

# Nonlinear Modelling of Inflation in Iran

1	Introduction .....	2
2	Macroeconomic performance.....	3
3	Theory and econometric methodology.....	7
3.1	Per capita money demand.....	8
3.2	PPP .....	9
3.3	Goods market.....	10
4	Empirical analysis of linear modelling .....	11
4.1	The data .....	11
4.2	Order of integration .....	11
4.3	Cointegration results.....	14
4.4	Linear model of inflation.....	17
5	Modelling nonlinear behaviour .....	20
5.1	Nonlinear adjustment.....	20
5.2	Testing Linearities .....	20
6	Empirical analysis of nonlinear modelling .....	21
7	Policy Implications.....	22
8	Conclusion.....	26

# Nonlinear Modelling of Inflation in Iran

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## Abstract

This article investigates the main determinants of inflation in Iran over the period 1959 – 1996. First a linear model is specified and estimated and then due to the slow adjustments towards equilibriums a nonlinear process is used as a plausible explanation of this adjustment to model inflation and also some major policy implications are derived.

Keywords: Inflation; Money demand; Purchasing power parity; Goods Market, Cointegration and ECM; Nonlinearity; Islamic Republic of Iran

JEL classifications: E31; E41; F31; C22; O53

## 1 Introduction

The purpose of this paper is twofold. First, it investigates domestic and international transmission effects on inflation in Iran. More specifically, it sheds more light on the determinants of inflation in Iran as a small open economy using the data over the period 1959 – 1996. Second, due to the slow adjustments towards equilibriums a nonlinear process is used as a plausible explanation of the adjustments to model inflation. In addition, some major policy implications are derived and analysed from the findings of the paper.

There are a number of studies concerning the analysis of inflation in Iran.<sup>1</sup> Some recent studies such as Bahmani–Oskooee (1995), Tavakkoli (1995), and Tabibian and Souri (1997) investigate the determinants of inflation in Iran using cointegration techniques. Bahmani–Oskooee, and Tabibian and Souri use an augmented monetarist model to describe the long–run behaviour of inflation, while Tavakkoli also considers single equation error correction mechanism and investigates the determinants of inflation using the long–run money demand schedule. However, this model is restricted to a single market and is more appropriate for a closed economy rather than an open economy such as Iran.

In order to understand the behaviour of inflation and its determinants it is necessary to examine the special characteristics of the Iranian economy. This examination provided a ground

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<sup>1</sup> These studies such as Dadkhah (1985), Nili (1985), Looney (1985), Eikani (1987), darrat (1987), Makkian (1990), Tabatabai–Yazdi (1991), and Taiebnia (1995) examine the determinants of inflation without considering the integration properties of the relevant variables. The presence of nonstationary variables may lead to spurious regression. Also even if the relationship is cointegrated, standard inference procedures are inappropriate. Consequently, these studies must be considered with some scepticism.

to use three equilibrium relationships modelling inflation. First equilibrium is excess money supply, which explains aggregate prices using money demand based on a representative agent model. Second equilibrium is PPP that explains traded prices in terms of foreign competition and the third equilibrium relates to goods market which explains excess demand in the economy. These equilibrium relationships, which possibly describe the main determinants of inflation, are used and a dynamic model of inflation is developed to analyse the dynamics of inflation.

However, since the linear price equation using the associated error correction terms provides a slow speed of adjustment, nonlinear processes are considered to model inflation as an alternative approach. Following Granger and Terasvirta (1993), the nonlinear structure of inflation is investigated by testing linearity against two parametric nonlinear models: the exponential smooth transition autoregressive (ESTAR) and the logistic smooth transition autoregressive (LSTAR) models.

This paper proceeds as follows. Section two describes briefly the performance of the Iranian economy during the recent decades. Section three spells out theory and econometric methodology. Section four reports empirical results of linear model. Section five introduces the class of parametric nonlinear models while section six reports empirical results of nonlinear model. Section seven describes some policy implications derived from the study. A final section concludes.

## **2 Macroeconomic performance**

This section examines the evolution of main macroeconomic variables over the period 1959 – 1996. They comprise inflation measures, economic growth rate, money supply, exchange rates, and exports and imports.

In the recent decades Iran has experienced several important events in the economic and political fields. These included the three oil shocks of 1972, 1979 and 1986; the Islamic revolution in 1978 which was followed by nationalisation of major sectors of the economy; the eight-year war with Iraq during 1980 – 1988; and the economic reform programme generally implemented over the period 1989 – 1993. The effects of the oil shocks were particularly profound due to the dependence of the economy and of the macroeconomic policies on oil revenue. After the war the economic reform programme also had major effects through the removal of price controls and government subsidies, currency devaluation, and the deregulation of trade and tariffs.

There are several measures to examine domestic inflation. These measures include consumer price index (CPI) and GDP deflator (GDPD).<sup>2</sup> From the plots of these inflation measures in Figure 1, it appears that the measures move in a similar direction. Moreover, the sample period may be split into two inflation regimes as follows:

- 1960 – 1972: relatively low and stable inflation
- 1973 – 1996: higher and more variable inflation

The GDP deflator and CPI inflation rates rose by an annual average rate of 14.4 and 13.9 percent, respectively, over the period. The inflation rates were in single figures from 1960 to

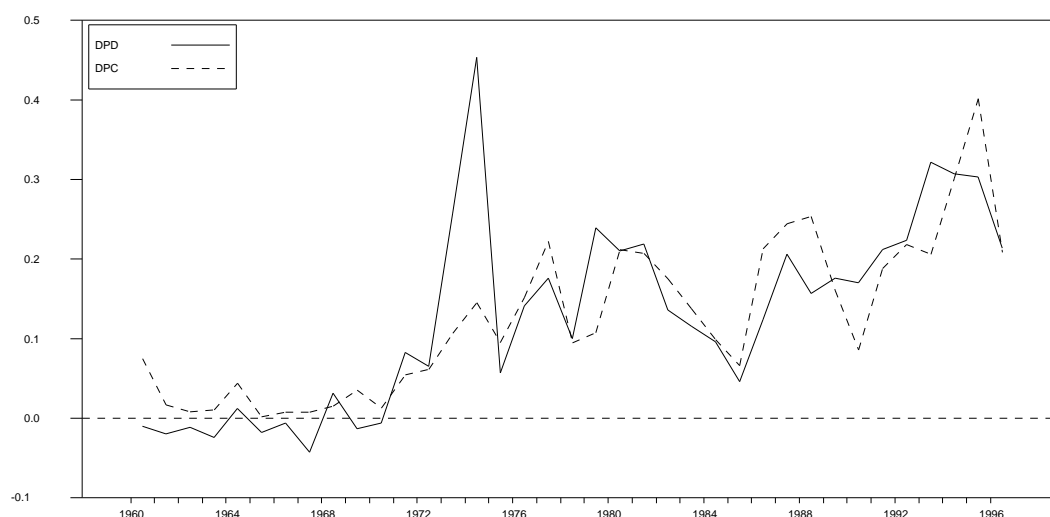
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<sup>2</sup> Since there were extensive government subsidies on consumer goods such as food, fuel and electricity over the period 1959 – 1996, consumer price index (CPI) is unlikely to reflect the true inflation rate and, therefore, the GDP deflator is used in the multivariate analysis.

1972. After 1972, with the oil price and the quantity of oil exports increasing, the rates of inflation rose sharply and exhibited large fluctuations. The annual average rate of the GDP deflator and CPI inflations was 22.9 and 14.7 percent, respectively, during the period 1973 – 1978. A spike for the GDP deflator inflation appeared in 1974 with a rate of 57.4 percent. Indeed, the oil value added is one of the main components of GDP and, through the definition of the GDP deflator (calculated using the ratio of nominal GDP over real GDP), has strongly affected the GDP deflator in 1974. The rates of inflation accelerated to an annual average of 17.0 and 18.9 percent, respectively, over the period 1979 – 1988. This period was particularly rich of events that are sources of inflation pressure, since the revolution, second oil boom, the war, third oil crisis, and the economic embargo took place. Over the period of 1989 – 1993, when the economic reform programme was implemented, the average rate of the GDP deflator inflation was 24.9 while the CPI inflation was exactly the same as in the previous sub-period. The rates of inflation increased further over the period following the structural adjustment programme. The GDP deflator and CPI inflation rates were 31.7 and 35.9 percent, respectively, over the period 1994 – 1996. The CPI inflation rate reached a peak of 49.5 percent in 1995.

Overall, the Iranian inflation rate was very variable and steadily increasing, whatever the inflation measure considered [for details of other inflation measures see, for example, Moradi (2000)].

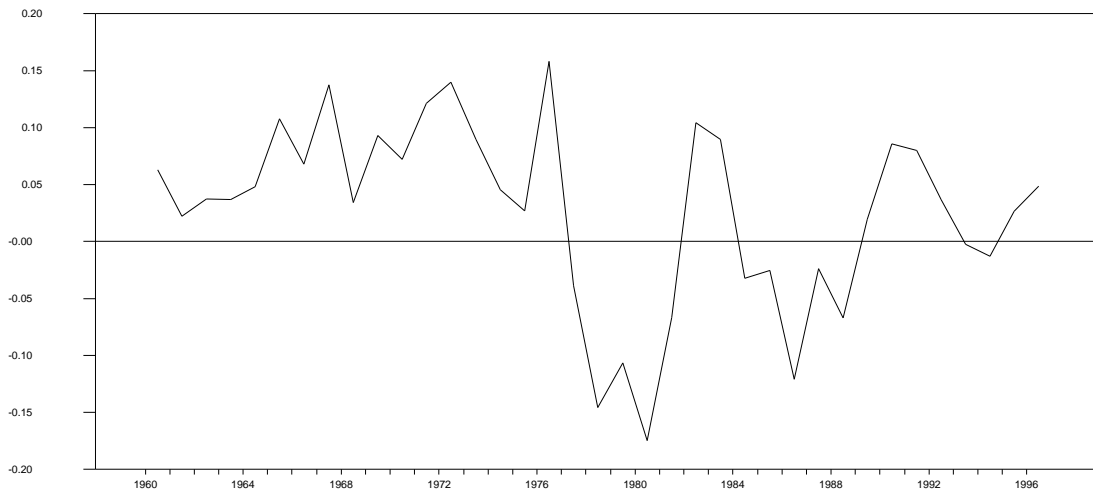
Figure 1 The Plot of the CPI Inflation ( $\Delta P_c$ ) and GDP deflator Inflation ( $\Delta P_d$ ): Annual Data (1960 – 1996)



Next, we examine how the economic growth pattern in Iran has changed over the period 1959 – 1996. The evolution of real GDP is closely associated with the evolution of the oil sector. Since 1959, as long as oil revenue increased, GDP increased too. It continued to rise until 1976. After this period, GDP declined significantly and the economy was in recession. This was mainly the consequence of the reduction in oil revenue. It continued to decline following the revolution and the first years of the war. From 1981 to 1983 GDP increased following an increase in oil exports. Then, there was no significant change in GDP until 1985. Following the fall in the oil price in 1986, GDP again showed a decline. With the end of the war in 1988, GDP rose continuously until 1996.

The growth rate of real per capita GDP, shown in Figure 2, is examined, since it gives a better picture of the welfare in the society. It is characterised by wild fluctuations: until 1976 it fluctuated between 4 percent and 14 percent; while over the period 1978 – 1988 the growth rate was persistently negative with the exception of the mini-boom of 1982/1983; and a more normal pattern is observed after the war.<sup>3</sup>

Figure 2 The Growth Rate of Real GDP per Capita

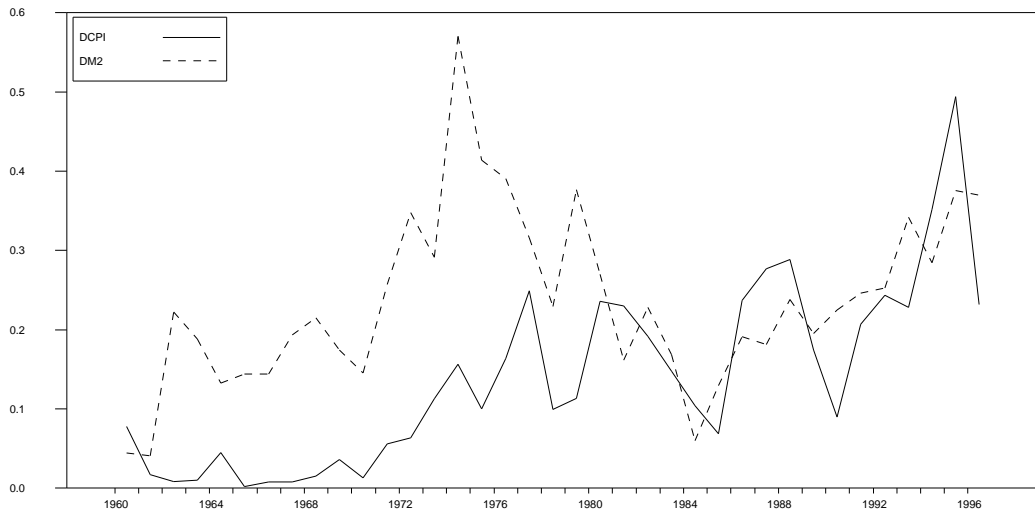


The government budget deficit has been financed largely by printing money since both bond financing and external borrowing were insignificant, if not illegal, and tax revenue formed a small proportion of total government revenue (24.3 percent on average over the period 1959 – 1996). The monetisation of the budget deficit, along with the conversion of foreign currency from oil export into domestic currency, implied a close link between monetary and fiscal policies. Increases in government expenditure, financed mainly through oil revenue, were accompanied by expansion in the money supply. Oil revenue made up 57.7 percent of the government revenue on average over the whole period.

It was the expansionary fiscal and monetary policies following the first oil boom which caused the sharp increase in inflation. The growth rate of money supply is compared with the rate of inflation in Figure 3. It can be seen that the movements in inflation follow closely those of money growth.

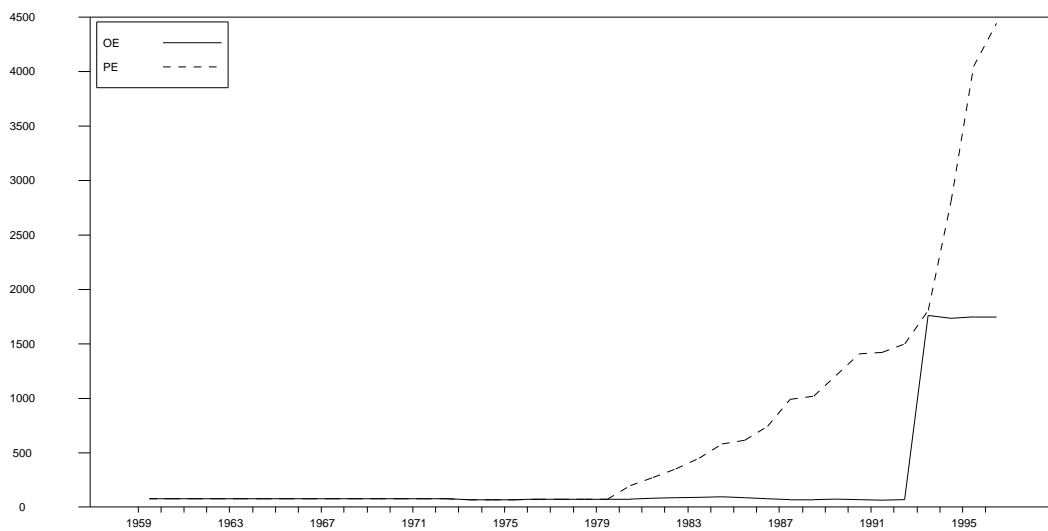
<sup>3</sup> The level of the per capita GDP (at 1990 prices) was lowest, at 342300 rials (domestic currency) in 1959. It steadily increased to reach a peak of 1183510 rials in 1976. Since then it decreased markedly and never exceeded 797600 rials.

Figure 3 The Money Supply Growth (DM2) and Inflation (DCPI)



A fixed exchange rate system prevailed throughout the period along with the existence of an active parallel market. The official exchange rate was re-evaluated several times over the period 1959 – 1988, after which a devaluation policy was initiated. After the revolution, the parallel market rate diverged increasingly from the official rate (see Figure 4). After the war, the authorities launched a unification policy for the official and parallel exchange markets and the eventual move to a floating system. This policy was completed in 1993. However, due to the debt crisis and the resulting higher inflation, this policy was abandoned and the government reverted to a dual official exchange rate system.

Figure 4 Official (OE) and Parallel (PE) Exchange Rates (rials per US\$)



Concerning the trade policy, oil exports constituted the main part of exports, with imports closely linked to oil revenue. The government has played an important role in the international trade of Iran as a regulator, an oil exporter, and the sole (official) provider of foreign currencies. The trade policy led by the government was characterised by several switches between

liberalisation and tightening. The government has generally aimed at improving the competitiveness of the economy and, in this regard, a big devaluation of the domestic currency was implemented. But due to the rigidities in the non–oil sector and other structural problems, production was not significantly boosted by the devaluation.

### **3 Theory and econometric methodology**

A dynamic model of inflation is developed to embed the combination of the following theories, which describe the main determinants of inflation in Iran:

- monetarist theories of inflation
- goods market theories
- external theories of inflation
- inertia theories of inflation

In a closed economy, the monetary theories emphasise the unique role of excess money as an independent cause of inflation and excess output demand considers the output gap measured the difference between actual and potential output. The external theories of inflation describe the foreign transmission channels of inflation in an open economy. Among the inertia theories of inflation, backward–looking indexation is considered by using lagged inflation to explain price inertia.<sup>4</sup>

Theoretically, other markets such as labour and capital markets also affect inflation. However, as it was noted earlier, in the case of Iran, there are no strong labour unions and wage rates are controlled by the authorities [see, for example, Tabibian and Souri (1995) and Taiebnia (1995)]. Moreover, the capital market transmits foreign price inflation, which can be analysed through uncovered interest rate parity (UIP). But there is no active capital market in Iran. Therefore, labour and capital markets are ignored in this study.

The model is also generalised to investigate the effects of other variables on the rate of inflation. They comprise oil prices, terms of trade, real (nominal) per capita government spending, as well as a set of dummy variables to account for the effects of internal and external shocks and the various government interventions.

In an ideal world, the relevant variables should be analysed as a single system. But due to the small sample size of the data available, an alternative approach is used [see, for example, Juselius (1992), Durevall (1998) and Durevall and Ndung’u (1999)]. The relevant equilibrium relations are first specified. The money demand and PPP are estimated separately using cointegration technique while the output gap as a proxy for excess demand is calculated using the difference between actual and potential output. Then, a general error correction model is specified which includes the error correction terms from both the money demand function and the PPP relation as well as the output gap calculated using three measures. These measures comprise the deviations of the log of output from a linear trend, the deviations from a segmented trend, and

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<sup>4</sup> For details of the inertia theories of inflation such as backward and forward looking indexations see, for example, Heyman and Leijonhufvud (1995).

the deviations from the Hodrick-Prescott filter.<sup>5</sup> The model also contains other relevant variables, which are stationary and may have short-run effects on inflation.

### 3.1 Per capita money demand

The proposition that an inverse relationship exists between real balances and inflation and a direct relationship exists between real balances and real income are uncontroversial. The microfoundations of this proposition (based on a representative agent model) is developed corresponding to the characteristics of the Iranian economy where interest rates and bonds have no significant function in the economy. Using a cash-in-advance framework, the above predictions emerge [see Moradi (1999) for details]. The theoretical microfoundation model of the money demand function is derived for Iran as follows:

$$\ln\left(\frac{M_t}{P_t}\right) = \psi_0 - \psi_1 \ln\left(\frac{P_t}{P_{t-1}}\right) + \psi_2 \ln(Y_{t-1}) + \varepsilon_t \quad (1)$$

and then, the following model is used for empirical estimation:

$$M2_t = c - \alpha \Delta P_t^e + \gamma Y_t + u_t \quad (2)$$

where  $M2_t$  is the log of the real per capita balances;  $c$  is intercept;  $\alpha$  and  $\gamma$  are the semi-elasticity of the rate of inflation and income elasticity, respectively;  $P$  is the log of the implicit GDP deflator;  $\Delta P_t^e$  is the expected rate of inflation, used as the opportunity cost of holding money;  $Y_t$  is the log of per capita GDP at 1990 prices.

The empirical money demand specification differs from the theoretical model derived in Moradi (1999). First consider per capita real income. When the variables included in the model are cointegrated,  $Y_{t-1}$  can be replaced by  $Y_t$ , since in the long-run the difference between  $Y_{t-1}$  and  $Y_t$  can be ignored. Concerning the question whether actual or expected inflation should be included, the answer is that it does not matter for the cointegration analysis. Consider the relationship:

$$\Delta P_t = \Delta P_t^e + \omega_t \quad (3)$$

where  $\omega_t$  is normally distributed with a mean of zero and a constant variance of  $\sigma^2$ . Provided the expectation error  $\omega_t$  is stationary, it does not matter whether expectations are rational or adaptive. Substituting  $\Delta P_t$  from the above equation into equation (2) yields:

$$M2_t - \gamma Y_t = c - \alpha \Delta P_t + v_t \quad (4)$$

where  $v_t = u_t + \alpha \omega_t$ . Since  $\omega_t$  is I(0),  $v_t$  is also I(0) provided the original error  $u_t$  is I(0). Hence, if the original equation (2) is cointegrated then equation (4) will also be cointegrated.

If a vector of dummy variables is included, the model may be written as follows:

$$M2_t = c - \alpha \Delta P_t + \gamma Y_t + \Phi D_t + \varepsilon_t \quad (5)$$

where  $D_t$  is a set of dummy variables [ $DO_t$ ,  $D78_t$ ,  $D79_t$ ,  $DW_t$ ,  $D86_t$ , and  $D91_t$ ] included in the model to evaluate the effects of the following internal and external shocks and the government interventions:

- first oil boom ( $DO_t$ )

<sup>5</sup> Ideally, a production function should be estimated. In the case of Iran, since there are some major internal and external shocks such as the eight-year war, Hodrick-Prescott filter is an appropriate approach.

- revolution (D78<sub>t</sub>)
- second oil boom and start of the eight–year war (D79<sub>t</sub>)
- war period (DW<sub>t</sub>)
- third oil boom (D86<sub>t</sub>)
- devaluation of domestic currency, removal of price controls, and deregulation of trade and tariffs considered as a core objective of the economic reform programme initially launched after the eight–year war (D91<sub>t</sub>).

### 3.2 PPP

There are various channels involving the transmission of foreign price inflation into the domestic economy. The capital and goods markets are two major channels of the transmission. The transmission of foreign price inflation via the capital market is based on uncovered interest rate parity (UIP). In a small open economy such as Iran, where there is no well–developed capital market, the transmission mainly happens through the goods market. Consequently, domestic prices are affected through the adjustment towards PPP. PPP mainly relies on the assumption that internationally traded goods are perfect substitutes for domestic goods. This assumption is an oversimplification due to the differences of tastes and technology [see, for example, Juselius (1992), (1995)]. Iran depends heavily on trade. Therefore, this condition is fulfilled for the Iranian economy.

PPP implies that any change in the exchange rate between two currencies is determined by the relative price of domestic and foreign goods. The empirical analysis is concerned with the long–run equilibrium relationship. The long–run PPP may be specified as follows:

$$E_t = \gamma P_t + \delta P_t^f \quad (6)$$

where  $E_t$  is the logarithm of the exchange rate defined as rials (R) per dollar (\$); and  $P_t$  and  $P_t^f$  are the logarithms of the domestic and foreign price levels, respectively. Theory postulates that  $\gamma = 1$  and  $\delta = -1$ .

In testing PPP, it is important to select appropriate definitions of the variables included in equation (6) as well as its generalised form. Concerning prices, three measures are available: wholesale price index, consumer price index, and GDP deflator. As noted earlier, in Iran there have been considerable government subsidies to consumer goods such as foods, fuel and electricity. This means that the CPI does not reflect the true inflation in the economy. Hence, the GDP deflator is preferred as the appropriate measure for domestic prices. The wholesale price index of the US is chosen as the appropriate measure of foreign prices. Concerning exchange rates, the parallel market exchange rate is used, since this more adequately represents the behaviour of agents in the foreign exchange market. The exchange rate against the US dollar is used, since this currency has dominated the exchange markets in Iran.

The time series plots of the relevant variables are first examined using the following equation:

$$Z_t = E_t - P_t + P_t^f \quad (7)$$

The graph shows two significant breaks in the real exchange rate. The first oil boom explains the first break in 1973, while the second oil boom together with the first years of war explain the second break in 1980. To account the effects of these breaks, two dummy variables are included in equation (7):  $D7379_t$  takes the value of 1 if  $t$  is 1973 – 1979 and 0 otherwise, and  $D79_t$  takes

the value of 1 if  $t > 1979$  and 0 otherwise. As noted earlier, several other dummy variables will also be considered in the empirical analysis.

The growth rate of the US wholesale price index is negligible compared with the GDP deflator of Iran, so that the nominal exchange rate and GDP deflator follow each other fairly closely over the period. More specifically, these two series increase by a similar proportion after 1979 when there was an active parallel market for foreign exchanges.

In addition of those dummy variables considered in money demand, a dummy variable for the period 1973 – 1979 ( $d7379_t$ ) is included to account for the effects of a break in the real exchange rate. The following cointegrating relationship is specified:

$$E_t = \beta_0 + \gamma P_t + \delta P_t^f + \Phi D_t + u_t \quad (8)$$

Equation (8) is also generalised to consider the effects of other relevant variables such as terms of trade, oil prices and government spending.

### 3.3 Goods market

Goods market is considered to investigate the effects of output gap as proxy for excess demand [see, for example, Durevall (1998)]. Theoretically, the production function approach is appropriate to estimate potential output. However, in the case of Iran, due to the presence of some major shocks such as eight-year war and draughtiness, this approach is not employed. Instead, three different measures are used to decompose the per capita real output to potential and cyclical components and then calculate the output gap by differencing the actual output from its trend. These measures are as follows:

- linear trend
- segmented trend
- Hodrick-Prescott (HP) filter

The HP filter minimizes the squared deviations of a trend from a sequence subject to the constraint that the sum of the squared first difference of the growth rate should not be too large, that is:

$$\text{Min} \quad \sum_{t=1}^T (y_t - y_t^*)^2 \quad (9)$$

subject to

$$\sum_{t=2}^{T-1} [(y_{t+1}^* - y_t^*) - (y_t^* - y_{t-1}^*)]^2 \leq \lambda \quad (10)$$

where  $y_t$  is the logarithm of output and  $y_t^*$  a trend component (potential output). The smaller the  $\lambda$ , the smoother the trend component. When  $\lambda$  is zero,  $y_t = y_t^*$  and the cycle is zero for all  $t$ .

The term  $y_t - y_t^*$  can be interpreted as the cyclical component while the term  $[(y_{t+1}^* - y_t^*) - (y_t^* - y_{t-1}^*)]$  can be interpreted as the change in the growth rate of the trend component.

## 4 Empirical analysis of linear modelling

### 4.1 The data

The data are annual over the 1959 – 1996 period. Population, wholesale price and official exchange rate (which is period average rate) were collected from International Financial statistics of the IMF, various issues. The source of other data is the Central Bank of Iran.

### 4.2 Order of integration

The Perron's procedure (1989) is applied to determine the degree of integration of the macroeconomic variables considered in this paper. Moreover, the augmented Dickey–Fuller (ADF) test are applied to provide further information concerning the degree of integration of the time series. The order of lags in the regression is chosen according to the Schwarz Bayesian Criterion and Akaike Information Criterion together with Likelihood–ratio tests. Moreover, the lags are not omitted if their exclusion results in serial correlation.

Table 1 Univariate Augmented Dickey–Fuller Test for Unit Roots in the Level and First Difference of Time Series

Regression: $\Delta Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\delta}Y_{t-1} + \sum_{i=1}^k \hat{c}_i \Delta Y_{t-i} + \hat{\varepsilon}_t$				
Variables	n	k	$\hat{\delta}$	$t_{\hat{\delta}}$
$P_t$	36	1	-0.06	-1.78
$\Delta P_t$	36	0	-0.64	-3.91**
$M2_t$	37	0	-0.07	-1.66
$\Delta M2_t$	36	0	-0.83	-4.79***
$Y_t$	36	1	-0.08	-1.98
$\Delta PY_t$	36	0	-0.42	-3.03*
$O_t$	36	1	-0.09	-1.35
$\Delta O_t$	36	0	-0.71	-4.25***
$E_t$	37	0	-0.06	-1.20
$\Delta E_t$	36	0	-0.84	-4.82***
$P_t^f$	36	1	-0.08	-2.17
$\Delta P_t^f$	35	1	-0.38	-3.19*
$P_t^{EX}$	36	1	-0.09	-1.76
$\Delta P_t^{EX}$	35	1	-0.94	-4.65***
$P_t^{IM}$	37	0	0.07	2.68
$\Delta P_t^{IM}$	36	0	-0.73	-4.39***
$TOT_t$	36	1	-0.21	-2.24
$\Delta TOT_t$	36	0	-0.71	-4.21***
$Z_t$	36	1	-0.16	-1.84

Notes:

- $P_t$  is the log of the implicit deflator of GDP at market prices;  $M2_t$  is the log of the per capita real M2;  $Y_t$  is the log of the per capita real GDP;  $O_t$  is the log of the Iranian oil export prices;  $E_t$  is the log of the parallel market exchange rate; and  $E_t$  is the log of the parallel market exchange rate;  $P_t^f$  is the log of the wholesale prices of the US;  $P_t^{EX}$  is the log of the prices of exports;  $P_t^{IM}$  is the log of the prices of imports;  $TOT_t$  is the log of the terms of trade;  $Z_t$  is the real exchange rate; and  $\Delta$  is the difference operator.
- $n$  is the number of observations; and  $k$  is the number of lags.
- \*\*\*, \*\*, and \* indicate statistical significance at the 1 %, 2.5 % and 5% levels, respectively, according to the critical values of the ADF test.

Inspection of the plots indicates the presence of structural breaks in the following series:

- the per capita real balances M2
- GDP deflator
- parallel market exchange rate
- real exchange rate

Model (C) of the Perron procedure is used to test for unit roots in the level of the series and model (A) is used for the first difference. Table 2 and Table 3 report the results of the test for the levels and first differences, respectively. The results show that for all series there is a unit root in the level but not in the first difference. These results are consistent with the ADF results except the real exchange rate.

Table 2 Univariate Perron Tests for Unit Roots in Levels: 1959 – 1996

Regression: $Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\beta}D_t + \hat{d}TB_t + \hat{\delta}DT_t + \hat{\gamma}Y_{t-1} + \sum_{i=1}^k \hat{c}_i \Delta Y_{t-i} + \hat{\varepsilon}_t$			
	$M2_t$	$P_t$	$E_t$
$n$	36	36	36
$k$	0	1	1
$\lambda$	0.50	0.35	0.54
$\hat{\mu}$	2.67	-0.60	1.69
$t_{\hat{\mu}}$	(4.20)	(-1.49)	(2.89)
$\hat{\alpha}$	0.080	0.004	-0.002
$t_{\hat{\alpha}}$	(4.00)	(0.60)	(-0.71)
$\hat{\beta}$	-0.100	-0.320	-0.930
$t_{\hat{\beta}}$	(-2.25)	(-0.98)	(-2.36)
$\hat{d}$	0.07	0.11	0.47
$t_{\hat{d}}$	(1.06)	(1.22)	(2.63)
$\hat{\delta}$	-0.09	0.03	0.07
$t_{\hat{\delta}}$	(-3.88)	(1.21)	(2.87)
$\hat{\gamma}$	0.31	0.82	0.61
$t_{\hat{\gamma}-1}$	(-4.06)	(-1.38)	(-2.90)

Notes:

- $M2_t$  is the log of the per capita real M2;  $P_t$  is the log of the GDP deflator; and  $E_t$  is the log of the parallel market exchange rate.

- $D_t$ ,  $TB_t$ , and  $DT_t$  are dummy variables taking values as follows:  
 $D_t = 1$  if  $t \geq t^*$  and 0 otherwise;  $TB_t = 1$  if  $t = t^*$  and 0 otherwise;  $DT_t = t$  if  $t \geq t^*$  and 0 otherwise, where  $t^* = 1979$  for per capita real balances,  $t^* = 1973$  for GDP deflator, and  $t^* = 1980$  for parallel exchange rate.
- $n$  is the number of observations;  $k$  is the number of lags; and  $\lambda$  denotes the ratio of pre-break sample size to total sample size.

Table 3 Univariate Perron Tests for Unit Roots in First Differences: 1959 – 1996

Regression:	$\Delta M2_t$	$\Delta P_t$	$\Delta E_t$
$Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\beta}D_t + \hat{d}TB_t + \hat{\gamma}Y_{t-1} + \sum_{i=1}^k \hat{c}_i \Delta Y_{t-i} + \hat{\epsilon}_t$			
$n$	36	36	35
$k$	0	0	1
$\lambda$	0.50	0.35	0.54
$\hat{\mu}$	0.120	-0.020	-0.001
$t_{\hat{\mu}}$	(3.16)	(-0.68)	(-0.01)
$\hat{\alpha}$	0.001	0.003	-0.020
$t_{\hat{\alpha}}$	(0.14)	(1.29)	(-0.06)
$\hat{\beta}$	-0.14	0.08	1.01
$t_{\hat{\beta}}$	(-2.61)	(1.51)	(3.66)
$\hat{d}$	0.07	0.13	-0.02
$t_{\hat{d}}$	(0.93)	(1.58)	(-2.07)
$\hat{\gamma}$	-0.04	0.25	-0.44
$t_{\hat{\gamma}-1}$	(-5.78)***	(-4.41)***	(-6.26)***

Notes:

- $M2_t$  is the log of the per capita real M2;  $P_t$  is the log of the GDP deflator; and  $E_t$  is the log of the parallel market exchange rate; and  $\Delta$  is the difference operator.
- $D_t$  and  $TB_t$  are dummy variables taking values as follows:  
 $D_t = 1$  if  $t \geq t^*$  and 0 otherwise;  $TB_t = 1$  if  $t = t^*$  and 0 otherwise, where  $t^* = 1979$  for per capita real balances,  $t^* = 1973$  for GDP deflator, and  $t^* = 1980$  for parallel exchange rate.
- $n$  is the number of observations;  $k$  is the number of lags; and  $\lambda$  denotes the ratio of pre-break sample size to total sample size.
- \*\*\* and \* indicate statistical significance at the 1% and 5% levels, respectively, according to the critical values of the Perron test (1989, Table IV.A).

The finding of a unit root in the real exchange rate may be due to the existence of breaks. To check for structural breaks, the Perron procedure is used. The Perron test which allows for a break in intercept, after 1979, is employed (model A of the Perron test). Moreover, an additional dummy variable is considered to account for the shift in the intercept of the series in 1973. In contrast with the ADF test that could not reject the null of a unit root in the real exchange rate ( $Z_t$ ), the results of the Perron test show the rejection of the null hypothesis at 5% level.<sup>6</sup> Hence, it is concluded that the real exchange rate is  $I(0)$ . The result implies that the  $I(1)$  series included in the PPP relationship are cointegrated, which provides evidence in support of long-run PPP.

<sup>6</sup> The Perron critical values are not strictly appropriate, since two dummy variables are considered.

The results show that foreign price inflation,  $\Delta P_t^f$ , is only rejected at the 5 % level. However, if the real exchange rate is I (0) and the two other series, nominal exchange rate and the GDP deflator, included in the PPP relationship are I (1), then the US wholesale price series should also be I (1), i. e.,  $\Delta P_t^f$  should be I (0) rather than I (1). Also, the ACF of  $\Delta P_t^f$  tails off quickly, implying that the series should be stationary. Furthermore, when the time trend is excluded from the ADF test, the null of a unit root in  $\Delta P_t^f$  is rejected at the 2.5 % level ( $t_{\hat{\gamma}} = -3.23$ ). Thus, the finding that  $\Delta P_t^f \sim I(0)$  is stronger than the evidence from Table 1 would suggest.

### 4.3 Cointegration results

#### a. Long-run per capita money demand

The Johansen-Juselius (1990) cointegration technique is used to estimate the per capita money demand function using annual data for the 1959-1996 period. Structural breaks are considered in equation (5) by taking account of the effects of big shocks and government interventions such as the oil shocks, the revolution, the eight-year war, and big devaluation of the domestic currency.

The function includes two I (1) variables: per capita real balances and per capita real income; one I (0) variable: the rate of inflation; and a set of appropriate dummy variables. After considering all relevant dummy variables, only two were found significant: first dummy accounts for a one-time shift due to the revolution in 1978 and the second dummy accounts for an outlier in 1978.

The order of VAR (p) considered in the cointegration tests is determined on the basis of the information criteria provided by the AIC and SBC as well as LR tests.<sup>7</sup> From Table 4, the SBC and AIC suggest one lag while the likelihood ratio (LR) test suggests VAR (1) at 5 percent level and VAR (2) at 10 percent level. However, p = 1 is chosen.

Table 4 Test Statistics and Choice Criteria for Selecting the Order of the VAR Model Based on Observations from 1962 to 1996 and the Order of VAR (2)

List of variables included in the unrestricted VAR: M2		Y				
List of deterministic and/ or exogenous variables: $\Delta P$		D78	TB78			
Order	LL	AIC	SBC	LR test	Adjusted LR test	
2	106.6927	92.6927	81.6080	-	-	
1	102.7225	92.7225	84.8049	CHSQ( 4)= 7.9403[.094]	6.3964[.171]	
0	-96.4492	-102.4492	-107.1998	CHSQ( 8)= 406.2838[.000]	327.2842[.000]	

Notes:

- $M2_t$  is the log of the per capita real M2;  $Y_t$  is the log of the per capita real gross domestic product (GDP); and  $\Delta P_t$  is the rate of inflation.
- $D78_t$  is dummy variable for the revolution, which takes 1 if  $t > 1978$  and 0 otherwise;  $TB78_t = 1$  if  $t = 1978$  and 0 otherwise.
- LL is the Maximised log-likelihood; AIC is the Akaike information criterion; SBC is the Schwarz Bayesian Criterion; and LR is the likelihood ratio test.

<sup>7</sup> Due to the small sample size, a maximum of two lags is employed.

Table 5 reports the results of two likelihood ratio statistics,  $\lambda_{\max}$  statistic and  $\lambda_{\text{trace}}$  statistic, in order to determine the number of cointegrated vectors. Both  $\lambda_{\max}$  statistic and  $\lambda_{\text{trace}}$  statistic suggest the cointegrating rank of one at 5 percent level. So, it is concluded that there exists a long-run relationship between per capita real balances, inflation, and per capita real income when a break point in 1978 is accounted for.<sup>8</sup>

Table 5 Cointegration Tests Based on Johansen's Maximum Likelihood Procedure

Null	Alternative	$\lambda_{\max}$ Statistic	Critical Value (95%)	$\lambda_{\text{trace}}$ Statistic	Critical Value (95%)
$r = 0$	$r = 1$	19.48**	14.88	21.35**	17.86
$r \leq 1$	$r = 2$	1.87	8.07	1.87	8.07

Notes:

- Lags in the VAR = 1.
- \*\* and \* indicate statistical significance at the 5%, and 10% levels, respectively.

The long-run money demand function is estimated and normalised to represent the per capita demand function for money as follows:

$$M2_t = 2.09Y_t + \hat{\varepsilon}_t \quad (11)$$

The parameters of inflation and dummy variables are estimated and included in the model. The estimates are as follows:

$$\hat{M}2_t = -3.40\Delta P_t + 2.09Y_t - 8.18 + 1.11D78_t + 0.30TB78_t \quad (12)$$

As can be seen, the signs of all coefficients are consistent with the theory. The semi-elasticity of inflation is 3.40 while the income elasticity is 2.09.

The robustness of estimates is also investigated using other procedures. The autoregressive distributed lag (ARDL) method is employed as an alternative method to specify and estimate the models. An ARDL (2, 2, 2) is considered. The long-run semi-elasticity of inflation is 3.26 and the income elasticity is 2.33, which are very similar to the estimates reported in equation (12). The ARDL method was also applied to sub-sample periods, pre-1978 and post-1978. This suggested the need to include the dummy variables D78 and TB78 to account for the break.<sup>9</sup> The cointegrating regressions are also estimated using both OLS and the fully modified Phillips-Hansen (1990) methods.<sup>10</sup> The results again confirm that the signs of coefficients are consistent with the theory, provided the models allow for the break in 1978.

In the Johansen method, VAR (2), which is selected by the LR at 10 percent level, is used to estimate the long-run coefficients. The elasticity of real income is 1.96 and the semi-elasticity of the rate of inflation is 3.29. Comparing these results with those from VAR (1), the magnitudes of the values are very similar. Furthermore, when the VAR (1) is specified to include a trend, the results show that the trend is not significant in all the models. The t-value of the trend is 0.30.

<sup>8</sup> It should be noted that time trend is not significant in the models and so it is excluded.

<sup>9</sup> Like the Johansen procedure based on the VAR, the ARDL method estimates the long-run effects jointly with the short-run effects. For small sample, as in the comparison of the sub-periods above, the ARDL method may be the most appropriate.

<sup>10</sup> Both of these methods estimate the long-run effects by ignoring the short-run adjustments. The P-H procedure makes an adjustment for simultaneity as well as autocorrelation and heteroscedasticity in the residuals. With OLS the standard errors are invalid even though the coefficient estimates are superconsistent in large samples.

Finally, to test the robustness of the per capita demand function for money, the log of the exchange rate ( $E_t$ ) is included as an additional variable. The estimated equation of the per capita function shows that the coefficient of the parallel market exchange rate is insignificant.<sup>11</sup> An ECM was also estimated, with  $\Delta M2$  as the dependent variable, but the exchange rate was again insignificant.

*b. PPP*

The cointegrating relationship is specified as follows:

$$E_t = \beta_0 + \beta_1 D7379_t + \beta_2 D79_t + \gamma P_t + \delta P_t^f + u_t \quad (13)$$

It can be seen from Table 6 that all those criteria suggest the order of the VAR to be one.

Table 6 Test Statistics and Choice Criteria for Selecting the Order of the VAR Model Based on Observations from 1962 to 1996 and the Order of VAR (2)

List of variables included in the unrestricted VAR: $E_t$ $P_t$ $P_t^f$						
List of deterministic and/or exogenous variables: $D7379_t$ $D79_t$						
Order	LL	AIC	SBC	LR test	Adjusted LR test	
2	168.3332	144.3332	125.3310	-	-	
1	159.9783	144.9783	133.1019	CHSQ( 9)= 16.7097[.053]	12.9965[.163]	
0	-91.0438	-97.0438	-101.7944	CHSQ( 18)= 518.7540[.000]	403.475[.000]	

Notes:

- $E_t$  is the log of the parallel market exchange rate;  $P_t$  is the log of the GDP deflator; and  $P_t^f$  is the log of the wholesale price of the US.
- $D7379_t$  and  $D79_t$  are dummy variables;  $D7379_t$  takes 1 if  $t$  is 1973 – 1979 and 0 otherwise and  $D79_t$  takes 1 if  $t > 1979$  and 0 otherwise.
- LL is the Maximised log-likelihood; AIC is the Akaike information criterion; SBC is the Schwarz Bayesian Criterion, and LR is the likelihood ratio test.

Table 7 reports the results of the Johansen test statistics for the determination of the number of cointegration vectors. As can be seen, the null of no cointegration can be rejected strongly. The tests indicate that there is only one cointegration relationship between the nominal exchange rate and the two price indices when two dummy variables are indicated to account for breaks in PPP.

Table 7 Cointegration Results Based on Johansen's Maximum Likelihood Procedure

Null	Alternative	$\lambda_{\max}$ Statistic	Critical Value (95%)	$\lambda_{\text{Trace}}$ Statistic	Critical Value (95%)
$r = 0$	$r = 1$	60.05*	21.12	77.84*	31.54
$r \leq 1$	$r = 2$	13.51	14.88	17.79	17.86
$r \leq 2$	$r = 3$	4.28	8.07	4.28	8.07

Notes:

- Order of the VAR = 1.
- \* indicates statistical significance at the 5% level.

<sup>11</sup> When the official exchange rate is used instead of the parallel market rate, the results confirmed that this is also insignificant. It should be mentioned that the parallel market exchange rate data for the period 1959 – 1993 collected from World Currency Yearbook, which were available, were also used, but the results did not change.

Table 8 reports the results of OLS, Phillips–Hansen, and ML estimation of this equation.<sup>12, 13</sup> It is interesting that the three alternative estimators provide similar estimates. All of the estimated parameters have the expected signs. Moreover, the magnitudes of the coefficients of domestic and foreign prices are close to 1 and -1 as expected. The hypothesis that the cointegration vector for the variables  $E_t$ ,  $P_t$ , and  $P_t^f$  is [1 -1 1] was in fact tested and could not be rejected at the 5 % significance level.

Table 8 OLS, Phillips–Hansen (P–H), and ML Estimates of the PPP Relationship

Regression: $E_t = \hat{\beta}_0 + \hat{\beta}_1 D7379_t + \hat{\beta}_2 D79_t + \hat{\gamma} P_t + \hat{\delta} P_t^f + \hat{u}_t$										
	$\hat{\beta}_0$	$t_{\hat{\beta}_0}$	$\hat{\beta}_1$	$t_{\hat{\beta}_1}$	$\hat{\beta}_2$	$t_{\hat{\beta}_2}$	$\hat{\gamma}$	$t_{\hat{\gamma}}$	$\hat{\delta}$	$t_{\hat{\delta}}$
OLS	6.16	-	-0.44	-	0.82	-	1.01	-	-1.11	-
P-H	5.27	18.81	-0.54	-2.90	0.75	2.37	0.95	15.58	-0.86	-2.39
ML	7.52	156.22	-0.45	-5.38	0.87	13.37	0.95	11.17	-1.41	-3.65

Notes:

- $E_t$  is the log of the parallel market exchange rate;  $P_t$  is the log of the GDP deflator; and  $P_t^f$  is the log of the wholesale price of the US.
- $D7379_t$  and  $D79_t$  are dummy variables;  $D7379_t$  takes 1 if  $t$  is 1973 – 1979 and 0 otherwise and  $D79_t$  takes 1 if  $t > 1979$  and 0 otherwise.
- P–H is an estimation procedure proposed by Phillips and Hansen (1990).

It should be noted that all the dummy variables mentioned in section two were considered in estimating the PPP relationship but only those included in equation (13) were found to be significant. If a VAR of order 2 is employed, the results are qualitatively the same. Also if the CPI measure is used instead of the GDP deflator, the results again do not change. Finally, if the classical PPP relationship is generalised to include terms of trade ( $TOT_t$ , defined as the ratio of exports prices to imports prices) and, or the oil price ( $O_t$ ) in log levels, the results show that neither of these variables is significant.

### c. Excess demand

The excess demand is calculated by using all three measures as noted earlier. In the estimation of the HP filter,  $\lambda = 7$  is selected as recommended by Microfit for the annual data. The plot of the excess demand calculated by using Hodrick-Prescott (HP) filter shows a cyclical trend in the output gap and the wild fluctuation was over the period 1976 – 1987.

## 4.4 Linear model of inflation

Given annual observations and the limited sample size, only lagged value of the differenced series is included in the general model. The general form of the error correction model is as follows:

<sup>12</sup> Since the standard errors of the OLS estimator are not valid,  $t$ -values of the coefficients are not reported.

<sup>13</sup> The Phillips–Hansen (1990) procedure estimates a single cointegration relationship by the fully modified OLS procedure. In this method, it is assumed that the variables included in the model are  $I(1)$ .

$$\Delta P_t = \beta_0 + \beta_1 T + \beta_2 \Delta M2_{t-1} + \beta_3 \Delta Y_{t-1} + \beta_4 \Delta P_{t-1} + \beta_5 \Delta E_{t-1} + \beta_6 \Delta P_{t-1}^f + \delta_1 \Delta O_{t-1} + \delta_2 \Delta TOT_{t-1} + \delta_3 \Delta G_{t-1} + \lambda_1 EC1_{t-1} + \lambda_2 EC2_{t-1} + \lambda_3 EC3_{t-1} + \Phi D_t + \varepsilon_t \quad (14)$$

where  $M2_t$  is the log of per capita real balances;  $Y_t$  is the log of per capita real GDP;  $P_t$  is the log of the GDP deflator;  $E_t$  is the log of the parallel market exchange rate;  $P_t^f$  is the log of the foreign price proxied by the wholesale price index of the US;  $O_t$  is the log of the oil price in Iran;  $TOT_t$  is the log of the terms of trade defined as the ratio of exports prices over import prices;  $G_t$  is the log of real per capita government spending;  $D_t$  is a set of dummy variables;  $EC1_t$  and  $EC2_t$  are the error correction terms derived from the money demand function and the PPP relationship and are defined as follows:

$$EC1_t = PMP2_t + 3.40\Delta P_t - 2.09PY_t + 8.18 - 1.11D78_t - 0.30TB78_t \quad (15)$$

$$EC2_t = E_t - P_t + P_t^f - 6.27 + 0.50D7379_t - 0.72D79_t \quad (16)$$

and  $EC3_t$  is the output gap as a proxy for excess demand. Long-run determinants of inflation are explained by error correction terms while the short-run determinants are explained by the first differences of the variables included in the model. After simplification the following model is obtained:

$$\Delta \hat{P}_t = 0.17DO_t + 0.10D91_t - 0.36TB75_t - 0.11TB88_t + 0.14\Delta O_{t-1} + 0.10EC1_{t-1} + 0.11EC2_{t-1} \quad (17)$$

(12.71)    (3.56)    (-4.92)    (-1.82)    (3.46)  
(2.23)    (2.05)

n = 36	$\bar{R}^2 = 0.802$	s = 0.0532
$\chi_{SC}^2(1) = 0.05 [0.83]$	$\chi_{FF}^2(1) = 2.03 [0.15]$	$\chi_N^2(2) = 0.9 [0.95]$
$\chi_{ARCH}^2(1) = 0.58 [0.45]$	$F_1(8, 21) = 0.62 [0.70]$	$F_2(4, 25) = 1.95 [0.14]$

where n is the number of observations;  $\bar{R}^2$  is the adjusted squared multiple correlation coefficient; s is the standard error of regression;  $\chi_{SC}^2$  is Lagrange Multiplier (LM) test statistic for residual autocorrelation;  $\chi_{FF}^2$  is RESET statistic for misspecification;  $\chi_N^2$  is Jarque–Bera test statistic for normality;  $\chi_{ARCH}^2$  is test statistic for autoregressive conditional heteroscedasticity;  $F_1$  is F–statistic for the joint significance of the omitted variables:  $\Delta M2_{t-1}$ ,  $\Delta Y_{t-1}$ ,  $\Delta P_{t-1}$ ,  $\Delta E_{t-1}$ ,  $\Delta P_{t-1}^f$ ,  $\Delta TOT_{t-1}$ ,  $\Delta G_{t-1}$  and  $EC3_{t-1}$ ; while  $F_2$  is F–statistic for the joint significance of the omitted dummy variables: period between first and second oil booms (1973 – 1979), revolution in 1978, eight–year war (1980 – 1988), and third oil shock in 1986.

As can be seen, the model passes all the diagnostic tests. There is no evidence of serial correlation, functional form misspecification, non–normal errors, or ARCH effects. The two F–tests confirm the insignificance of all the variables that are omitted from the model. These variables are also individually insignificant on the basis of their t–ratios.

The interesting result is that the coefficients of the error correction terms derived from the money demand function and the PPP relationship are significant and have the correct signs, while

the coefficient of the  $EC3_t$ , as a proxy for excess demand, is not significant. The coefficient of excess money is 0.10, indicating that excess money raises domestic inflation in the long-run. The coefficient of the deviations from long-run PPP is of a similar magnitude and suggests that the exchange rate and foreign prices also raise inflation in the long-run. However, none of the output gap measures have significant coefficients.

Apart from the effects of adjustment to deviations from PPP and equilibrium money demand, there are no long-run effects from excess demand. There are also no short-run effects on inflation apart from a positive effect from changes in oil prices. In particular, there is no effect from changes in the terms of trade or real per capita government spending (nominal government spending was included as an alternative, but this was again insignificant). Also, the fact that the coefficient of  $\Delta P_{t-1}$  is insignificant implies that there is no evidence for the inertia hypothesis.

Given that the sample period covers two different political regimes (pre- and post-revolution), three oil shocks, the eight-year war and the economic reform programme, it was necessary to include several dummy variables in the model. The results show that the first oil boom in 1973 ( $DO_t$ ) and the reform programme ( $D91_t$ ) had significant positive effects on the rate of inflation. The need for the latter dummy was indicated by the plot of the residuals, and the effect can be explained in terms of the reform programme that began in 1989. The fact that the effect on inflation was seen only from 1991 reflects the fact that the removal of price controls and government subsidies were gradual. Also by 1991 the eventual depreciation of the domestic currency was probably fully anticipated.

The results also show that it was necessary to account for two outlier observations (1975 and 1988). Although the estimates are not very sensitive to the removal of  $TB75_t$  and  $TB88_t$ , they were included in order to ensure the normality of the residuals and, therefore, the validity of the statistical tests. As shown by the  $F_2$  statistic, the effects of other dummy variables (accounting for the revolution, eight-year war, and other oil shocks) were not significant.

In conclusion, the linear analysis shows that inflation in Iran was affected by both domestic factors through excess money supply, and external factors through deviations from PPP. This finding suggests the possibility that the government could attempt to control inflation through monetary or exchange rate policies. The results do not support the inflation-inertia hypothesis for Iran. This hypothesis reflects inflation indexation. A finding of random walk behaviour in inflation would provide evidence for this. Since the lagged dependent variable in the model for  $\Delta P_t$  was insignificant, no such evidence is obtained here.

However, the fact that both adjustment coefficients are very low means that such policies may not be effective. An explanation of slow adjustment may be that the true adjustment process is nonlinear as in Michael, Nobay and Peel, (1999). Their specification implies that adjustment is faster for large deviations from equilibrium. Considering the fact, nonlinear behaviour of inflation is investigated to compare with the linear specification in equation (17) in the following section.

## 5 Modelling nonlinear behaviour

### 5.1 Nonlinear adjustment

Following Granger and Terasvirta (1993), the nonlinear structure of inflation is investigated by testing linearity against two parametric nonlinear models: the exponential smooth transition autoregressive (ESTAR) and the logistic smooth transition autoregressive (LSTAR) models. Granger and Terasvirta (1993) also note that the LM-type tests against a STAR model very often have good power even when the true alternative is a switching regression model [see, for example, Luukkonen et al. (1988a) and Peteucci (1990) for details]. The basic STAR model of order  $p$  is

$$\Delta P_t = \beta_0 + \sum_{j=1}^p \beta_j X_{t-j} + (\beta_0^* + \sum_{j=1}^p \beta_j^* X_{t-1}) F(Z_{t-d}) + u_t \quad (18)$$

where  $\{\Delta P_t\}$  is assumed stationary;  $u_t \sim \text{i.i.d. } (0, \sigma^2)$ ;  $X_t$  is a vector of explanatory variables;  $Z_t$  is transition variable; and  $F$  is a transition function which by convention is bounded by zero and one. The form of the logistic function is

$$F(Z_{t-d}) = (1 + \exp\{-\gamma(Z_{t-d} - c)\})^{-1}, \quad \gamma > 0 \quad (19)$$

and the form of the exponential function is

$$F(Z_{t-d}) = (1 - \exp\{-\gamma(Z_{t-d} - c)^2\})^{-1}, \quad \gamma > 0 \quad (20)$$

Model (18) with (19) is called the LSTAR model, while (18) with (20) is called the ESTAR model.

When  $\gamma \rightarrow \infty$  in equation (19), then  $F(Z_{t-d}) = 0$  if  $Z_{t-d} \leq c$ , while  $F(Z_{t-d}) = 1$  if  $Z_{t-d} > c$ , consequently, equation (18) becomes a threshold AR ( $p$ ) model:

$$\Delta P_t = \begin{cases} \beta_0 + \sum_{j=1}^p \beta_j \Delta X_{t-j} + u_t & Z_{t-d} \leq c \\ \beta_0 + \sum_{j=1}^p \beta_j \Delta X_{t-j} + (\beta_0^* + \sum_{j=1}^p \beta_j^* \Delta X_{t-1}) + u_t & Z_{t-d} > c \end{cases} \quad (21)$$

When  $\gamma \rightarrow 0$  or  $\beta_j^* = 0$  ( $j = 0, 1, \dots, p$ ), then model (18) becomes a linear AR ( $p$ ) model:

$$\Delta P_t = \beta_0 + \sum_{j=1}^p \beta_j \Delta X_{t-j} + u_t \quad (22)$$

### 5.2 Testing Linearities

The linearity hypothesis can be expressed as  $H_0: \gamma = 0$  against  $H_1: \gamma > 0$ . A Lagrange multiplier (LM) type test of linearity against STAR (both LSTAR and ESTAR), assuming  $d$  is known, is equivalent to the test of the following null hypothesis:

$$H_0: \beta_{2j} = \beta_{3j} = \beta_{4j} = 0, \quad (j = 1, \dots, p) \quad (23)$$

in the artificial regression

$$\Delta P_t = \beta_0 + \sum_{j=1}^p \beta_{1j} \Delta X_{t-j} + \sum_{j=1}^p \beta_{2j} \Delta X_{t-j} Z_{t-d} + \sum_{j=1}^p \beta_{3j} \Delta X_{t-j} Z_{t-d}^2 + \sum_{j=1}^p \beta_{4j} \Delta X_{t-j} Z_{t-d}^3 + v_t \quad (24)$$

against the alternative that  $H_0$  is not valid.

To specify  $d$ , the test is repeated for the range of values  $1 \leq d \leq D$ . If linearity is rejected for more than one value of  $d$ , then  $d$  is determined as the value  $\hat{d}$ , which minimises the P-value of the test. The logic behind this rule is that the test has maximum power if  $d$  is chosen correctly, whereas an incorrect choice of  $d$  weakens the power of the test.

If linearity is rejected, we have to choose the appropriate model. Since economic theory may not help to distinguish between LSTAR and ESTAR models, Terasvirta and Anderson propose a criterion to choose between these models. They consider the following sequence of hypotheses to be tested:

$$H_{04}: \beta_{4j} = 0, \quad (j = 1, \dots, p) \quad (25)$$

$$H_{03}: \beta_{3j} = 0 \mid \beta_{4j} = 0, \quad (j = 1, \dots, p) \quad (26)$$

$$H_{02}: \beta_{2j} = 0 \mid \beta_{3j} = \beta_{4j} = 0, \quad (j = 1, \dots, p) \quad (27)$$

If the model is an ESTAR model, then  $\beta_{4j} = 0$ ,  $j = 1, \dots, p$ , but  $\beta_{3j} \neq 0$  for at least one  $j$  if  $\beta_j^* \neq 0$ . If the model is a LSTAR model,  $\beta_{2j} \neq 0$  for at least one  $j$  if  $\beta_j^* \neq 0$ . For example, if (25) is rejected we choose the LSTAR model. If (25) is accepted and (26) is rejected, the ESTAR model is selected. Moreover, if (25) and (26) are accepted and (27) is rejected, then the LSTAR model is chosen.

## 6 Empirical analysis of nonlinear modelling

Linearity tests are applied where  $p$  and a delay of one period ( $D = 1$ ) are considered as a plausible value due to small sample size. The following models is used to test linearity:

$$\begin{aligned} \Delta P_t = & \beta_0 + \beta_{11} \Delta P_{t-1} + \beta_{12} \Delta O_{t-1} + \beta_{13} \Delta E_{t-1} + \beta_{14} \Delta P_{t-1}^f + \beta_{15} \Delta M2_{t-1} + \beta_{16} \Delta Y_{t-1} + \beta_{17} EC1_{t-1} + \\ & \beta_{18} EC2_{t-1} + \beta_{19} EC3_{t-1} + \beta_{27} EC1_{t-1} Z_{t-1} + \beta_{28} EC2_{t-1} Z_{t-1} + \beta_{29} EC3_{t-1} Z_{t-1} + \\ & \beta_{37} EC1_{t-1} Z_{t-1}^2 + \beta_{38} EC2_{t-1} Z_{t-1}^2 + \beta_{39} EC3_{t-1} Z_{t-1}^2 + \beta_{47} EC1_{t-1} Z_{t-1}^3 + \beta_{48} EC2_{t-1} Z_{t-1}^3 + \\ & \beta_{49} EC3_{t-1} Z_{t-1}^3 + v_t \end{aligned} \quad (28)$$

where  $\Delta$  is difference operator;  $P_t$  is GDP deflator;  $O_t$  is the Iranian oil export price;  $E_t$  is parallel market exchange rate;  $P_t^f$  is wholesale prices of US;  $M2_t$  is per capita real balances;  $Y_t$  is per capita real income;  $Z_t$  is transition variable; and  $EC1_t$ ,  $EC2_t$ , and  $EC3_t$  are three error correction terms.

The above equation is estimated while all variables are used one by one as a transition variable as well as  $t^* = t/T$  suggested by Jansen and Terasvirta (1997). Furthermore, the above equation is estimated while in the nonlinear part are also included all other variables. The results show that the null hypotheses of the linearity are rejected for different transition variables.

Using the STAR family of the models there is no economic theory to distinguish between LSTAR and ESTAR. So that the choice between these models has to be based on the data. Therefore, in the next step, the null hypotheses (25) through (27) are tested in order to choose between ESTAR and LSTAR. The results suggested that the nulls of  $H_{04}$  and  $H_{03}$  is accepted in most cases while the null of  $H_{02} = 0$  is rejected. So that the LSTAR model is selected.

Due to problems of convergence when the value of  $\gamma$  is large, Granger and Terasvirta suggest rescaling the argument of  $F$ , which facilitates the choice of a starting-value for  $\gamma$ . The standardised transition function in LSTAR model is as follows:

$$F(Z_{t-d}) = (1 + \exp\{-\gamma(Z_{t-d} - c)/\hat{\sigma}_{(Z)}\})^{-1}, \quad \gamma > 0 \quad (29)$$

where  $\hat{\sigma}_{(Z)}$  is the sample standard deviation of transition variable,  $Z_t$ . A reasonable starting value for iterative nonlinear least squares estimation then is  $\gamma = 5$ . However, in the final model, different starting values are used and they generate quite similar estimates implying the presence of convergence in the model. After imposing restrictions on some coefficients supported by the data, the following plausible model is estimated when  $t^*$  is used as a transition variable:

$$\Delta P_t = 0.05 + 0.21D72_t + 0.20D91_t - 0.37TB75_t - 0.14TB78_t + 0.07\Delta O_{t-1} + \quad (30)$$

(1.87) (2.74) (4.51) (-5.53) (-2.59) (1.79)

$$0.13EC1_{t-1} + 0.15EC2_{t-1} - 0.32t^* + (0.13 - 0.16\Delta Y_{t-1})\hat{F} + \hat{v}_t$$

(2.78) (2.29) (-2.90) (1.21) (-1.11)

$$\hat{F} = (1 - \exp\{2.68(t^* - 0.30)\})^{-1} \quad (0.57)$$

$$s = 0.0487 \quad \gamma^* = 9.65 \quad s_{NL}^2 / s_L^2 = 0.837$$

where the numbers in brackets are  $t$ -statistics;  $s$  is the standard error of estimate;  $\gamma^*$  is the standardised value of  $\gamma$  ( $\gamma^* = \hat{\gamma} \times s_{(Z)}$ ); and finally  $s_{NL}^2 / s_L^2$  is the ratio of the residual variances from the nonlinear and linear models.

To compare the linear and nonlinear models, I checked the reduction in the estimated residual variances delivered by nonlinear specifications. The value of this ratio shows that the nonlinear model produces a smaller standard error compared to the corresponding linear model and provides a substantial improvement over the linear model. Moreover, the speed of adjustments of nonlinear model is faster than linear one. The values of  $\gamma^*$  show that the speed of transition between regimes is higher so that the transition from low inflation regime to high inflation regime is quite fast. The  $t$ -value of  $\gamma^*$  should not be interpreted in the customary fashion, because the above model is not identified for  $\gamma^* = 0$ .

## 7 Policy Implications

This paper provides some major policy implications for the Iranian economy. This section focuses mainly on the implications for the conduct of monetary and exchange rate policies which are crucial determinants of inflation in Iran.

It was shown graphically that the rate of inflation and monetary growth move quite closely together over the period under study. Moreover, the dynamic models of inflation showed that excess money supply affects positively the rate of inflation. Thus, monetary growth plays a crucial role in determining inflation in Iran. Therefore, monetary policy can make a principle

contribution for the society's welfare and the economy as a whole through reducing inflation and maintaining an environment of low inflation and price stability.

To reduce inflation through a reduction of monetary growth, it is necessary to understand what causes money growth. It was explained that there is a close link between fiscal and monetary policies mainly through the following channels:

- the conversion of oil revenue into domestic currency
- monetisation of the budget deficits.

It was shown that the authorities have no strong influence on oil revenue, since the oil price is determined in the international oil market and also the quantity of oil exports is determined by OPEC. The authorities should rely less on oil revenue and follow those policies which make the economy less dependent on the oil sector. Moreover, this policy will protect the economy against the various external shocks.

As long as the government deficit persists and government resorts to printing money to pay it, the money supply rises and the aggregate demand increases, causing the price level to rise. So, budget deficit can explain some part of inflationary monetary policy as an ultimate source of inflation. The inflationary pressure through this channel was more profound when the authorities were faced with the various restrictions to finance its budget deficit through other means. Therefore, due to the lack of alternative instruments in practice, the policymakers have little power and also little credibility in fighting against inflation.

Another point regarding monetary policy is the bi-directional causality between per capita real balances and per capita real income growth, which was found in this study by estimating an ECM [see also Moradi (2001) for details]. It means that a reduction in money supply has a negative effect on per capita real income. So, money does matter to aggregate supply and the authorities must have an accurate assessment of the timing and effect of their policies on the economy. Moreover, structural rigidities due to the presence of uncertainty are important in assessing how monetary policy impacts the economy. To understand it, it is necessary to know the mechanisms through which monetary policy affects the economy. Anticipated and unanticipated changes in monetary growth have very different effects on the economy and specifically on inflation. Anticipated monetary expansions have seigniorage effects through inducing inflation premium, while unanticipated monetary expansions can stimulate production and, symmetrically, unanticipated contractions can induce depression [see, for example, Sargent (1986) and Lucas (1996)]

Since the authorities set interest rates in Iran, the transmission channel of monetary expansion effects on real income through interest rates is not clear. So, other possible transmission channels should be considered for the Iranian economy [see, for example, Mishkin, (1998) for the monetarist and Keynesian views]. One of the channels might be through the exchange rate which affects net exports. An increase in money supply depreciates domestic currency. The lower value of the domestic currency makes domestic goods cheaper than foreign goods. Consequently, net exports rise and hence aggregate income increases. This transmission channel can be shown as follows:

Money Supply (M)  $\uparrow$   $\Rightarrow$  Inflation  $\uparrow$   $\Rightarrow$  Exchange Rate (E)  $\downarrow$   $\Rightarrow$  Net Export (NX)  $\uparrow$   $\Rightarrow$  income (Y)  $\uparrow$

Expansionary monetary policy increases inflation and leads to a rise in wealth, which increases consumption and follows by an income growth. So, the transmission channel through wealth effects can be shown as

M  $\uparrow$   $\Rightarrow$  Inflation  $\uparrow$   $\Rightarrow$  wealth  $\uparrow$   $\Rightarrow$  consumption  $\uparrow$   $\Rightarrow$  Y  $\uparrow$

Bank lending is another channel of transmission. When M increases, bank loans increase to finance borrowers' activities. This increase in loans will cause investment to rise. So,  
 $M \uparrow \Rightarrow \text{Bank Deposits} \uparrow \Rightarrow \text{Bank Loans} \uparrow \Rightarrow \text{Investment} \uparrow \Rightarrow Y \uparrow$

Another channel is through consumer liquidity effects through spending, particularly on consumer durable goods and housing. This links to the bank lending to promote consumption. More specifically, when inflation is higher, it works. So,  
 $M \uparrow \Rightarrow \text{Inflation} \uparrow \Rightarrow \text{Consumer Durable and Housing Expenditure} \uparrow \Rightarrow Y \uparrow$

An anti-inflationary policy, which can be successful in reducing inflation at the lowest income cost, is related to fiscal policy through reconsideration of the sources of government revenue, expenditure and the budget deficit financing. The government must reduce the budget deficit by solving the problem of public enterprises, eliminating subsidies, collecting revenue through taxes, and relying more on the national "participation papers" and financial innovation consistent with the Islamic banking system. Consequently, a reduction in the budget deficit would have a large effect on money creation and a beneficial effect on price stability. This also reduces the dependency of fiscal policy on monetary policy and thus, money supply can be controlled.

Overall, monetary policy can then be used as nominal anchor to reduce inflation. This can be accompanied by a credible inflation target which provides a clear framework in a formulation of a more disciplined and consistent goal of monetary policy and is essential for the stability of price level.

Central bank independence, as an aid to reduce inflationary pressure through monetary policy, is a controversial issue. The theoretical and empirical literature shows that central bank independence alone is insufficient in designing macroeconomic policies. For developing countries it even increases the conflicts between fiscal and monetary authorities when the government is constrained by the lack of efficient instruments to solve the budget deficit financing problem [see, for example, Alesina and Summers (1993), Posen (1993), and Hayo (1998)]. Cukierman (1992) finds that the empirical relationship between central bank independence and inflation is much weaker in developing countries. For the Iranian economy, more research is necessary concerning political independence of the central bank to pursue a policy of price stability, and its economic independence to increase its ability to select its monetary policy instruments.

The black market exchange rate is another determinant of inflation in Iran. It was shown that a depreciation of domestic currency causes an increase in the rate of inflation, specifically following the devaluation of exchange rate in formal sector. The authorities have maintained a fixed exchange rate system as a nominal anchor to control inflation over the period under study. Although a fixed exchange rate influences expectations and has a dampening effect on inflation and also increases the credibility of the authorities responsible for macroeconomic policy, it is harmful for the allocation of resources as well as for the national economy. However, frequent devaluation of the exchange rate after the war along with other policy packages caused a surge in the black market exchange rate which led to price instability or high volatility of inflation.

Since anti-inflationary policy requires an increase in the value of the domestic currency, this study recommends that the authorities should not let the black market exchange rate depreciate mainly through the exchange rate policy. Because of the finding of the bi-directional causality between black market exchange rate and inflation by estimating an ECM, the management of exchange rate markets is crucial for the authorities to design an anti-inflationary policy. Moreover, the presence of rigidity in non-oil exports such as agricultural sector and

higher proportion of oil exports to total export are consistent with the above policy recommendation.

However, much more research is needed on the question of optimal monetary and exchange rate policy rules, which work well in the country by considering various channels of transmission suggested by the characteristics of the economy.

This study suggested a weak-form currency substitution in the economy only when the black market exchange rate is included in the demand function for money (either real monetary base or M2). Since depreciation of the black market exchange rate tends to decrease the demand for domestic currency, agents demand more foreign currencies and less domestic currency. Monetary authority should take the above phenomenon into account in the execution of monetary policy.

Agents seek to find an optimal combination of real balances in domestic currency and alternative (foreign) currencies when they are faced with a higher inflation rate in the economy. Since foreign currencies such as dollar and pound are more credible than domestic currency under the inflationary pressure, higher inflation leads agents to demand foreign currencies instead of domestic currency because the expected benefits of holding foreign currencies are higher. Thus, the higher the domestic inflation, the larger the currency substitution [see, for example, Golikov (1998)].

The finding of a low adjustment coefficient may be due to the following interrelated facts:

- uncertainty,
- structural changes and exogenous factors,
- nonlinear structure.

The presence of uncertainty in the economy is important for the effectiveness of economic policies and the decision of agents. Uncertainty implies that the policymaker cannot guarantee that his target value is attainable, since the target is affected by other factors in addition to policy actions. Obviously, the results of policy under uncertainty are different from the policy which would be pursued in a world of certainty [see, for example, Brainard (1967)]. Although measuring the impacts of uncertainty on the effectiveness of policy is difficult and it is beyond the scope of this study, using GARCH models it was shown that the rate of inflation increases uncertainty [see Moradi (2000) for details of GARCH models].

Although the government was able to earn revenue through seigniorage by accepting a higher rate of inflation,<sup>14</sup> higher inflation resulted in higher uncertainty in the economy and affected the effectiveness of government policies (more specifically monetary and exchange rate policies). To boost the economy, the policymakers have to take into account the uncertainty surrounding the transmission mechanism of monetary and exchange rate policies in the economy. The policymakers should avoid an expansionary monetary policy and a depreciation of the domestic currency in order to reduce inflation. Consequently, this will reduce uncertainty.

Since the rate of inflation increases uncertainty, this implies substantial costs of inflation in the economy through various channels. Firstly, unanticipated changes in inflation affect the redistribution of wealth in the society. Consequently, the greater inflation variability increases uncertainty and lowers welfare. Secondly, inflation uncertainty and variability have large effects on incentives for investment and saving in the economy. As a result, the growth rate of the economy declined.

Inflation in Iran was dominated by movements in exogenous factors such as the oil price and various other shocks and government interventions. Even the effects of the reform

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<sup>14</sup> See Moradi (1380) for details.

programme, captured by the dummy  $D91$  in both linear and nonlinear models, may be considered as exogenous in the sense that it was initiated by the government in order to rebalance the economy after the war. Similarly, the permanent increase in inflation after the first oil shock, captured by the dummy  $DO$ , may be regarded as outside the government's control due to political and social pressure to spend the oil revenue.

Another explanation of slow adjustment may be that the true adjustment process is nonlinear as in Michael, Nobay and Peel, (1999). Their specification implies that adjustment is faster for large deviations from equilibrium. This study also showed that the speed of adjustment is faster in nonlinear compared to the linear one. However, The finding of a small adjustment coefficient is not an uncommon result in macroeconomic studies. The low adjustment coefficient carries the important policy implication that monetary and exchange rate policies have lost their effectiveness. Consequently, it can be difficult for the authorities to conduct those policies aimed at a stable price target.

## 8 Conclusion

This paper investigated the main determinants of inflation in Iran. First long-run relations of money demand and PPP were specified and estimated. Moreover, the output gap as a proxy for the excess demand was calculated using three measures. In the next step, an ECM was developed to investigate the joint analysis of long-run and short-run behaviour. The findings of linear model showed that both adjustment coefficients are very low. An explanation of the slow adjustments may be that the true adjustment process is nonlinear meat a linear model is inappropriate. Consequently, nonlinear behaviour of inflation was investigated. Linearity was strongly rejected and an LSTAR process was suggested by the data. The estimated LSTAR model suggested slightly faster adjustments towards equilibriums. The empirical evidence suggesting that modelling of inflation is in favour of nonlinear rather than linear.

The analysis shows that inflation in Iran was affected by both domestic factors through excess money supply, and external factors through deviations from PPP. The results do not support the output gap as a proxy for excess demand and the inflation-inertia hypotheses for Iran. This finding suggests the possibility that the government could attempt to control inflation through monetary or exchange rate policies by reducing inflation and maintaining an environment of low inflation and price stability. However, the slow adjustment coefficients imply that monetary or exchange rate policies to control inflation are unlikely to be more effective.

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