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THE ASYMMETRIC AND NONLINEAR EFFECTS OF OUTPUT ON INFLATION FOR AUSTRALIAN ECONOMY

Abstract*: The aim of this study is to test the asymmetric effect of output on inflation for the Australian economy, using a nonlinear autoregressive distributed lag (NARDL) model. The data are quarterly and cover the periods of 2000:01-2016:03. All data come from World Bank Databank. Using quarterly data for the period 2000:01-2016:03, we first investigate the nonlinear pass-through effects of output to inflation, using the Almon model. We then go on to employ the recently developed nonlinear autoregressive distributed lag (NARDL) model, to examine the asymmetric effects of output on inflation in the short and long runs. The results of Almon model show that the pass-through impact of output on inflation is nonlinear and negative for Australia economy. The Almon model estimates of the regression coefficients are found to satisfy the inverted U-shaped relationship between inflation and output. In particular, inflation increases (decreases) by 1.17 per cent if output decreases (increases) by 10 per cent, in the short run. On the other hand, inflation increases (decreases) by 0.65 per cent if output decreases (increases) by 10 per cent in the long run. The results of the NARDL model show that the symmetric effect of the output on inflation can be rejected in both the short and long run. These findings indicate that output affects inflation asymmetrically, in both the short run and the long run.*

Key words*: Almon model, nonlinear autoregressive distributed lag, Australian economy.*

Language*: English*

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1. INTRODUCTION

The theoretical basis for the statistical evidence with regard to both output and inflation is limited. The effect of a permanent inflation shocks on the level of output to be positive, zero, or negative. The relationship between the slope of the short run Phillips curve, which is the inflation-output tradeoff, and the variance of the aggregate demand disturbance has been subject to intensive empirical investigation in recent years. On the theoretical framework within the rational expectations, the pioneering of Lucas (1973) has showed that inflation-output tradeoff parameter is inversely associated with the variance of the aggregate demand disturbances. The Lucas variability hypothesis states that the reaction of real output to changes in aggregate demand depends negatively on the variance of the changes of aggregate demand (Yamak and Küçükkale, 1997).

The investigation of the presence of nonlinear mechanisms (the Phillips curve) between inflation and output has been an important topic in the recent literature. The presence of nonlinearities in the Phillips curve has relevant implications. The slope of the Phillips curve – measuring the response of inflation to output gap – affects directly the cost of disinflation (Correa and Minella, 2010). Bullard and Keating (1995) tested the relationship between inflation and real output in a large sample of postwar economies. They showed that permanent inflation shocks permanently increase real output growth rates. Stiglitz (1997), Eisner (1997), Laxton et al. (1999), Bean (2000) found evidence that the Phillips curve is nonlinear. Fischer (1991) and De Gregorio (1991) found evidence for a negative link between inflation and growth. Sarel (1995), and Andres and

Hernando (1997) found a negative effect of inflation on output, not on the growth rate of output. They also found that there exists a nonlinear relationship. Levine and Zervos (1993) and Sala-i-Martin (1997) suggested that inflation was not a robust determinant of economic growth. However, Ericsson et al. (2001) implied that output and inflation are positively related in cointegrating relationships.

The aim of this study is to test the asymmetric effect of output on inflation for the Australian economy, using a nonlinear autoregressive distributed lag (NARDL) model. The data are quarterly and cover the periods of 2000:01-2016:03. In this study, we first investigate the nonlinear pass-through effects of output to inflation, using the Almon model. We then go on to employ the recently developed nonlinear autoregressive distributed lag (NARDL) model, to examine the asymmetric effects of output on inflation in the short and long runs.

This paper is organized as follows. Section 2 reviews data and methodology. In Section 2, the Almon estimation method of distributed lag models and nonlinear autoregressive distributed lags (NARDL) are given as theoretical. Section 3 raises empirical findings. Section 4 presents some conclusions.

2. DATA AND METHODOLOGY

2.1. DATA

The data are quarterly and cover the periods of 2000:01-2016:03 for the Australian economy. All data come from World Bank Databank. Before starting the analysis, consumer price index was seasonally adjusted by using the Census X12 method. The details of all variables are given in Table 1.

Table 1

Symbols Used for Variables

GDP	Gross Domestic Product, Real, Seasonally Adjusted
CPI	Consumer Prices, Seasonally Adjusted
$LCPI_t$	The logarithm of the consumer price index level at time t
$OUTPUT_t$	The logarithm of the gross domestic product (GDP) at time t
π_t	Inflation Rate, $\pi_t = LCPI_t - LCPI_{t-1}$

2.2. METHODOLOGY

This paper addresses how the output does asymmetrically pass on to the inflation both the short and long run. In this paper, asymmetric and nonlinear pass-through of the output to the inflation is tested.

The econometric process used is followed in this way:

Firstly, as an empirical enquiry, we deal unit root tests procedures to determine whether output and inflation variables are indeed stationary. We use two different unit root tests to determine whether the output and inflation series are stationary: developed by Dickey and Fuller (1979) (Augmented Dickey-Fuller (ADF)) and by Phillips and Perron (1988) (PP).

Secondly, we determine the nonlinear relationship between output and inflation by employing Almon model[1].

Thirdly, we analyze the recently developed nonlinear autoregressive distributed lags (NARDL) model to examine the asymmetric effect of output into inflation. This approach allows us to simultaneously test the short- and long-run nonlinearities through positive and negative partial sum decompositions of the predetermined explanatory variables.

2.2.1. THE ALMON ESTIMATION METHOD OF DISTRIBUTED LAG MODELS

The Almon estimation method is a procedure for estimating a distributed lag model one that uses polynomial distributed lags to specify the lag structure and the Lagrangian interpolation coefficients to specify the zero constraints in the lag structure (Monroe, 1981: 46).

We consider the distributed lag model.

[1]Almon, 1965.

$$Y_t = \gamma + \beta_0 X_t + \beta_1 X_{t-1} + \ldots + \beta_p X_{t-p} + u_t = \gamma + \sum_{i=0}^{p} \beta_i X_{t-i} + u_t \quad \textbf{(1)}$$

where (u_t) is an an uncorrelated random variables with zero mean and constant variance $\sigma^2$and (X_t) is distributed independently of (u_t).

According to Almon model (1), all coefficients (β_i) are defined by polynomial (2). In polynomial (2), r is the degree of the polynomial.

$$\beta_i = f(i) = \emptyset_0 + \emptyset_1 i + \emptyset_2 i^2 + \ldots + \emptyset_r i^r \quad \textbf{(2)}$$

For example, we have decided on a maximum lag-length ($p = 4$), and we have chosen a degree ($r = 3$) for the approximating polynomial (Köseoğlu ve Yamak, (2015), Erdem and Yamak (2016)), then we can re-write (3 and 4) as:

$$Y_t = \gamma + \beta_0 X_t + \beta_1 X_{t-1} + \beta_2 X_{t-2} + \beta_3 X_{t-3} + \beta_4 X_{t-4} + \varepsilon_t \quad \textbf{(3)}$$

$$\beta_i = f(i) = \emptyset_0 + \emptyset_1 i + \emptyset_2 i^2 + \emptyset_3 i^3 \quad \textbf{(4)}$$

Then, the polynomials are modeled as:

$$\beta_0 = f(0) = \emptyset_0 \quad \textbf{(5)}$$
$$\beta_1 = f(1) = \emptyset_0 + \emptyset_1 + \emptyset_2 + \emptyset_3 \quad \textbf{(6)}$$
$$\beta_2 = f(2) = \emptyset_0 + 2\emptyset_1 + 4\emptyset_2 + 8\emptyset_3 \quad \textbf{(7)}$$
$$\beta_3 = f(3) = \emptyset_0 + 3\emptyset_1 + 9\emptyset_2 + 27\emptyset_3 \quad \textbf{(8)}$$
$$\beta_4 = f(4) = \emptyset_0 + 4\emptyset_1 + 16\emptyset_2 + 64\emptyset_3 \quad \textbf{(9)}$$

We place (5-9) into (3), we get as:

$$Y_t = \gamma + \emptyset_0 W1_t + \emptyset_1 W2_t + \emptyset_2 W3_t + \emptyset_3 W4_t + \varepsilon_t \quad \textbf{(10)}$$

where W series are derived by using X series by following equations:

$$W1_t = X_t + X_{t-1} + X_{t-2} + X_{t-3} + X_{t-4}$$
$$W2_t = X_{t-1} + 2X_{t-2} + 3X_{t-3} + 4X_{t-4}$$
$$W3_t = X_{t-1} + 4X_{t-2} + 9X_{t-3} + 16X_{t-4}$$
$$W4_t = X_{t-1} + 8X_{t-2} + 27X_{t-3} + 64X_{t-4}$$

2.3. NONLINEAR AUTOREGRESSIVE DISTRIBUTED LAGS (NARDL)

The linear ECM specification without asymmetry in short-and long-run dynamics takes the following form

$$\Delta Y_t = \mu + \rho_Y Y_{t-1} + \rho_X X_{t-1} + \sum_{i=1}^{p-1} \alpha_i \Delta Y_{t-i} + \sum_{i=0}^{q-1} \beta_i \Delta X_{t-i} + \varepsilon_t \quad \textbf{(11)}$$

The co-integrating NARDL model of Shin et al. (2011) allows for short- and long-run asymmetries. This model uses the decomposition of the exogenous variable X_t^+ into its positive ΔX_t^+ and negative ΔX_t^- partial sums of increases and decreases such as

$$X_t^+ = \sum_{j=1}^{t} \Delta X_j^+ = \sum_{j=1}^{t} max(\Delta X_j, 0) \text{ and } X_t^- = \sum_{j=1}^{t} \Delta X_j^- = \sum_{j=1}^{t} min(\Delta X_j, 0) \quad \textbf{(12)}$$

When the asymmetries in the short- and long-run dynamics are introduced into the standard ECM, Shin et al. (2011) show that Eq. (11) is extended to obtain a more general co-integration model as follows

$$\Delta Y_t = \mu + \rho_Y Y_{t-1} + \rho_X^+ X_{t-1}^+ + \rho_X^- X_{t-1}^- + \sum_{i=1}^{p-1} \alpha_i \Delta Y_{t-i} + \sum_{i=0}^{q-1} (\beta_i^+ \Delta X_{t-i}^+ + \beta_i^- \Delta X_{t-i}^-) + \varepsilon_t \quad \textbf{(13)}$$

The superscripts (+) and (-) in Eq. (13) denote the positive and negative partial sums decomposition defined above, p and q represent the lag orders for the dependent variable and the exogenous variable in distributed lag part, respectively.

The long- run symmetry can be tested by using a Wald test of the null hypothesis $\rho_X^+ = \rho_X^-$. The positive and negative long-run coefficients can then be computed as $\theta^+ = -\rho_X^+ / \rho_Y$ ve $\theta^- = -\rho_{PF}^- / \rho_X$. The short-run adjustment to a positive and a negative shock in the X is captured by the parameters β_i^+ and β_i^-respectively. The short-run symmetry can equally be tested by using a standard Wald test of the null hypothesis $\beta_i^+ = \beta_i^-$ for all $i=0,\ldots\ldots,q-1$. The model in Eq. (13) reduces to the traditional ECM if both null hypotheses of short-run and long-run symmetry are not rejected. The non-rejection of either the long-run symmetry or the short- run symmetry will yield the co-integrating NARDL model with short-run asymmetry in Eq. (14) and with long-run asymmetry in Eq. (15), respectively.

$$\Delta Y_t = \mu + \rho_Y Y_{t-1} + \rho_X X_{t-1} + \sum_{i=1}^{p-1} \alpha_i \Delta Y_{t-i} + \sum_{i=0}^{q-1} (\beta_i^+ \Delta X_{t-i}^+ + \beta_i^- \Delta X_{t-i}^-) + \varepsilon_t \quad \textbf{(14)}$$

$$\Delta Y_t = \mu + \rho_Y Y_{t-1} + \rho_X^+ X_{t-1}^+ + \rho_X^- X_{t-1}^- + \sum_{i=1}^{p-1} \alpha_i \Delta Y_{t-i} + \sum_{i=0}^{q-1} \beta_i \Delta X_{t-i} + \varepsilon_t \quad \textbf{(15)}$$

When asymmetry is detected in the ARDL model (either in the short run, in the long run or in both), the asymmetric responses to positive and negative shocks (i.e., positive or negative variations of the X oil prices) are respectively captured by the positive and negative dynamic multipliers associated with unit changes in X^+ and X^- as follows

$$h \to \infty,\; m_h^+ \to \theta^+,\; m_h^- \to \theta^-$$

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial Y_{t+j}}{\partial X_t^+} \text{ and } m_h^- = \sum_{j=0}^{h} \frac{\partial Y_{t+j}}{\partial X_t^-} \quad h=0, 1, 2, \ldots\ldots$$

Based on the estimated multipliers, one can observe, following a shock affecting the system, dynamic adjustments from the initial equilibrium to the new equilibrium between the system variables (Atil et al. 2014: 568-569).

3. EMPIRICAL FINDINGS

Before applying the methodology given in Section 2, unit root test procedures were used to determine the stationary characteristics of output, inflation. The Augmented Dickey-Fuller (ADF) and the Phillps-Perron (PP) approaches were separately applied to all variables. Table 2 presents the results of the ADF and PP test statistics with and without the inclusion of a trend detecting a unit root in the levels and first differences of the variables. As seen as Table 2, output was to be stationary in its first differences. However, inflation was found to be stationary in its level.

Table 2

Unit-Root Test Results

ADF Unit-Root Test Results				
Variables	**Level** Constant	Constant+ Trend	**First Difference** Constant	Constant + Trend
$OUTPUT_t$	-1.4671	-1.0177	-7.1155^a	-7.2748^a
π_t	-7.5245^a	-8.0944^a	-7.0288^a	-6.9975^a
PP Unit-Root Test Results				
Variables	**Level** Constant	Constant+ Trend	**First Difference** Constant	Constant + Trend
$OUTPUT_t$	-1.6669	-0.9238	-7.0408^a	-7.2855^a
π_t	-7.5223^a	-8.1258^a	-19.4979^a	-20.3131^a

Note: [a], [b] , and [c] denote significance level of 1%, 5% and 10%, respectively.

3.1. EMPIRICAL FINDINGS: OUTPUT → INFLATION

3.1.1. THE EMPIRICAL FINDINGS OF ALMON MODEL: PASS-THROUGH EFFECT OF OUTPUT TO INFLATION

According to Akaike info criterion, optimal lag is 4. So, the duration of the impact of output on the inflation is one year. As seen as Table 3, In short run, if output 10% ↑, inflation 1.17%↓; in long run, if output 10% ↑, inflation 0.65%↓. The pass-through effect of output to inflation is negative.

Table 3

The Results of Non-linear Distributed Lag Almon Models

$$\beta_i = f(i) = \emptyset_0 + \emptyset_1 i + \emptyset_2 i^2$$

$$\hat{\pi}_t = 0.0452 + 0.1068 W1_t + 0.004 W2_t - 0.054 W3_t$$

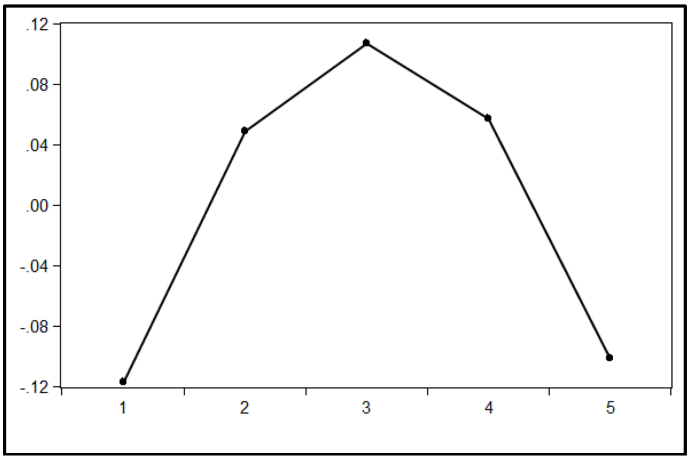
R-squared	0.101141
F-statistic	2.212917
Prob(F-statistic)	0.096040

Lag Distribution of OUTPUT		β_i	Coefficient	Std. Error	t-Statistic
* . |	The short run effect of output on →		-0.11749	0.06952	-1.69003
. * |		β_1	0.04873	0.03219	1.51388

. *|		β_2	0.10682	0.05522	1.93437
. * |	The long run effect of output on	β_3	0.05677	0.03445	1.64778
* . |		β_4	-0.10141	0.06422	-1.57909
		Sum of Lags	*-0.00659*	0.00352	-1.87308

In Graph 1, the pass-through of the output to the inflation is shown. According to the Graph 1, the pass-through impact of output on the inflation is non-linear in the case of Australia. The Almon model estimates of the regression coefficients are found to satisfy the inverted U-shaped relationship between inflation and output. Time variation on the regression coefficients and the inverted U-shaped curve is significant.

Graph 1. Output→Inflation



3.1.2. THE EMPIRICAL FINDINGS OF NARDL MODEL: IS PASS-THROUGH EFFECT OF OUTPUT TO INFLATION ASYMMETRIC OR SYMMETRIC?

The obtained results of the NARDL model are reported in Table 4. Wald tests are then conducted to examine the hypotheses of short-run and long-run symmetry. The results from these tests applied to the estimates of the NARDL model with short-run and long- run asymmetries indicate that the long-run and short-run symmetries can be rejected for the output–inflation relationship at the 10% level. Therefore, the output asymmetrically passes on to the inflation both the short and long run. The results of diagnostic tests on the residuals for serial correlation (LM_1, LM_2, LM_3, and LM_4) and heteroscedasticity (ARCH) are given in Table 4. There is no any model suffering from any autocorrelation problem. The calculated χ^2 is not greater than the critical value. Therefore, the null hypothesis that indicates non-existence of autocorrelation cannot be rejected at any significant level, and the heteroscedasticity does not appear to be a diagnostic problem on residuals.

Table 4

The Results of NARDL with Long run and Short run Asymmetry

Dependent Variable: $\Delta\pi$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.011504	0.002526	4.554320	0.0000
π(-1)	-1.207774	0.270309	-4.468131	0.0000
OUTPUTPOS(-1)	0.006180	0.008411	0.734765	0.4658
OUTPUTNEG(-1)	0.381416	0.200304	1.904182	0.0625
Δπ(-1)	0.325499	0.217819	1.494353	0.1412

Δπ(-2)	0.262068	0.185800	1.410486	0.1645
Δπ(-3)	0.060010	0.124429	0.482281	0.6317
Δπ(-4)	-0.054133	0.085208	-0.635311	0.5281
ΔOUTPUTPOS	-0.273831	0.119583	-2.289876	0.0262
ΔOUTPUTNEG	0.585867	0.424196	1.381125	0.1733
R-squared	0.564170			
Akaike info criterion	-8.527600			
F-statistic	7.335345			
Prob(F-statistic)	0.000001			

LM_1	0.037350 [0.8468]	LM_2	2.815540 [0.2447]
LM_3	4.028313 [0.2584]	LM_4	5.744181 [0.2191]
ARCH	0.042635 [0.8364]		
$Wald_{LONG\text{-}TERM}$ Test	3.786396 [0.0572]	$Wald_{SHORT\text{-}TERM}$ Test	3.071363 [0.0857]
$LONG\text{-}TERM_{OUTPUTPOS}$	0.0051168	$LONG\text{-}TERM_{OUTPUTNEG}$	0.3158

Figures 1-2 present CUSUM and CUSUMSQ of the NARDL model. As can be seen from Figures 1-2, the plots of CUSUM and CUSUMSQ statistics stay within the critical bonds of 5% level of significance. Thus, the null hypothesis that in the given regression are stable cannot be rejected at the 5% level. Therefore, all coefficients of the given regression are stable.

Figure 1. CUSUM

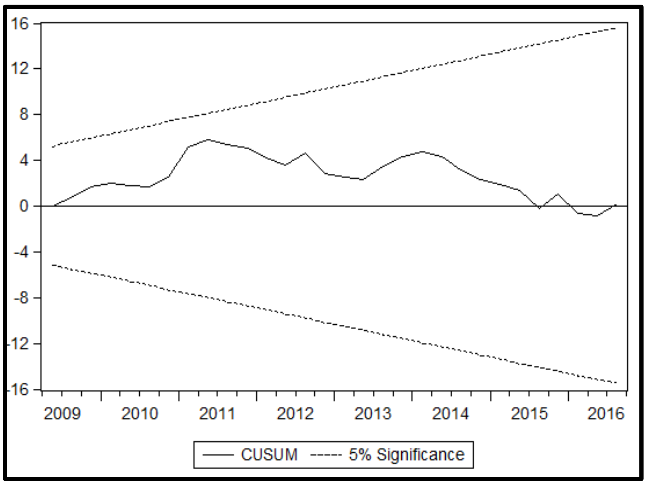
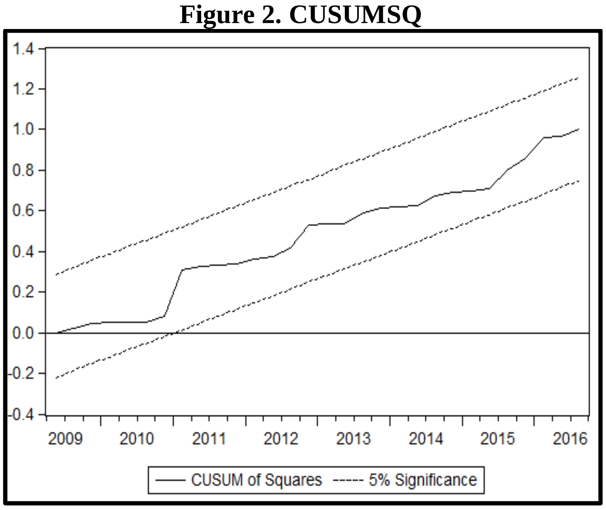


Figure 2. CUSUMSQ



4. CONCLUSION

The theoretical basis for the statistical evidence with regard to both output and inflation is limited. There is a growing interest in the asymmetric interplay between inflation and output. There is a gap in the literature as none of the previous studies concurrently examined both the size and sign effects of the output on inflation. The purpose of this study is to examine asymmetric effect of output on inflation for the Australian economy, using a nonlinear autoregressive distributed lag (NARDL) model. In this study, the nonlinear pass-through effects of output to inflation were investigated, using the Almon model. The data are quarterly and cover the periods of 2000:01-2016:03. All data come from World Bank Databank. According to the findings, the output asymmetrically passes on to the inflation both the short and long run. The Almon model estimates of the regression coefficients are found to satisfy the inverted U-shaped relationship between inflation and output. The pass-through impact of output on the inflation is non-linear in the case of Australia. In particular, inflation increases (decreases) by 1.17 per cent if output decreases (increases) by 10 per cent, in the short run. On the other hand, inflation increases (decreases) by 0.65 per cent if output decreases (increases) by 10 per cent in the long run.

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