit roots tests of the variables series in Equation (1) shows that, indeed, they are nonstationary in their levels, but stationary after first-differencing. Johansen's maximum likelihood procedure was adopted in conducting the cointegration tests, which provided evidence to support cointegration among the variable series in our model. This finding implies that there is a unique long-run equilibrium relationship, although weak, between the wage growth and inflation in the United States during the period under study. Furthermore, the error-correction model seems to validate the long-run relationship established by the cointegration regression results.

Contrary to Mehra's (1991) finding, our result

TABLE 3
Tests for Cointegrating Vectors

I. Maximum eigenvalue tests λ_1

Null	Alternative	Statistic	95% Critical Value	90% Critical Value
r=0	r=1	42.240*	20.967	18.598
r≤1	r=2	10.144	14.069	12.071
r≤2	r=3	2.395	3.762	2.687

II. Trace test λ_2

Null	Alternative	Statistic	95% Critical Value	90% Critical Value
r=0	r≥1	54.779*	29.680	26.785
r≤1	r≥2	12.539	15.410	13.325
r≤2	r≥3	5.395	3.762	2.687

* Denotes the rejection of the null hypothesis.
Critical values are obtained from Osterwald-Lunum (1990).

TABLE 4
Johansen's Cointegrating Regression Results

Variables	Normalized Coefficients	Hypothesis test[a] (λ_3)
π	−1.000	
w	0.014	0.002
g	−0.099	12.188*

[a] = The null hypothesis states that the normalized coefficient is not statistically different from zero.
* denotes significance at the 1% level. The likelihood ratio, λ_3, have a chi-square distribution under the null hypothesis.

seems to indicate, that although real wage growth may have some long-run impact on the inflationary process in the United States, it represents an insignificant determinant of inflation. This contradiction may be attributed to the two-step cointegration technique adopted by Mehra (1991) which, as indicated earlier, has been shown to be weak when compared to the Johansen's maximum likelihood cointegrating technique in testing and estimating cointegrating relationship where there are more than one explanatory variable in the model.

Even though conventional wisdom tells us that wages are the central component in explaining inflationary process, our result rejects such view for the period under study in the United States. The United States economy has changed radically since the 1970's when wages chased prices in self-sustaining upward spiral. Most workers used to be guaranteed cost-of-living adjustment (COLA) raises that increased wages in an attempt to keep up with inflation. But now, however, about only 25% of union workers still receive COLA raises which is down from 60% about ten years ago [see, Hage (1994); and Wunnava and Okunade (1996)]. It is a common practice in the 1990's for firms to tie wages to productivity instead of prices.

TABLE 5
Error Correction Model

Dependent Variable: $\Delta\pi_t$

Regressor	Parameter Estimates
Intercept	−1.290
Δw	−0.077
	(−1.729)
Δg	4.780
	(−0.739)
EC_{t-1}	−0.544
	(−5.132)

$R^{2a} = 0.245$
DW = 2.289
LM = 7.534
NORM = 6.900
RESET = 1.871

EC_{t-1} is the error obtained from the cointegrating regression test. t-values are in parentheses.

References

Arize, A. C., "An Econometric Analysis of Money Demand in Taiwan, 1950–1989," *The American Economist*, 38, no. 1, Spring 1994, 27–35.

Banerjee, A., Dolado, J. J. Galbraith, J. W. and Hendry, D. F., *Cointegration, Error Correction, and the Econometric Analysis of Non-Stationary Data*, (Oxford: Oxford University Press, 1993).

Dickey, D. A. and Fuller, W. A., "Distribution of the Estimators for Autoregressive Time Series With a Unit Root," *Journal of the American Statistical Association*, 74, 1979, 427–31.

———, "Likelihood Ratio Statistics for Autoregressive Time Series With A Unit Root," *Econometrica*, 49, 1981, 1057–72.

Engle, R. F. and Granger, C. W. J., "Cointegration and Error Correction: Representation, Estimation and Testing," *Econometrica*, 55, March 1987, 251–76.

Fuller, W. A., *Introduction to Statistical Time Series*, (New York: John Wiley & Sons, 1976).

Gordon, D. V., "Optimal Lag Length in Estimating Dickey-Fuller Statistics: An Empirical Note," *Applied Economics Letters*, 2, 18–90.

Gordon, R. J., "Understanding Inflation in the 1980s," *Brookings Papers on Economic Activity*, 1, 1985, 263–299.

———, "The Role of Wages in the Inflation Process," *American Economic Association Papers and Proceedings*, 78, no. 2, 1988, 276–283.

Granger, C. W. J. and Newbold, P., "Spurious Regression in Econometrics," *Journal of Econometrics*, 2, 1974, 111–120.

Hage, D., "Inflation Gets Nailed," *U.S. News & World Report*, May 23, 1994, Vol. 116, P. 53.

Hall, S. G., "Maximum Likelihood Estimations of Cointegration Vectors: An Example of the Johansen Procedure," *Oxford Bulletin of Economics and Statistics*, 51, 1989, 213–218.

Helpman, E. and Leiderman, L., "Real Wages, Monetary Accommodation and Inflation," *European Economic Review*, 34, 1990, 897–911.

Johansen, S., "Statistical Analysis of Cointegration Vectors," *Journal of Economic Dynamics and Control*, 12, 1988, 231–254.

Johansen, S. and Juselius, K., "Maximum Likelihood Estimation and Inference on cointegration with Applications to the Demand for Money," *Oxford Bulletin of Economics and Statistics*, 52, 1990, 169–209.

Mehra, Y. P., "Money Wages, Prices and Causality," *Journal of Political Economy*, 85, December 1977, 1227–44.

———, "Wage Growth and the Inflation Process: An Empirical Note," *American Economic Review*, 81, no. 4, September 1991, 931–937.

Murthy, N. R. V. and Ukpolo, V., "Aggregate Health Care Expenditure in the United States: Evidence from Cointegration Tests," *Applied Economics*, 26, 1994, 797–802.

Murthy, N. R. V., Ukpolo, V. and Mbaku, J. M., "Foreign Aid and Economic Growth in Cameroon: Evidence from Cointegration Tests," *Applied Economic Letters*, 1, 1994, 161–163.

Nelson, C. R. and Plosser, C. I., "Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications," *Journal of Monetary Economics*, 10, 1982, 139–162.

Nymeon, R., "A Small Linear Model of Wage- and Price-Inflation in the Norwegian Economy," *Journal of Applied Economics*, 6, 1991, 255–269.

Orden, D. and Fisher, L. A., "Financial Deregulation and the Dynamics of Money, Prices, and Output in New Zealand and Australia," *Journal of Money, Credit, and Banking*, 25, no. 2, 1993, 273–92.

Osxterwald-Lunum, M., "Recalculated and Extended Tables of the Asymtotic Distribution of Some Important Maximum Likelihood Cointegration Test Statistics," (unpublished).

Tanner, E., "Inertial Linkages Between Wages and Inflation: Evidence from Brazil," *Atlantic Economic Journal*, 21, no. 2, June 1993, 39–49.

U. S. President, *Economic Report of the President 1994*, (Washington DC: Government Printing Press)

Wunnava, P. W. and Okunade, A. A., "Countercyclical Union Wage Premium? Evidence for the 1980s", *Journal of Labor Research*, (forthcoming, Vol. 17, 1996).

Zeira, J., "Inflationary Inertia in a Wage-Price Spiral Model," *European Economic Review*, 33, 1989, 1665–1683.