Dynamic Modelling of Inflation in a Small Open Economy: The Case of Iran

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor in Philosophy

by

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January 2000

In the Name of God

the Compassionate the Merciful

I dedicate this work to my parents, my wife and my

children, Faezh and Ehsan

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ACKNOWLEDGMENTS

I would like to express my sincere thanks to my initial supervisors, Professors David Peel and Patrick Minford. Sincere thanks are also due to my supervisors, Professor Brian Hillier and Mr Panos Michael for their suggestions, comments, help and willingness to discuss any aspect of this research.

I am grateful to Dr Frederique Bracoud for her constructive comments and help concerning the second chapter of the thesis. I also owe thanks to the academic staff of the department, Mr Simon Blackman, computer officer and the other administrative staff of the Department of Economics and Accounting, University of Liverpool, for support and coorperation.

Many thanks to my parents, brothers and sisters for their encouragement and prayers.

Special thanks go to my wife for her patience, help and encouragement, and to my children Faezh and Ehsan for being so good.

Finally, I am grateful to my sponsor the Plan and Budget Organisation of Iran, for their help and financial support.

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Abstract

This thesis offers a study of the problem of inflation in Iran. The behaviour of inflation is analysed using univariate time series techniques, while the determinants of inflation are investigated using multivariate cointegration analysis and dynamic econometric methodology. The analysis is complicated by several big shocks experienced by the Iranian economy over the sample period 1959 –1996. These included the Islamic revolution, the eight–year war with Iraq, and a large economic reform programme after the war, as well as three big oil shocks. The latter had a particularly profound effect due to the dependence of the economy on oil revenue. The volatile nature of this source of revenue together with the need for the government to smooth its spending, meant that the government extensively resorted to financing its budget deficit through seigniorage. Our results suggest that following the oil shock of 1973 the government could have obtained extra revenue with a lower rate of inflation, except during the war period when output growth was mostly negative and the government could have accepted a higher inflation rate to raise extra seigniorage.

The univariate analysis suggests that inflation follows a stationary process with a break in 1973; however, the hypothesis of linearity is rejected and a plausible logistic smooth transition autoregressive model is identified and estimated. There is also evidence of autoregressive conditional heteroscedasticity, with the conditional variance positively associated with the level of inflation. The cointegration analysis shows that, despite the various shocks over the sample period, a plausible long–run demand for money can be identified after accounting for a break in 1979. The empirical estimates support the theoretical model of the demand function for money that is constructed for the Iranian economy using the cash–in–advance models. However, the speed of adjustment of real money balances towards equilibrium is very slow, implying that the government can generate considerable seigniorage over the adjustment period. Furthermore, the standard long–run PPP relationship is also supported after allowing for breaks in 1973 and 1980. The dynamic model for inflation shows that the error correction terms from the long–run relationships for money demand and PPP are both significant and have the correct signs. This suggests that inflation in Iran was affected both by domestic factors, through excess money supply, and by external factors, through deviations from PPP. However, the adjustment coefficients are very small, implying that monetary or exchange rate policies to control inflation are unlikely to be effective.

1 INTRODUCTION

The central focus of the thesis is on the problem of inflation in Iran. Following the oil boom in 1973, inflation increased sharply and exhibited large fluctuations. In order to understand the behaviour of inflation and its determinants it is necessary to examine the special characteristics of the Iranian economy. This is done in some detail in chapter two. It will be seen that this investigation has important implication for both the univariate analysis in chapters three and four, and the multivariate analysis in the rest of the thesis.

Characteristics of the Iranian Economy

In recent decades Iran has experienced several important events in the economic and political fields. These included the three oil shocks of 1973, 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.

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. 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.

It was the expansionary fiscal and monetary policies following the first oil boom which caused the sharp increase in inflation after 1972. The effects of the other oil shocks and the war explain the subsequent large fluctuations in the rate of inflation. Another sharp increase took place after the big devaluation of 1993 and the failure of the economic reform programme. It should be noted that in Iran there are no strong labour unions, with the government controlling the level of wages, and no active capital market.

This brief outline of the special features of the Iranian economy has important implications which any study of inflation in Iran must take into consideration. In particular:

- the oil shocks and other major events make it necessary to allow for the possibility of structural breaks in both the univariate and multivariate analysis.
- the sharp increase in inflation after 1972 and also after 1993, together with the large fluctuations in between, imply the possibility of autoregressive conditional heteroscedasticity (ARCH) effects and nonlinear behaviour.

- given that Iran is a small open economy, the major determinants of inflation are likely to include external inflation as well as domestic factors through excess money.
- the fact that the budget deficit was largely monetised makes it interesting to consider the issue of seigniorage.
- since there were extensive government subsidies, over the period 1959 – 1996, on consumer goods such as food, fuel and electricity, consumer price index (CPI) is unlikely to reflect the true inflation rate and, therefore, the GDP deflator is used in the multivariate analysis.

Univariate Analysis of Inflation

Chapters three and four examine the univariate properties of inflation. *Chapter three* looks at the plots of the series and their ACFs and PACFs, applies unit root tests, and estimates linear ARIMA models. Given the evidence of a structural break in 1972, the Perron (1989) procedure is employed in testing for stationarity. Moreover, the standard Dickey–Fuller procedure is employed for two sub–periods, pre–1972 and post–1972.

Given the presence of ARCH effects in the linear models, *Chapter four* employs an extension of the GARCH model in order to test the hypothesis that high inflation rates associated with a high inflation variance or uncertainty. Since the presence of ARCH may be an indication of nonlinear behaviour, the null hypothesis of linearity is also tested against the alternative smooth transition autoregressive (STAR) model. When linearity is rejected, an appropriate STAR model is then specified and estimated.

Multivariate Analysis

The rest of the thesis examines the determinants of inflation. As noted above, these include domestic as well as external factors. Since most of the relevant variables are nonstationary, the Johansen procedure is employed to identify the long–run relationships among the variables. Given the limited number of annual observations and the large number of variables, the analysis of the complete system is impractical. Instead, a separate system is first undertaken. In the first stage, a dynamic model of inflation is developed which includes the stationary combinations from each of the sub–models.

Chapter five aims to design and estimate a per capita demand function for money in order to shed new light on both the theoretical and empirical ground. A theoretical demand function for money is constructed based on the characteristics of the Iranian economy in the framework of the cash–in–advance model. This provides the ground for the empirical results of the models in chapters seven and eight. To evaluate the per capita money demand function, cointegration analysis is carried out to identify a long–run money demand relationship using two alternative measures of money: Monetary base (MB) and M2. The rate of inflation is used as a proxy for the opportunity cost of holding money. Real money balances and real income are expressed in per capita terms based on the microfoundation model in order to allow for variations in the rate of growth of population. Dummy variables are included to allow for possible structural breaks. The short–run relationships among the variables are also analysed by estimating the associated error correction models (ECMs). The ECMs provide confirmation of the existence of cointegration; allow an examination of the direction of causality; show the speed of adjustment towards equilibrium; and can be used for forecasting, if necessary.

Chapter six considers the external source of inflation by examining the long–run purchasing power parity (PPP) relationship. Cointegration analysis is applied to the parallel market exchange rate against the US dollar, the domestic GDP deflator and the US wholesale price index. Appropriate dummy variables are included in the analysis to account for the effects of various shocks and government interventions. As in chapter five, the short–run relationships are investigated by estimating the associated ECMs.

Chapter seven develops a dynamic model for inflation which combines the error correction terms from the money demand and the PPP relationship. The model also considers the role of variables such as oil prices, terms of trade and government spending, as well as dummy variables to account for possible break.

Chapter eight uses the money demand relationship for the monetary base, estimated in chapter five, to investigate the relationship between seigniorage and inflation. This issue is important for Iran, as the tax system is inefficient and both bond financing and external borrowing are insignificant. Since oil revenue, which forms a high proportion of total government revenue, is very volatile, the government resorts extensively to seigniorage. The analysis here extends the basic Cagan model to allow for variations in the rates of growth of output and population.

Chapter nine focuses mainly on the implications for the conduct of monetary and exchange rate policies which are crucial determinants of inflation in Iran. Moreover, this chapter describes the factors which may explain the ineffectiveness of monetary and fiscal policies to control inflation.

Finally, *Chapter ten* summarises the main findings of the thesis and their policy implications.

To the author's knowledge, a complete dynamic model of inflation which includes both domestic factors (through excess money supply) and external factors (through deviations from PPP) has not been estimated for Iran before – although such a model was proposed by Juselius (1992) and developed recently by Durevall and Ndung'u (1999) and Price and Nasim (1999). However, other empirical studies for Iran, analysing the money demand function or the PPP relationship and or attempting to explain inflation, do exist. These studies will be reviewed later in the relevant chapters of the thesis.

The empirical findings of the thesis are encouraging. Concerning the behaviour of inflation, the univariate analysis suggests that inflation follows a stationary process with a break in 1973; however, the hypothesis of linearity is rejected and a plausible logistic smooth transition autoreressive model is identified and estimated. There is also evidence of autoregressive conditional heteroscedasticity, with the conditional variance positively associated with the level of inflation.

The cointegration analysis shows that, despite the various shocks over the sample period, a plausible long–run demand for money can be identified after accounting for a break in 1979; however, the speed of adjustment of real money balances towards equilibrium is very slow, implying that the government can generate considerable seigniorage over the adjustment period. Furthermore, the standard long–run PPP relationship is also supported after allowing for breaks in 1973 and 1980. The dynamic model for inflation shows that the error correction terms from the long–run relationships for money demand and PPP are both significant and have the correct signs. This suggests that inflation in Iran was affected both by domestic factors, through excess money supply, and by external factors, through deviations from PPP. However, the adjustment coefficients are very small, implying that monetary or exchange rate policies to control inflation are unlikely to be effective.

2 MACROECONOMIC PERFORMANCE OF IRAN: 1959 – 1996

2.1 Introduction

The aim of this chapter is to identify the major stylised facts of the Iranian economy over the period 1959 – 1996. The evolution of key macroeconomic indicators such as inflation, growth rate, consumption and investment is described. The chapter also reviews the macroeconomic policies implemented in Iran during the period of study, with special attention paid to their implications in terms of inflation.

Iran is a typical small open economy and an oil exporting developing country, member of the organisation of petroleum exporting countries (OPEC). As such, it is particularly sensitive to international disturbances. In the recent decades, Iran has experienced some important events in the economic, political, and social fields. These events comprise the three oil shocks in 1973, 1979, and 1986; the Islamic revolution in 1978; the eight–year war with Iraq between 1980 and 1988; the embargo imposed by the US and some European countries since the war; and finally the economic reform programme implemented during 1989 – 1993 followed by an external debt crisis. These events are examined and their impacts on the Iranian economy briefly described.

Due to the dependence of the country on the oil sector, *oil shocks* have significantly affected the economy. Two sharp increases in oil price took place in 1973 and 1979, and one sharp fall occurred in 1986. Since the oil sector is nationalised, the government receives the total oil revenue. Consequently, its revenue and expenditure fluctuate with the oil revenue. During the booms, the government has used most of the oil revenue for financing public consumption. This had obvious inflationary effects through the demand side. The fall in the oil price in 1986 also created inflationary pressures but, this time, through the supply side.

The revolution had significant structural effects on economic, political, and social grounds. For example, Islamic precepts have influenced the structure and the activities of the banking system. The payment and receipt of a fixed predetermined rate of interest have been prohibited and replaced by profit and loss sharing arrangements.[1] Moreover, the issue of bond has become illegal in Iran. Although the issue of bond was permitted before the revolution, the proportion of the government financing through bond issue was negligible, mainly, due to the lack of well-developed financial markets. A large-scale nationalisation was launched after the revolution, affecting some major sectors such as banking system, international trade, insurance, and steel industries.

The *eight-year war with Iraq* affected the economy in various ways. The Iraqi army occupied oil fields in the West and Southwest of the country. The war necessitated the allocation of resources such as labour and government revenues to the defence of the nation. The uncertainty during the war negatively affected investment in the productive sectors and, consequently, the growth rate of GDP declined and became even negative. As the war coincided with the third oil shock in 1986 consisting of a significant reduction in oil price, the economic depression became even worse. Overall, the pressure on inflation increased through both the supply and demand sides.

The economic *embargo* imposed on Iran increased the price of goods imported from abroad between 3 and 30 percent depending on the type of goods imported [see, for example, Taiebnia (1995)].

Iran launched an *economic reform programme* at the end of the war. The period of reconstruction coincided with the liberalisation initiated by the first five-year plan (1989 – 1993) after the revolution. The programme aimed at less government control, more private enterprises, and greater reliance on competition. Through this reform, the government also intended to get rid of the system of dual markets existing in most markets, i. e. in goods, foreign exchange, and loan markets. More specifically, the programme scheduled the liberalisation of the exchange rate system, the removal of controls on the retail and producer prices, the deregulation of the trade regime and tariffs, and the privatisation of some public enterprises.[2] To implement the reform, the government even borrowed from abroad, although external borrowing was illegal until then. As part of the reform, the government started the devaluation of the domestic currency in 1989, completed the unification of

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[1] See, for example, Errico and Farahbaksh (1998), Sundararajan el al. (1998), and Ul–Haque (1998) for a description of the Islamic banking system.

[2] This large–scale economic reform programme was generally consistent with the World Bank structural adjustment programme. See, for example, Farzin (1995).

the exchange rate in March 1993 through a big devaluation, and moved from a fixed exchange rate system to a floating system. However, the unification of the exchange rate did not last and liberalisation failed, mainly due to inflationary pressures and a debt crisis.

To fight the *debt crisis*, the government used currency reserves to pay some arrears. Because of large overdue external payments some external arrears were rescheduled through bilateral arrangements.[3] Nevertheless, the government was not able to hold the unification of the exchange rate. Consequently, the exchange system reverted to a dual official exchange system in May 1994, price controls were restored, and the government tightened trade.

The major events described above, along with the main policy measures, are summarised in Table 2.1. The rest of the chapter is organised as follows: In the next section, an overview of the performance of the main macroeconomic indicators is given. In this section, the trends of oil prices and oil revenue, inflation rate, economic growth rate, and consumption and investment are analysed. Section three deals with macroeconomic policies. Monetary, fiscal, exchange rate, and trade policies are examined in this section. Finally, section four sums up the chapter.

[3] See, for example, Farzin (1995) and Hakimian and Karshenas (1999).

Table 2.1 Events and Main Policy Measures in Iran during the Period 1959 – 1996

Year	Events	Policy Measures
1973	First Oil Boom	Price Control
1978	Revolution	
1979		Large Nationalisation
1979	Second Oil Boom	
1980 – 1988	Eight–Year War	
1980	Start of Embargo	
1986	Third Oil Shock	
1988	End of the War	
1989 – 1993		Economic Reform Programme
1993		Big Devaluation
1994	Debt Crisis	
1994 – 1996		Protectionism (price, exchange rate, and trade control)

2.2 Performance of the Main Macroeconomic Indicators

2.2.1 Oil Price and Revenue

Given its importance in the Iranian economy, the oil sector is discussed first. Figure 2.1 shows the evolution of the oil price over the period 1959 – 1996. The movements in the oil price can be split into four sub–periods:

- 1959 – 1972: no trend and little fluctuation
- 1973 – 1980: upward trend
- 1981 – 1986: downward trend
- 1987 – 1996: no trend but large fluctuations

As can be seen from Figure 2.1, there was no significant change in the oil price until 1972. But during 1973 – 1980 following the first oil boom, the oil price was steadily increasing. The rise has clearly accelerated over this period. The oil price increased about 2.4–fold in 1973, from $1.42 per barrel in 1972 to $3.46. The oil price reached a dramatic level in the subsequent years. For example, the oil price rose from $12.65 in 1978 to 22.17 in 1979, year of the second oil boom. Finally, it reached a peak of $35.46 in 1980. In the next sub–period 1981 - 1986, the oil price was declining until the collapse in 1986 known as the third oil shock, when the price dropped to its lowest level over the period 1979 – 1996 of $13.21 per barrel. In the final sub-period 1987 - 1996, the oil price fluctuated frequently and with a large magnitude around a constant mean. These oil price movements have deeply affected the whole economy, and some inflationary effects occurred through the aggregate demand pressure or the supply side.

The nominal values of the oil and gas revenue are plotted in Figure 2.2a and Figure 2.2b.[4] The oil revenue was steadily increasing up to 1977, but there was a decline in 1978 due to the revolution. The second oil boom caused the revenue to increase, although the start of the war with Iraq mitigated this rise. The revenue dropped substantially in 1986 because of the reduction in oil prices. After the third oil shock, the revenue started steadily increasing. This increase was very sharp after 1992, because the government significantly devaluated the domestic currency in 1993.[5]

The effects of the variation in oil price and oil revenue on the economy, and more specifically on inflation, will be described in the subsequent sections.

2.2.2 Inflation Rate

This section describes the trends of inflation, analysed using several measures. These measures may be categorised into three main groups as follows:

- consumer price index (CPI)
- GDP deflator (GDPD)
- wholesale price indices

[4] The revenue earned through the exports of gas is negligible.

[5] For example, the basic exchange rate, on average, increased from 67.04 rials in 1992 to 1646.3 rials in 1993.

The wholesale price indices cover domestic wholesale price index (WPI), imported goods prices, and exported goods prices. From the plots of all inflation measures in Figure 2.3 and Figure 2.4, it appears that 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

Since the measures move in a similar direction, the main focus here is on the percentage changes in the CPI. The important differences between the CPI and the other measures will be explained subsequently.

Table 2.2 shows that the CPI inflation rate rose by an annual average rate of 13.9 percent over the period. The inflation rate was in single figures from 1960 to 1972, with an annual average rate of 2.8 percent. After 1972, with the oil price and the quantity of oil exports increasing, the rate of inflation rose sharply. The rate of inflation jumped from 6.3 percent in 1972 to 11.3 percent in 1973. The annual average rate of inflation was 14.7 percent during the period 1973 – 1978. The rate of inflation accelerated to an annual average of 18.9 percent 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 inflation was exactly the same as in the previous sub-period. The rate of inflation increased further over the period following the structural adjustment programme, reaching a peak of 49.5 percent in 1995.

Table 2.2 Average Rates of Inflation (Percent): 1960 – 1996

Periods	DCPI	DGDP	DWPI	DPIM	DPEX
1960 – 1996	13.9	14.4	14.7	14.5	21.5
1960 – 1972	2.8	0.4	2.4	2.5	3.9
1973 – 1978	14.7	22.9	12.3	9.9	14.5
1979 – 1988	18.9	17.0	18.3	16.1	46.0
1989 – 1993	18.9	24.9	25.6	26.9	17.4
1994 – 1996	35.9	31.7	42.6	49.3	37.0

Notes:

- DCPI, DGDP, DWPI, DPIM, and DPEX are the percentage changes in the consumer price index, GDP deflator, wholesale price index, imported goods prices, and exported goods prices, respectively.

Now the other inflation measures are briefly discussed, with the emphasis on the differences from the CPI. The rate of the GDP deflator inflation was on average 14.4 percent per annum, which is slightly higher than the rate of the CPI. 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. Figure 2.4 plots the percentage change in the wholesale price indices that comprise domestic wholesale price index (WPI), imported goods prices (PIM), and exported goods prices (PEX). As can be seen, they move closely together, although the fluctuations of the PEX measure are higher than those of WPI and PIM. The percentage changes in the WPI, PIM, and PEX were on average 14.7, 14.5, and 21.5 percent, respectively, over the whole period. A very extreme spike in the percentage change of exported goods prices occurred in 1986, while was the result of the government policy of increasing the tax on exports [see, for example, The Economic Report of the Iranian Central Bank and its Balance Sheet, (1986)]. The spike for DWPI and DIMP occurred in 1995, which coincides with that for DCPI.

Overall, the Iranian inflation rate was very variable and steadily increasing, whatever the inflation measure considered. Next the major transmission channels that could have affected inflation in Iran during this period are analysed.

First consider the possible effects of oil price and revenue on inflation. One of the transmission channels is through the conversion of foreign currency from oil exports by the government into the domestic currency via the central bank of Iran. The process results in an increase in the money supply and government spending that transmits to the demand for goods. This mechanism could explain why each oil shock associated with higher oil revenues has stimulated inflation. Another transmission channel of oil shock on inflation is through the increase in the input cost of foreign products. Since the ratio of the foreign goods over the domestic consumption is significant in Iran, foreign inflation can be transmitted into the economy through imports. Moreover, the increase in foreign inflation affected the domestic inflation through the rise in the cost of foreign inputs used by national producers. It was thus inevitable that world inflation created by oil shock was transmitted to the domestic price level of tradable goods and later to that of non–tradable goods. The transmission channels described above could explain the first inflation surge that was observed in 1973.

The first oil shock and the resulting inflation increase alarmed the authorities. In response to the wide public concern, the government launched an anti–inflationary programme and started controlling retail prices, specifically the price of food. But their attempt was not strong enough to offset the effects of an expansionary fiscal policy. Another anti–inflationary measure was to increase the supply by importing goods from abroad. This policy also failed to correct the discrepancy between supply and demand, due to infra–structural problems such as insufficient seaports. Consequently, the rate of inflation accelerated during the 1970s and continued to increase in the period after.

Another channel of transmission is via exchange rate devaluation, which took place in Iran during the five–year plan, 1989 – 1993. Since large industries had dollar denominated expenditures, devaluation increased their input cost. This phenomenon caused the price of the products produced by those domestic industries to increase. The rise in the price level was profound when the government announced the removal of price controls during the five–year plan. Moreover, devaluation led to more money when the government converted foreign currencies, earned mainly through oil exports, into domestic currency. This process had obvious inflationary effects due to demand pressure. Unsurprisingly, the economy recorded the second inflationary surge following the big devaluation of 1993: the inflation rate in 1995 reached 49 percent, which was uncomfortably high for the Iranian economy and was never experienced before.

Little et al. (1993) point out that devaluation usually leads to an inflationary bubble but inflation is expected to fall afterwards. This phenomenon has not happened in the Iranian economy following the big devaluation in 1993 as the rate of inflation steadily increased in the years after the devaluation. This was because of simultaneous expansionary fiscal and monetary policies, price liberalisation, and trade deregulation. The fall in inflation did not happen until 1996: following the increase in inflation and the foreign debt crisis, the economic reform programme failed, and the government turned to an anti–inflationary policy by imposing a dual exchange rate system in the official market (along with the illegality of parallel market exchanges) and re–imposing price controls.

2.2.3 Economic Growth Rate

This section examines how the economic growth pattern in Iran has changed over the period 1959 – 1996. Figure 2.5 plots real GDP and its components (oil and non–oil sectors) at market prices. GDP shows an accelerating upward trend until 1976, and then displays a different pattern with two business cycles. The pattern of real GDP (as well as that of the non–oil sector) follows closely the movements of the oil value added, which illustrates how strongly the economy depends on the oil sector.

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 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 2.6, 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.[6]

2.2.4 Consumption and Investment

The average growth rates of total (public and private) nominal consumption and investment were 19.9 and 23.6 percent, respectively, during the period 1959 – 1996, while at constant 1990 prices the rates were 5.8 and 7.7 percent, respectively. As with GDP, total consumption and investment follow closely the movements in oil revenue over the whole period. The rates of change were at their peaks following the first oil boom and were at their lowest when the economy was faced with a dramatic reduction in the oil price in 1986.

Figure 2.7 shows the evolution of the ratios of total consumption and investment over GDP in real terms. The share of total consumption in GDP was falling until 1972. This drop was even more profound for private consumption. After 1972, the consumption ratio rose sharply and reached a peak of 86 percent of GDP in

1981. The government channelled the revenue of the oil booms into consumption, either by increasing its current expenditure or by promoting private consumption through transfers. No significant change in the consumption ratio was recorded after the revolution, while the investment ratio had significantly decreased. Although the investment ratio increased over the first and second oil booms, this rise was not significant compared to that in the consumption ratio over the period 1973 – 1981. The peak of the investment ratio appears after the first oil boom.

The increase in total consumption had, inevitably, inflationary effects through the demand pressure that it exerted on the economy.

2.3 Macroeconomic Policies

This section examines fiscal, monetary, foreign exchange, and trade policies. Before examining the performance of fiscal and monetary policies in the subsequent parts, some information is provided that is useful in understanding the close link that generally prevails between them in Iran.

The government earns foreign currencies mainly through oil exports, and then sells those currencies to the central bank. The central bank prints money for an equivalent amount, which will be spent by the government. When the government borrows from abroad, which happened during the implementation of the economic reform plan after the war, the same mechanism is at work and also leads to an increase in money supply and government spending.

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[6] 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

Due to an inefficient tax system and popular expansionary government spending in response to public pressure, the government budget was structurally in deficit in Iran during the period under study. The government very often relies on the central bank to finance the budget deficit as there is very little external borrowing and the domestic financial markets are poorly developed, the issue of bond being generally forbidden.

The conversion of foreign currency into domestic currency and the monetisation of the budget deficit constitute special links between fiscal and monetary policies. The resulting increase in the money supply generates inflationary pressures in the economy. This also raises the related question of seigniorage, defined as the real revenues of a government acquired by printing new money, and inflation tax. The relationship between seigniorage and inflation will be discussed in detail in chapter six of the thesis.

2.3.1 Fiscal Policy

The general pattern of the government revenue is affected by oil revenue either directly or indirectly as follows. When oil revenue increases, the windfall goes entirely to the government and directly affects its revenue. Then, the government through its expenditure stimulates the domestic activities and collects more tax revenue from them. As long as the imports of final and intermediate goods increase, the tax revenue on imports is also boosted. The rise in the tax revenue represents the indirect effects of oil on government revenue, making the government revenue even

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and never exceeded 797600 rials.

more sensitive to the oil sector. Since the price of oil exports is determined in the international oil market and the quantity by OPEC, the government has no strong influence on its oil revenue. Figure 2.8 shows the ratio of each component of the government revenue (oil and tax) over the total government revenue during the 1963 – 1996 period. Although oil and tax revenues are moving in a similar direction, their shares in the total government revenues by definition are moving in an opposite direction. As the indirect effects of oil revenue on the total government revenue through taxes are weaker than the direct effects, the share of oil revenue follows the evolution of oil revenue, whereas the tax ratio displays the reverse pattern.

Oil revenue made up 57.7 percent of the government revenue on average over the whole period. Since 1959 the economy has in general experienced a marked increase in the ratio of oil revenue to the government revenue until 1974 when it reached a peak of 86.4 percent. Thereafter, the ratio was decreasing until 1986. It reached its lowest value of 24.4 percent in 1986 when the third oil shock took place. After 1986 as long as the oil price was increasing, this ratio was also increasing.

The ratio of the annual tax revenue in relation to total government revenue was 24.3 percent on average over the period 1963 – 1996. This low average ratio reflects the inefficiency of the tax collection system in Iran, explained partly by the existence of an active underground economy, more specifically in the domestic trade market [see, for example, Mohammad–Baigi (1997)]. The lowest value of the tax ratio was 11.3 percent in 1974 after the first oil shock, while the peak of 57.5 percent was in 1986 following the third oil shock.

The mechanism by which the government transfers revenues from oil to money via the central bank has already been described. Actually, since 1983 there has been an innovation in the method of converting oil revenue: the government began to generate revenue through selling foreign currencies in the parallel market – rather than selling exclusively to the central bank – at a rate between the official and parallel market rates. This kind of conversion of foreign currencies does not affect money supply, since the extra money put in circulation via spending has been withdrawn from the public beforehand. This practice leads to less inflationary pressure compared to the previous case when the government sells all foreign currencies to the central bank. Although the new practice does not lead to an increase in the money supply, it still has inflationary effects through the increase in government expenditure, which stimulates aggregate demand.

Figure 2.9 plots the percentage changes in government expenditure. There are two spikes in this series, reflecting the effects of the first oil boom and the big devaluation of the domestic currency in 1993, respectively. The average growth was 23.8 percent over the whole period, which shows how expansionary the government expenditure policy was overall. Indeed, the government chose an expansionary policy when oil revenue increased but did not tighten policy when revenue declined. This was mainly because the government undertook more projects during the booms, which had to be financed in the following years whatever the oil sector performance was.

Figure 2.10 plots the ratio of current (CEXR) and development (DEXR) expenditures over total government expenditure during the 1959 – 1996 period. Overall the share of current expenditure dominated that of development expenditure. The average shares of current and development expenditures were 68.1 and 31.9 percent, respectively. It may be observed that after each oil boom the gap between the ratios was increasing. As the government allocated most of its resources to current expenditure, the inflationary effects on the economy were profound.

Figure 2.11 shows the trend of the government budget deficit. It should be noted that the available data for budget deficit after 1989 misrepresent the true budget deficit, since the government excluded public enterprises from its budget [see, for example, Nili (1997)]. Following the first oil boom, the budget deficit was increasing sharply, reaching a peak in 1988, the final year of the war. The subsequent decline in the deficit does not represent an actual improvement due to the exclusion of public enterprises.

Due to the poorly developed domestic financial markets and the restrictions on foreign borrowing, the government could not finance the budget deficit through sources other than monetisation: the budget deficit was financed through borrowing from the central bank, which increased money supply. This kind of financing is called seigniorage or inflation tax. Since an increase in money supply causes inflation and thus a reduction in the real value of money, printing money to increase revenue is similar to imposing an inflation tax paid by money holders.

An exception to the general practice of monetisation is the period 1989 – 1993 when the government borrowed from abroad mainly to implement the first five-year plan. Consequently, monetisation of the public sector deficit was partly replaced by foreign financing in this period. As already explained, this method also creates money through the conversion of the loans into domestic currency at the central bank. As the exchange rate increased markedly following the first five-year plan, a very large increase in the money supply was recorded.

Overall, the fiscal policy followed by the government is characterised by a lack of control. Since the revenue mainly depends on the oil sector, it is beyond the control of the authorities. Moreover, the level of government expenditure reflects the demands of parliament following public pressure. Although the government has realised the importance of anti-inflationary policy, the tighter fiscal policy as scheduled in the government plans was not always maintained.

In order to show the inflationary effects of fiscal policy, Figure 2.9 compares the evolution of the growth rate of government expenditure with CPI inflation. There is a close relationship between the two series, which could be explained in terms of the monetisation of the budget deficit and the converting of foreign currencies earned through oil revenues into domestic currency.

2.3.2 Monetary Policy

The evolution of the money supply is shown in Figure 2.12, which represents the growth rate of M2 over the period of study, 1959 – 1996. The average growth rate of M2 was 23.7 percent over the whole period. Since 1959 the growth rate was increasing sharply, reaching a peak of 57.1 percent in 1974 following the first oil boom. The main reason for this was the converting of foreign currencies earned from oil exports to domestic currency through the central bank, which caused the first inflation surge [see, for example, The Economic Report of the Iranian Central Bank and its Balance Sheet, (1974)]. Then, the authorities followed a tighter monetary policy as part of their anti-inflationary policy. This restrictive policy continued during the revolution and the early years of war until 1984. At the same time the demand for investment substantially decreased and the economy fell into recession.

Since 1985, in order to stimulate the economy, the authorities have followed an expansionary monetary policy along with an expansionary fiscal policy. The third oil shock in 1986 caused the government revenue through oil exports to decline to less than one-third of the level of the previous year. Therefore, the government financed its budget deficit through the central bank. This policy led to an increase in money supply. The large increase in the growth rate of money continued in the following years, mostly because of the converting of foreign loans and the monetisation of the budget deficit to implement the economic reform programme. This happened in spite of the decision to tighten monetary policy, as scheduled in the five-year plan. For example, in 1991 the government borrowed 83 percent of its budget deficit from the central bank [see, for example, The Economic Report of the Iranian Central Bank and its Balance Sheet, (1991)]. The monetary policy became even more expansionary later when the government was faced with an external debt crisis. Although it should have corrected its expansionary policy given the inflationary pressure, the government did not react and, consequently, has lost its credibility.

The growth rate of money supply is compared with the rate of inflation in Figure 2.12. It can be seen that the movements in inflation follow closely those of money growth.

As well as the money supply, the role played by interest rates in Iran has to be considered. The authorities administratively set all interest rates in the banking system whereas the forces of demand and supply determined the interest rates in the parallel market. In order to stimulate the economy the official rates were set at a low level compared with the parallel market rates. Due to the low cost of official credit, the demand for loans always exceeded the supply from the banking system. A system of differentiated interest rates was used to encourage particular forms of investment in the preferred sectors. For example, over the period 1973 – 1996 for which some data are available, the interest rates for the agricultural sector were relatively low. The interest rate instrument apparently was not used in the fight against inflation, as this would have required higher rates.

In addition to the control of the interest rates, the authorities also controlled the quantities of credits allocated to the economy in two ways. The credits that are directly distributed by the government were determined in the annual budget. Moreover, the authorities controlled the supply of credits made by banks, through a system of quotas. The government determined the quantity of credit for the main economic sectors such as agriculture, manufacture, construction, exports, and services again in order to give priority to the preferred sectors.

Finally, consider the deposit side. The rates of profit paid on investment deposits were less than the rate of inflation during the period of the study. Therefore, the real interest rates on deposits were negative, which adversely affected the economy by altering the combination of assets held by people. Substantial resources were invested in financial assets, such as foreign currencies, or in durable goods such as gold, houses, and cars, rather than in savings with the banking system.

2.3.3 Foreign Exchange Policy

Evolution of the Structure of the Foreign Exchange Market

In the Iranian economy a parallel market for foreign currencies has always operated along with the official market [see, for example, Bahmani–Oskooee (1995)]. The government manages the official market whereas the forces of demand and supply run the parallel market. The Iranian parallel market has always been dominated by the US dollar.

Since 1974 the domestic currency has officially been pegged to SDR, whereas it had been pegged to the dollar before. Since SDR–dollar fluctuations are small, the fluctuations in the official rial–dollar rate are also limited. In contrast, the parallel market rates fluctuate very widely, particularly after 1980, following the revolution and the war. In the early period under study, the economic conditions were such that the exchange rates in the official and parallel markets were moving in the same way. By 1979 the government had introduced a variety official exchange rates according to the nature of the related transactions. This multi–exchange rate system lasted for a decade.

The exchange rate unification policy was aimed at removing the duality in the foreign exchange market. This implied a devaluation of the official rates towards the level of the parallel rate. In order to set a common rate, the 'real' value of the domestic currency or equilibrium rate was required. The practical problem was how to determine this equilibrium rate. It was thought to be below the parallel rate and above the official rates. Some policymakers were optimistic enough to think that the unification process would bring down the exchange rate in the parallel market. This analysis had convinced the authorities to implement the unification policy and to switch to a floating system.

The principal objective of the devaluation was to give a boost to domestic production and to exports of non-oil tradable goods along with reducing imports, through an increase in import prices and efficient allocation of the resources such as foreign currencies.

This unification policy was initiated in the first five–year plan for 1989 – 1993 and had been implemented gradually. As a start, in 1989, the number of official rates was reduced to three: 'official' rate, 'competitive' rate, and 'floating' rate. Despite their names, the 'competitive' rate and 'floating' rate are also official rates set by the government. The 'official' exchange rate was applied to the public sector, the 'competitive' rate was introduced essentially for private sector imports, while the 'floating' rate was used for final goods as well as education, travel, and medical services. In addition to these three rates, one has to mention the parallel rate since a parallel market was active outside the banking system over this period. In 1992 the levels of the three official rates set by the government compare with the parallel rate as follows:

- 'official' rate: 65.7 rials per US$
- 'competitive' rate: 600 rials per US$
- 'floating' rate: 1459 rials per US$
- parallel rate: 1498 rials per US$

The above system lasted until 1993. At the end of the adjustment programme, policymakers went further in the process of unifying exchange rates by announcing a unique official rate and a big devaluation of the official rates in order to unify the official and the parallel rates. However, a distinct preferential exchange rate was maintained for some customers in order to avoid the consequences in the parallel market of the expected devaluation.

The big devaluation in 1993 was one of the major changes in economic policy under the five–year plan. However, the government was not fully aware of the effects of the unification policy. The devaluation created serious problems for banks and industries with dollar denominated expenditure. The failure of the economic reform programme forced the government to restore a dual official exchange rate system rather than letting it float. The 'official' rate and the 'export' rate were set by the government 1749 and 3000 rials per US$, respectively, in 1994. The parallel market has been declared illegal. Even then, the parallel market was still active.

The Performance of Exchange Rates

Figure 2.13 shows the trend of the official and the parallel market exchange rates[7] over the period 1959 – 1996. Until 1988 the official rate was regularly re–evaluated. The nominal exchange rate was re–evaluated by about 11 percent in 1973, from 76.38 rials to 67.63 rials, because of the windfall of the first oil shock. Another 10 percent re–evaluation took place in 1981. During the period 1985 – 1987, the rate was again re–evaluated by about 30 percent. In 1989 the opposite policy of devaluation was initiated through the adjustment programme. The official rate has been devaluated several times and consequently there has been a constant increase in

[7] Among the official exchange rates set by the government in a multi–exchange rate system, the rate plotted is the 'official' rate.

the official rate until 1993 when the big devaluation took place and the official rate reached 1749 rials per dollar.

The evolution of the exchange rate in the parallel market was the same as in the official market until 1979 [see, also, Jalali–Naeeni (1997), Nili (1997), and Pesaran (1998) who use similar exchange rates in their analysis]. The parallel rate was increasing steadily over the period 1980 – 1992. Since 1993, when the big devaluation of domestic currency occurred and a floating exchange rate system was announced, the parallel exchange rate has been rising markedly, reaching 4049 rials per dollar in 1995.

Figure 2.14 shows the exchange rate premium defined as the ratio of the parallel market rate over the official rate. The ratio was equal to unity until 1979, but since 1980 it increased sharply and reached a peak in 1992. It was again equal to unity in 1993, when the exchange rate was unified and a floating exchange rate system announced. After the failure of the unification policy, and the reintroduction of a dual official exchange rate system, the premium increased again. As long as there was a difference between the official and parallel rates, the allocation of resources was distorted and some resources moved to the parallel market. This phenomenon was even more profound when inflationary pressures increased. Since the exchange rate premium was greater than one, the government effectively subsidised to those who used the official markets.

After examining the evolution of the exchange rates, some remarks on particular aspects of the exchange rate policy are in order. First, the fixed exchange rate system was aimed as an anchor for the price level, that is, as an anti–inflationary mechanism. However, since monetary policy was linked to fiscal considerations, the authorities mechanically created money, as explained in the previous section, which stimulated inflation. The policy package of a fixed exchange rate and expansionary monetary and fiscal policies was not consistent, and the fixed exchange rate system could not work as a nominal anchor to keep down the price level.

Next, the big devaluation of 1993 is analysed. The devaluation was associated with the adjustment programme and motivated by a balance of payments problem. The devaluation was supposed to restrict imports and to boost exports in order to improve the trade balance. The immediate effect of that devaluation was to make imports more expensive in rial terms and non–oil exports cheaper in dollar terms without having the expected beneficial effects on quantities. However, because of the slow response of resources moving to export sectors and also because the domestic inflation rate exceeded the inflation rate of trading partners, the effects of real devaluation was eroded. The effects of the devaluation on the balance of payment were not as strong as might have been expected.

The devaluation had inflationary effects through various channels. Since the industrial sector of the economy was characterised by dollar denominated expenditure, wholesale prices increased through the rise in input costs. Furthermore, expected future price increases were passed onto retail prices. Moreover, the devaluation increased the price of traded goods relative to non–traded goods. Thus, due to the high proportion of imports, inflationary pressures in the economy increased.

2.3.4 Trade Policy

The Iranian government plays an important role in the international trade of the country, since – as a main exporter – it receives most of the foreign currencies earned by the country. The government not only affects the trade balance directly by exporting oil and importing goods and services but also exerts an indirect control on the allocation of foreign currencies to private importers. In addition, like any other regulator, the government has used price–oriented measures such as tariffs, export taxes or subsidies, retaining schemes, duty exceptions, and import deposits as well as quantity–orientated measures such as import quotas, import bans, licensing of imports, and export quotas.

The evolution of real exports and imports of goods and services is shown in Figure 2.15. Over the whole period, the average growth rates of real exports and imports were 6.2 and 6.3 percent, respectively. If nominal values are considered, the average annum growth rate was 27.7 percent for exports, and 23.4 percent for imports. Exports and imports (either in nominal or in real terms) move in the same direction. This illustrates the dependence of imports on oil exports, as oil revenue is allocated to the imports of goods.

Following the first oil boom, nominal imports and exports increased significantly, and then fluctuated until 1988. Since 1989 nominal imports and exports have risen sharply. This huge rise was due to the implementation of the economic reform programme that included the liberalisation of trade, the facilitating of the imports procedure and the allocation of foreign currencies at the official 'floating' rate, as mentioned earlier [see, for example, The Economic Report of the Iranian Central Bank and its Balance Sheet, (1992)].

Figure 2.16a and Figure 2.16b plot the trade balance at current prices. As can be seen, the trade balance is stable over the period 1959 – 1972. During the period 1973 – 1988, the trade balance is characterised by fluctuations. In particular it displayed three spikes in 1974, 1979, and 1982. The first spike was due to the first oil boom that affected total exports. A reduction in total imports following the revolution and the start of the war explained the second peak. Finally, the third peak came from an increase in the quantity of oil exports, as the economic and political environment was relatively stable. Over the period 1988 – 1992, imports rose faster than exports and this generated a deficit. In contrast, since 1993 the economy has experienced a large surplus in trade balance. This was the result of the government's control of imports using either price– or quantity–orientated measures [see, for example, An Independent Economic Plan from Oil Sector: Oil Revenue, (1997)].

An economy is usually considered as 'open' if the ratio of trade (exports and imports) to GDP exceeds 40 percent [see Little et al., (1993)]. In Iran this ratio on average was 43 percent over the period 1959 – 1996, which illustrates the high degree of openness of the country.

The trade policy led by the Iranian authorities over the period is characterised by several switches between liberalisation and tightening. Following the first oil boom, a liberalisation policy was launched which encouraged imports through financial supports and reductions in custom duties. After the revolution, ideologically–driven inward looking policies prevailed and this included trade policy which became more protectionist. The government indeed restricted imports along with encouraging non–oil exports. This policy roughly lasted until the end of the war. As mentioned before, in 1989 the government started implementing a liberalisation programme which included a big devaluation in order to improve non–oil exports and restrict imports. However, devaluation had little effect on competitiveness, since non–oil exports mainly consisted of the traditional agriculture products and mineral goods which suffered from chronic problems. Following the failure of the structural adjustment programme, the government again tightened trade and imposed more restrictions. This policy became more restrictive when the oil crisis started in 1996.

2.4 Conclusion

The salient features of the Iranian economy and of the macroeconomic policies over the period 1959 – 1996 can be summarised as follows:

The economy has experienced some important external and internal shocks such as the three oil shocks, the Islamic revolution, and the eight–year war with Iraq. In addition, significant government interventions such as nationalisation, liberalisation, and a big devaluation of the domestic currency took place. The effects of oil shocks were particularly profound due to the dependence of the economy on oil revenue which influenced macroeconomic policies. For example, monetary policy involved printing money to convert oil revenue into domestic currency before being spent by the government. Fiscal policy was also linked to the oil sector as government expenditure was financed mainly through oil revenue.

The first part of the chapter has focused on the trends of the main macroeconomic indicators. The evolution of oil prices and oil revenue showed wide fluctuations with a huge increase following the first and the second oil shocks and a significant decrease after the third oil shock. Real GDP followed closely the evolution of the oil value added. After the first oil boom the GDP was boosted until 1976 and then exhibited similar fluctuations to the oil sector. Iran has experienced high inflation, which was a main concern for the public and the government. Inflation increased sharply following the first oil shock and also after 1994 following the failure of the economic reform programme.

The chapter has described in detail the close link that prevailed between monetary and fiscal policies in Iran through the conversion of oil revenue into domestic currency and through the monetisation of the budget deficit. As far as fiscal policy is concerned, it is clear that the oil sector dominated the evolution of government revenue. The low ratio of tax revenue to total government revenue reflects the inefficiency of the tax system in Iran. The government expenditure policy was expansionary mainly due to political pressure. The current government spending, on average, was more than twice the level of the government development expenditure. The government budget was generally in deficit, mainly due to political pressures in favour of expansionary expenditure. Due to the poorly developed financial markets, with bond issue generally illegal and restrictions on foreign borrowing, the government mainly relied on the central bank to finance budget deficits.

The chapter has also examined monetary policy. Following the inflationary consequences of the first oil boom, the government aimed to control money supply to fight against inflation. But the authorities could not offset the creation of money due to the fiscal policy interaction. Since the government expenditure and the budget deficit were linked to the central bank as a main source financing, monetary policy was actually passive. Monetary policy has become even more expansionary since the end of the war.

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. 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.

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, production was not significantly boosted by the devaluation.

In conclusion, fiscal and monetary policies have generally been expansionary and had obvious inflationary effects. Moreover, exchange rate and trade policies failed to reduce inflation. Although the government intended to fight inflation, the policy packages that were followed were not consistent with each other, and high inflation has remained a problem until now.

Figure 2.1 Oil Price of Iran for Exports (US$)

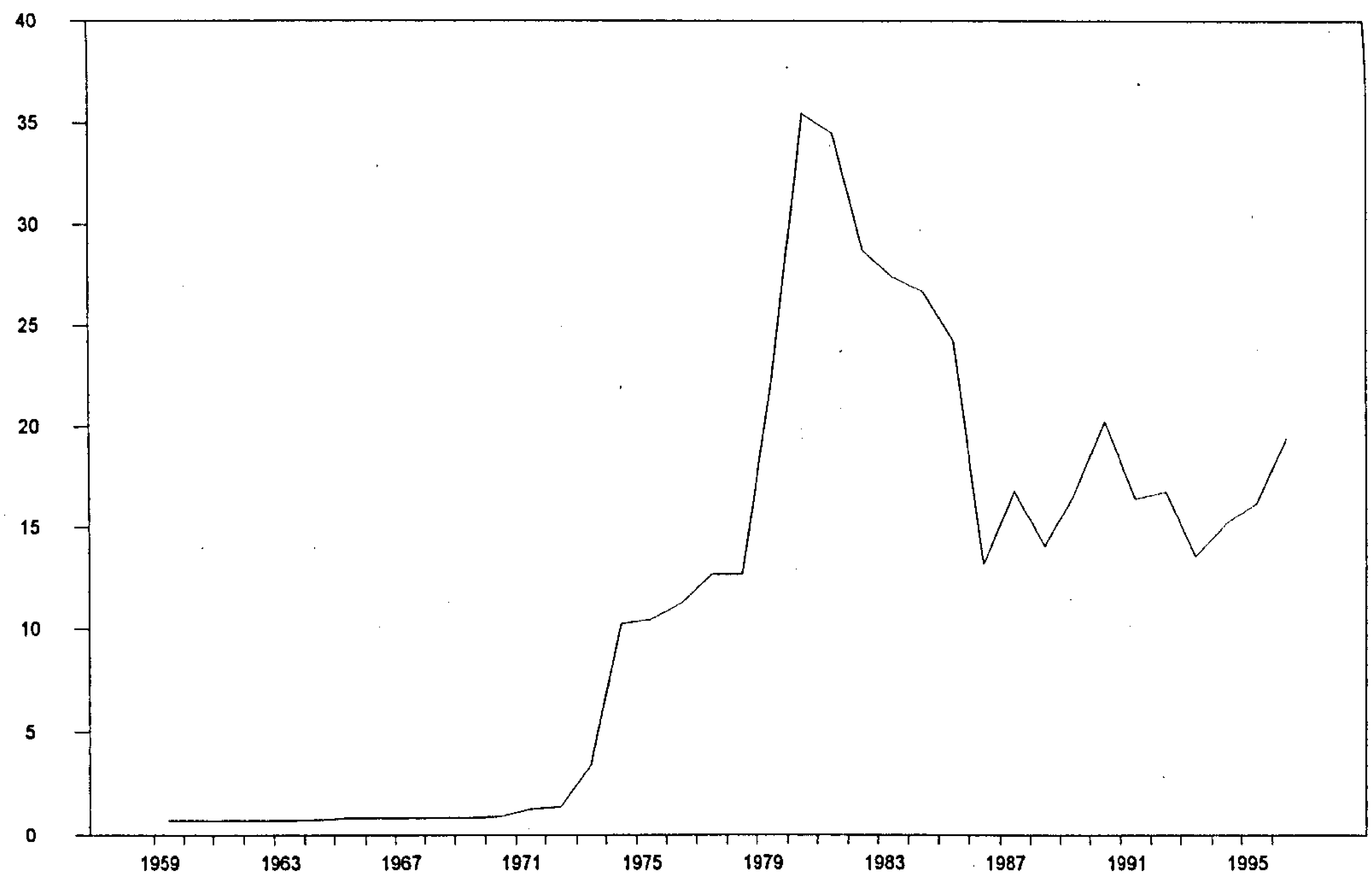


Figure 2.2a The Oil and Gas Revenue (thousands millions of rials): 1963 – 1996

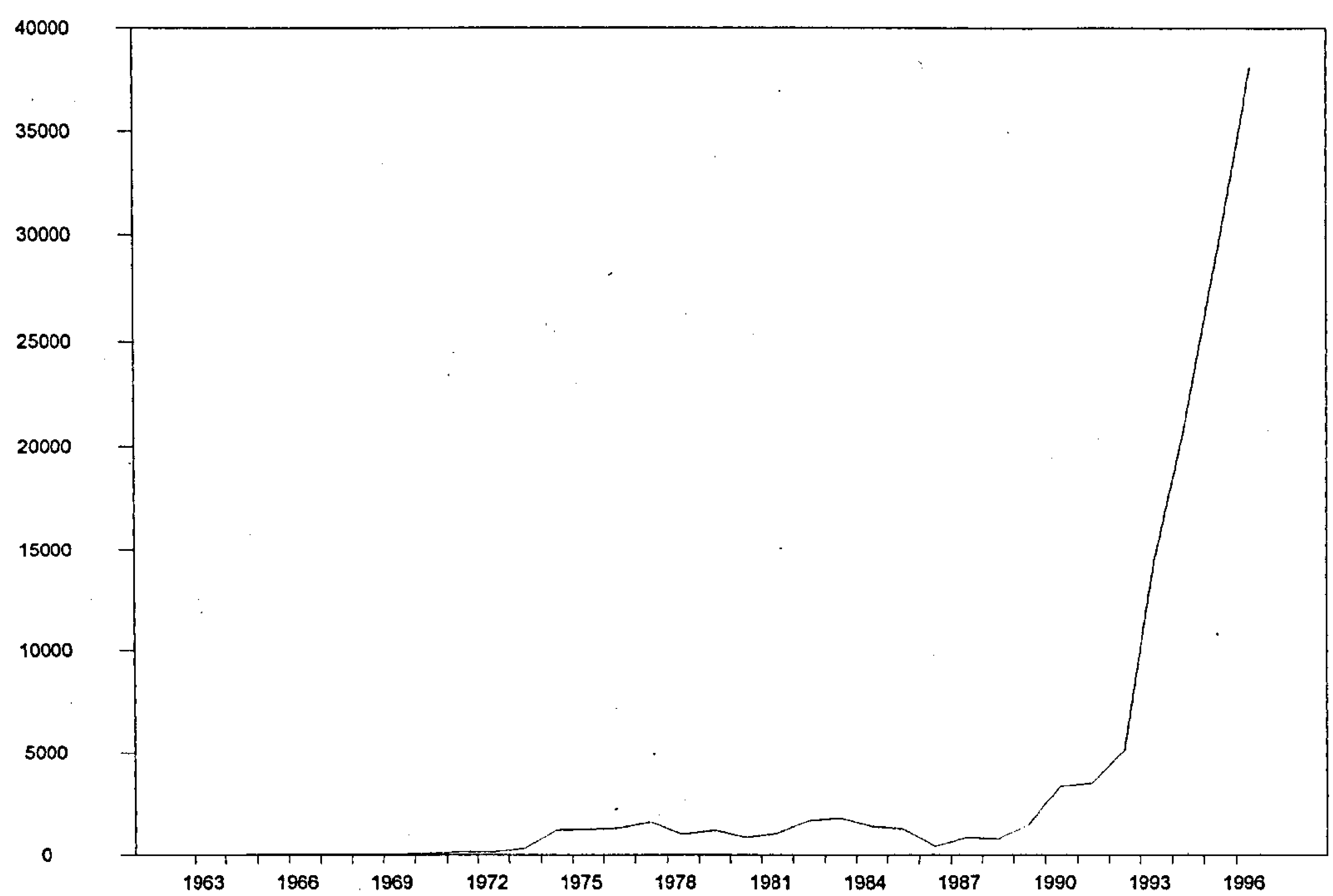


Figure 2.2b The oil and Gas Revenue (thousands millions of rials): 1970 – 1991

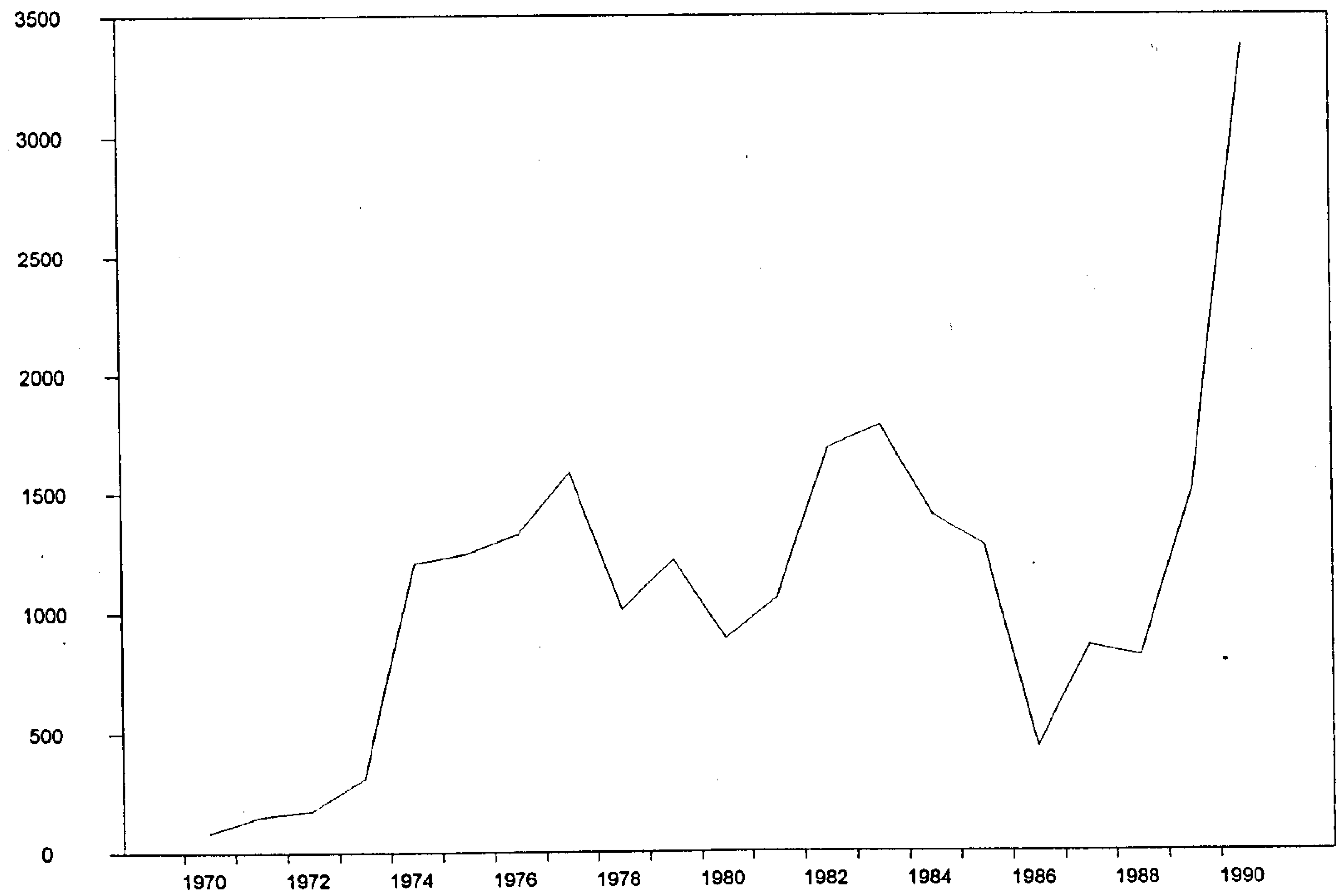


Figure 2.3 Domestic Inflation Rates Calculated Using CPI and GDP Deflator (%)

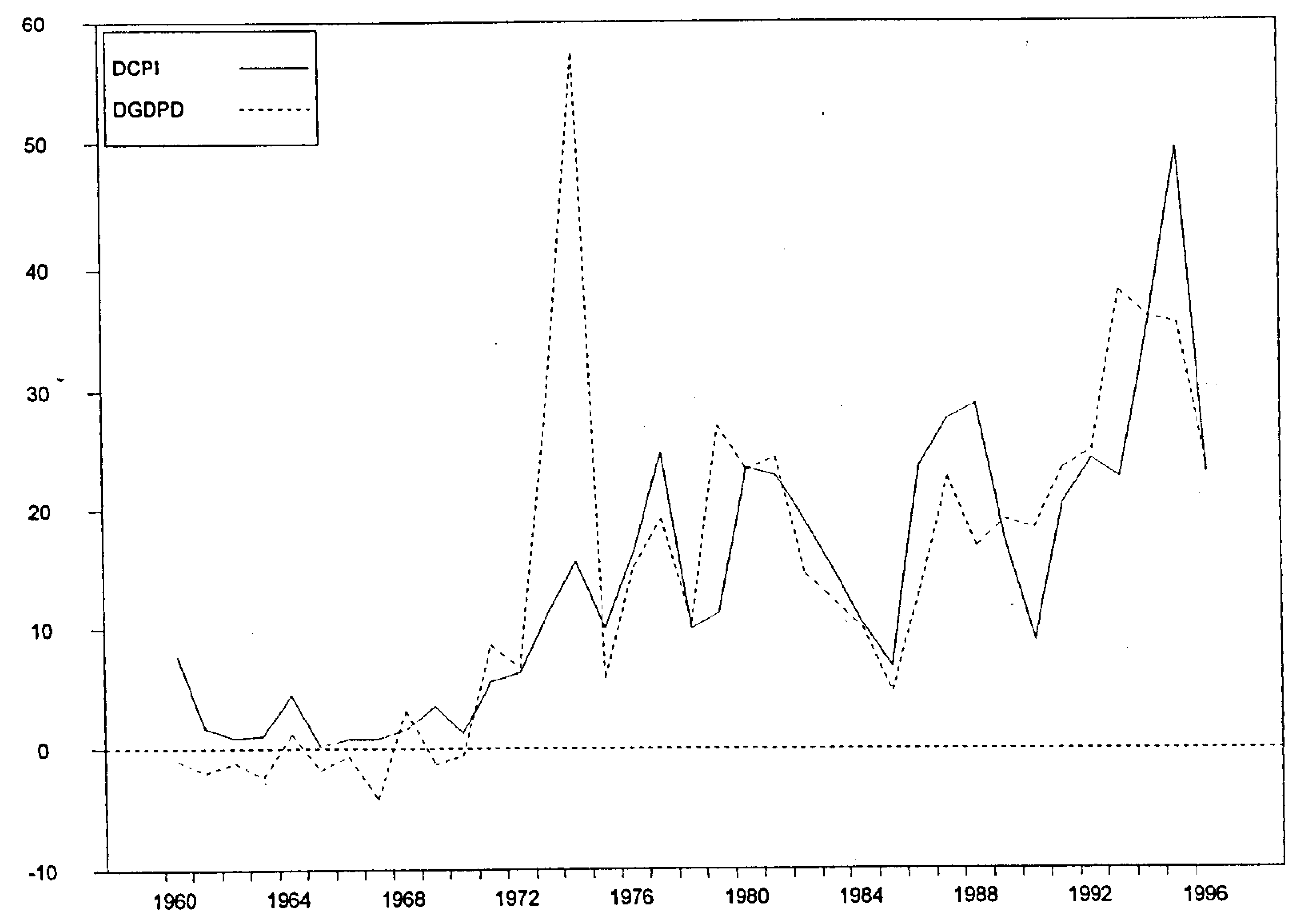


Figure 2.4 Inflation Rates Calculated Using WPI, PIM, and PEX (%)

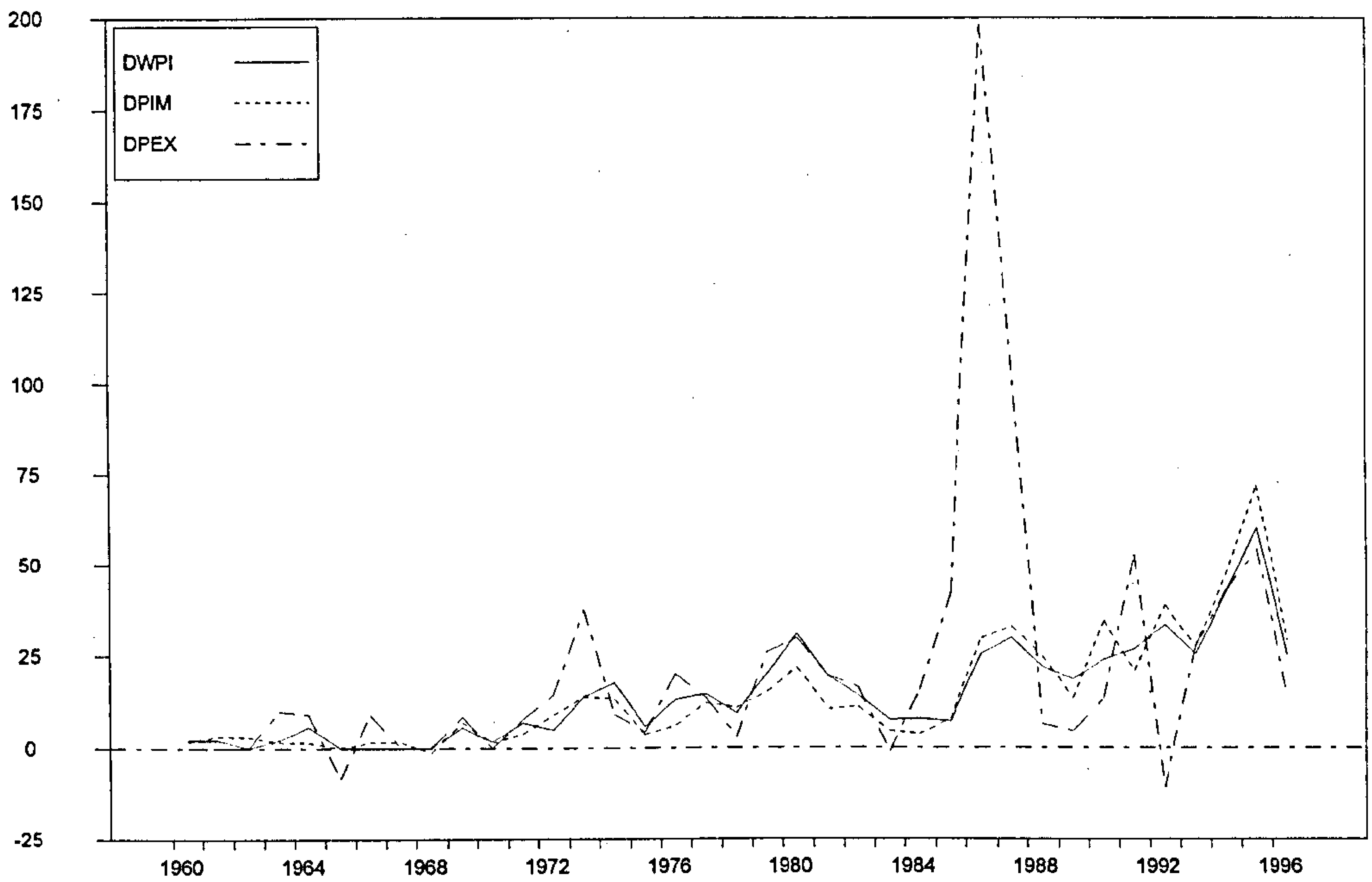


Figure 2.5 GDP (Y) and its Components at Market Price (thousands millions of rials, at 1990 Prices)

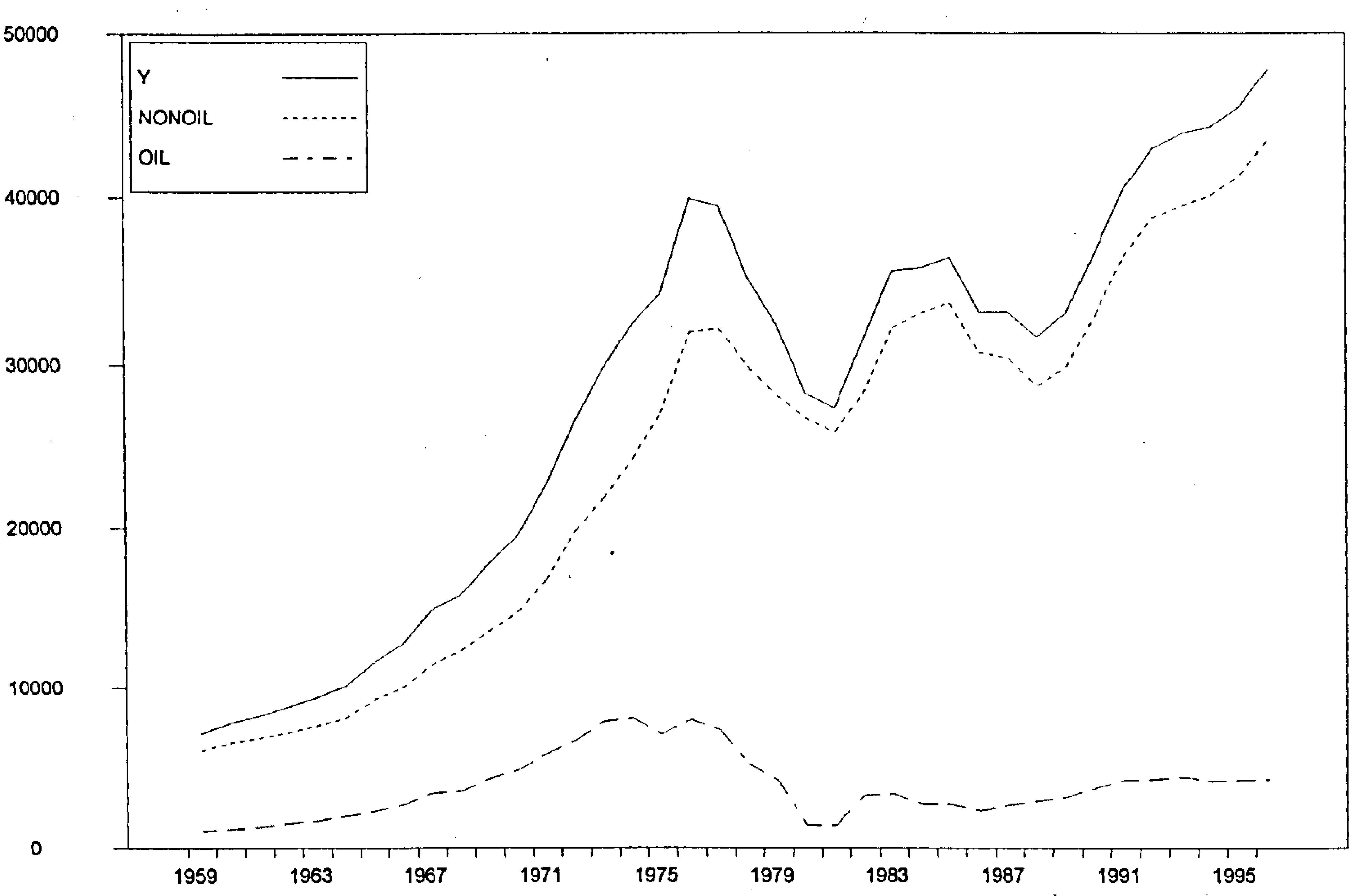


Figure 2.6 The Growth Rate of Real GDP per Capita

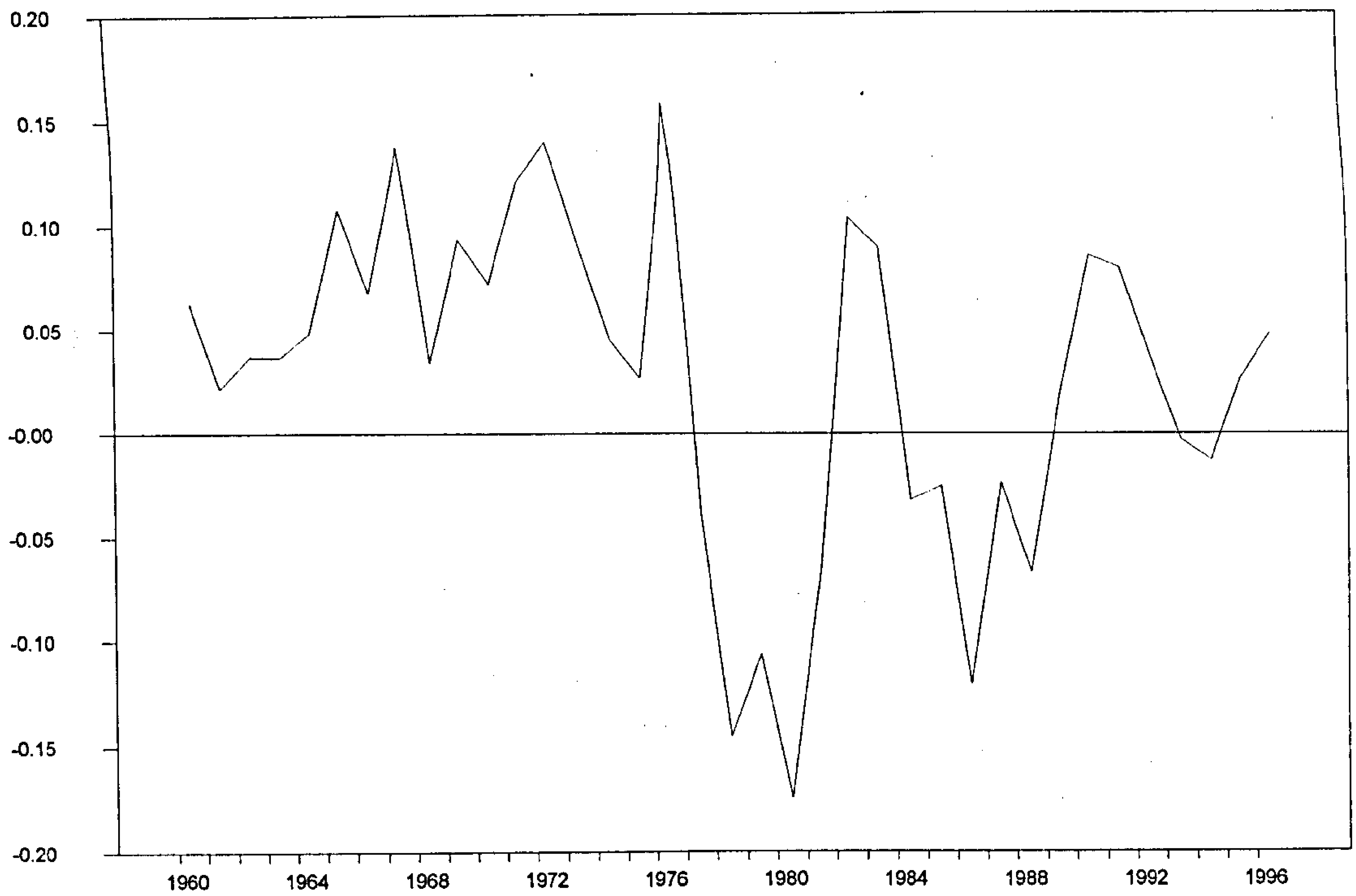


Figure 2.7 Total Real Consumption and Investment (Public & Private) as Shares of GDP

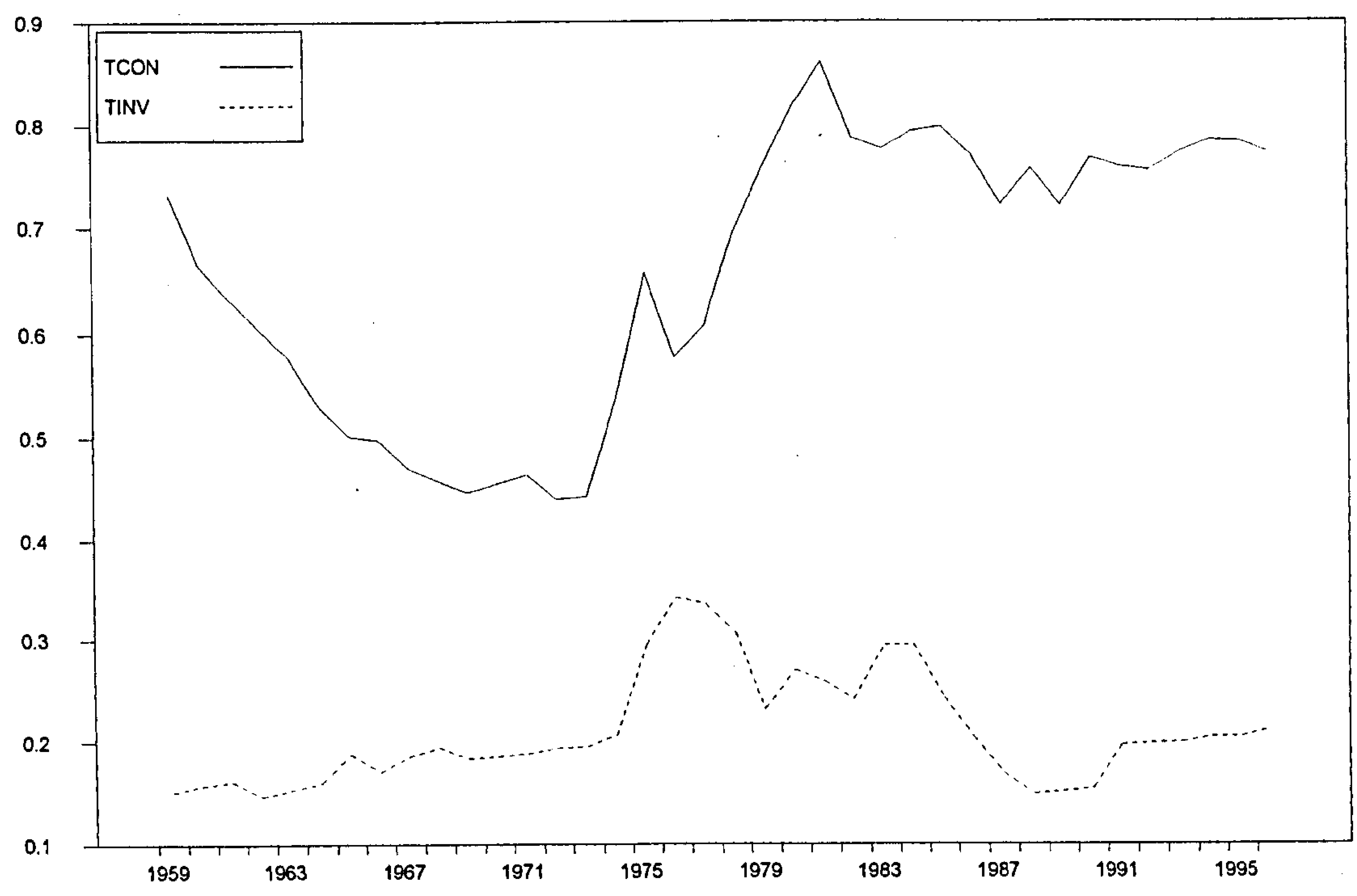


Figure 2.8 The Components of Government Revenue as a Share of Total Government Revenue

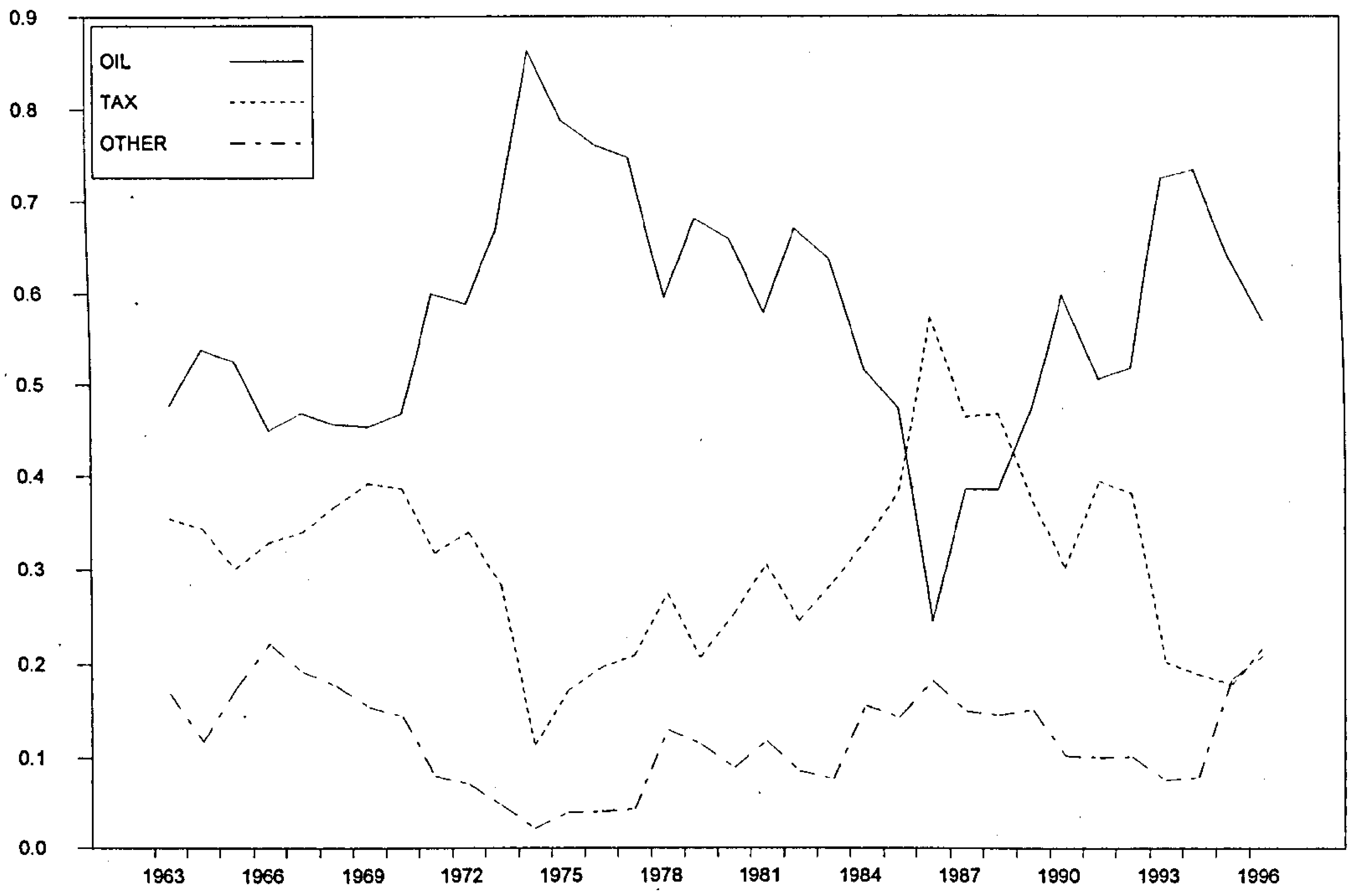


Figure 2.9 The Growth Rate of Government Expenditure (DG) and Inflation (DCPI)

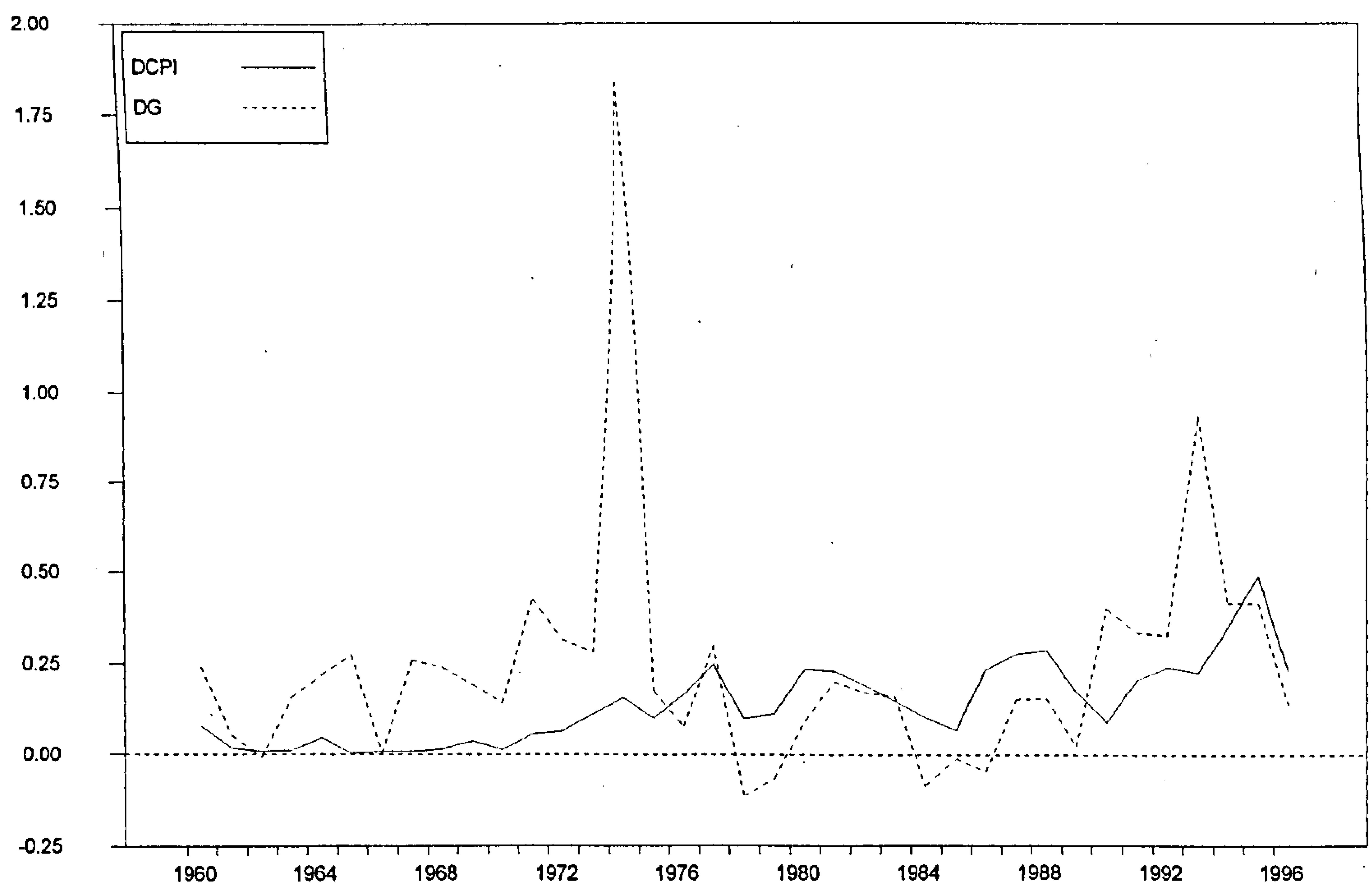


Figure 2.10 The Share of the components of Government Expenditure 1959 – 1996

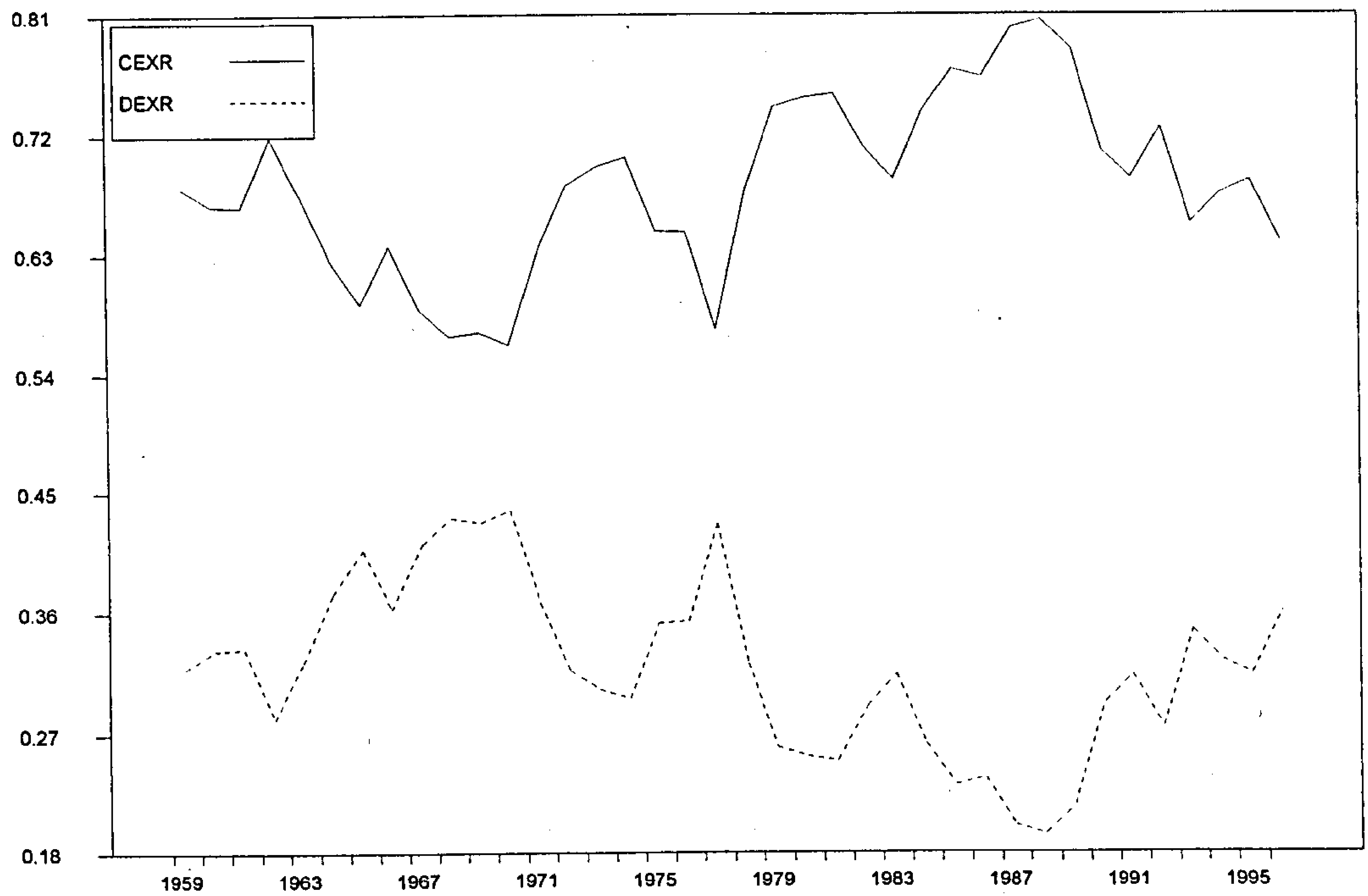


Figure 2.11 Budget Deficit (thousands millions of rials)

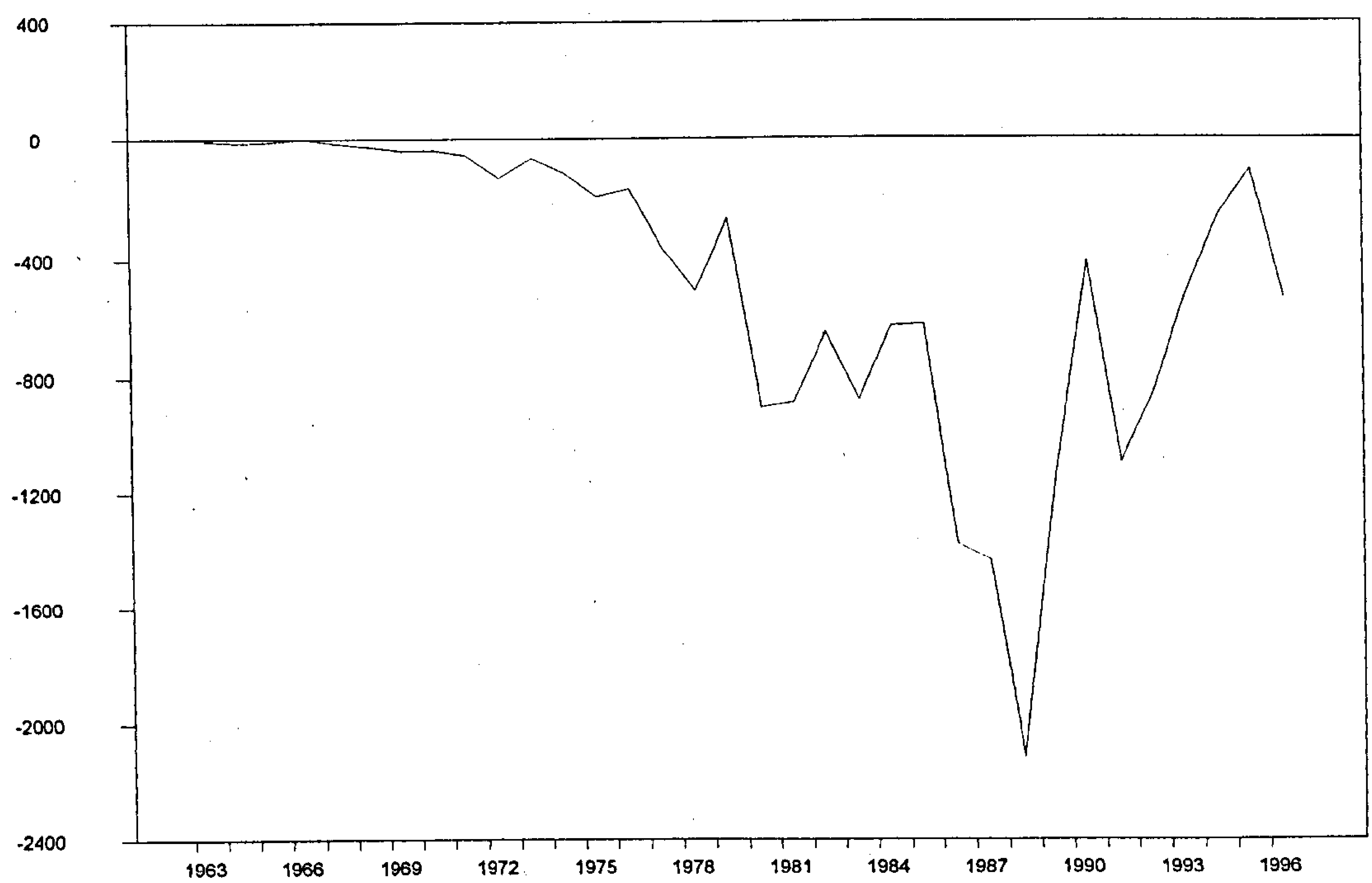


Figure 2.12 The Money Supply Growth (DM2) and Inflation (DCPI)

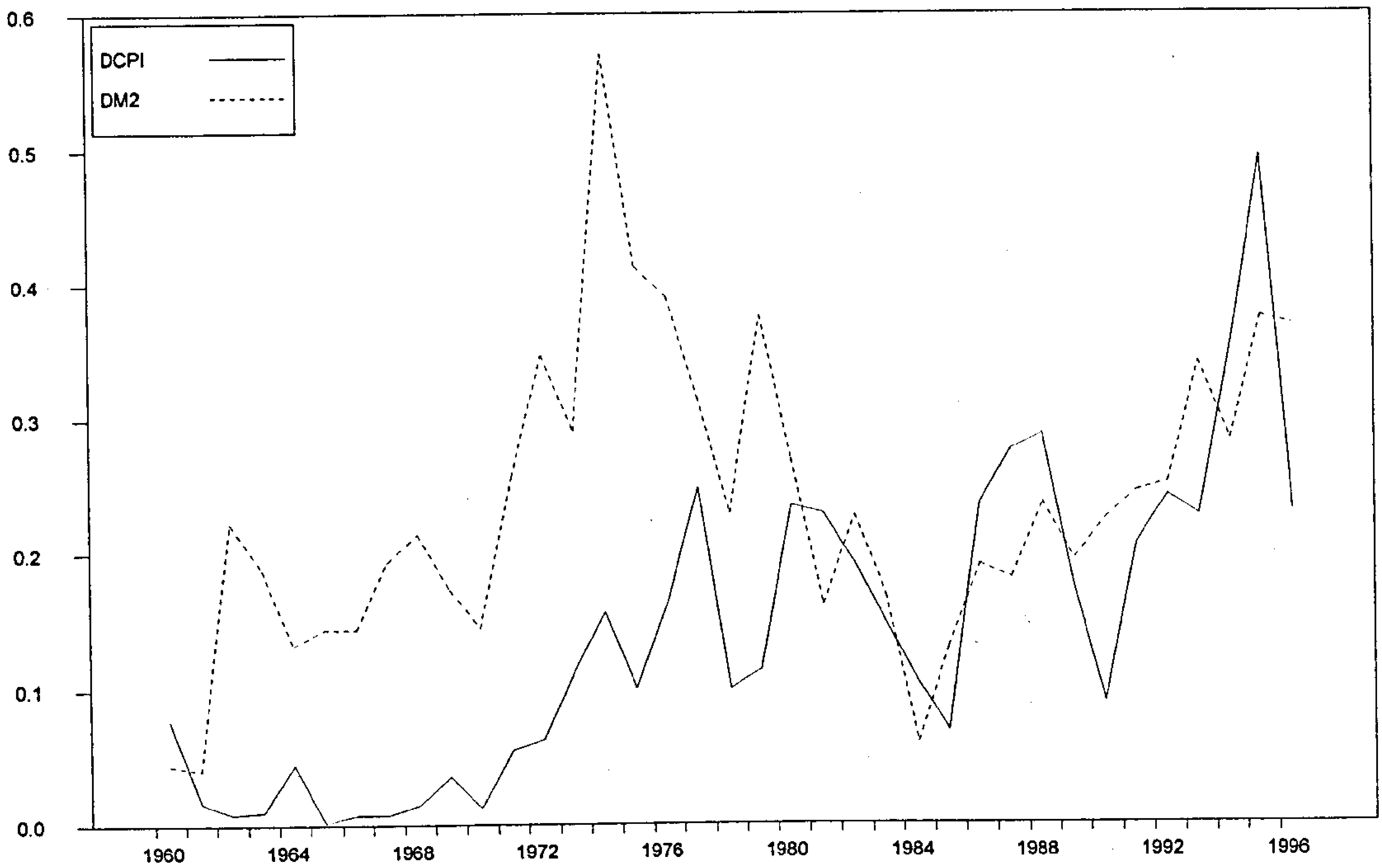


Figure 2.13 Official (OE) and Parallel (PE) Exchange Rates (rials per US$)

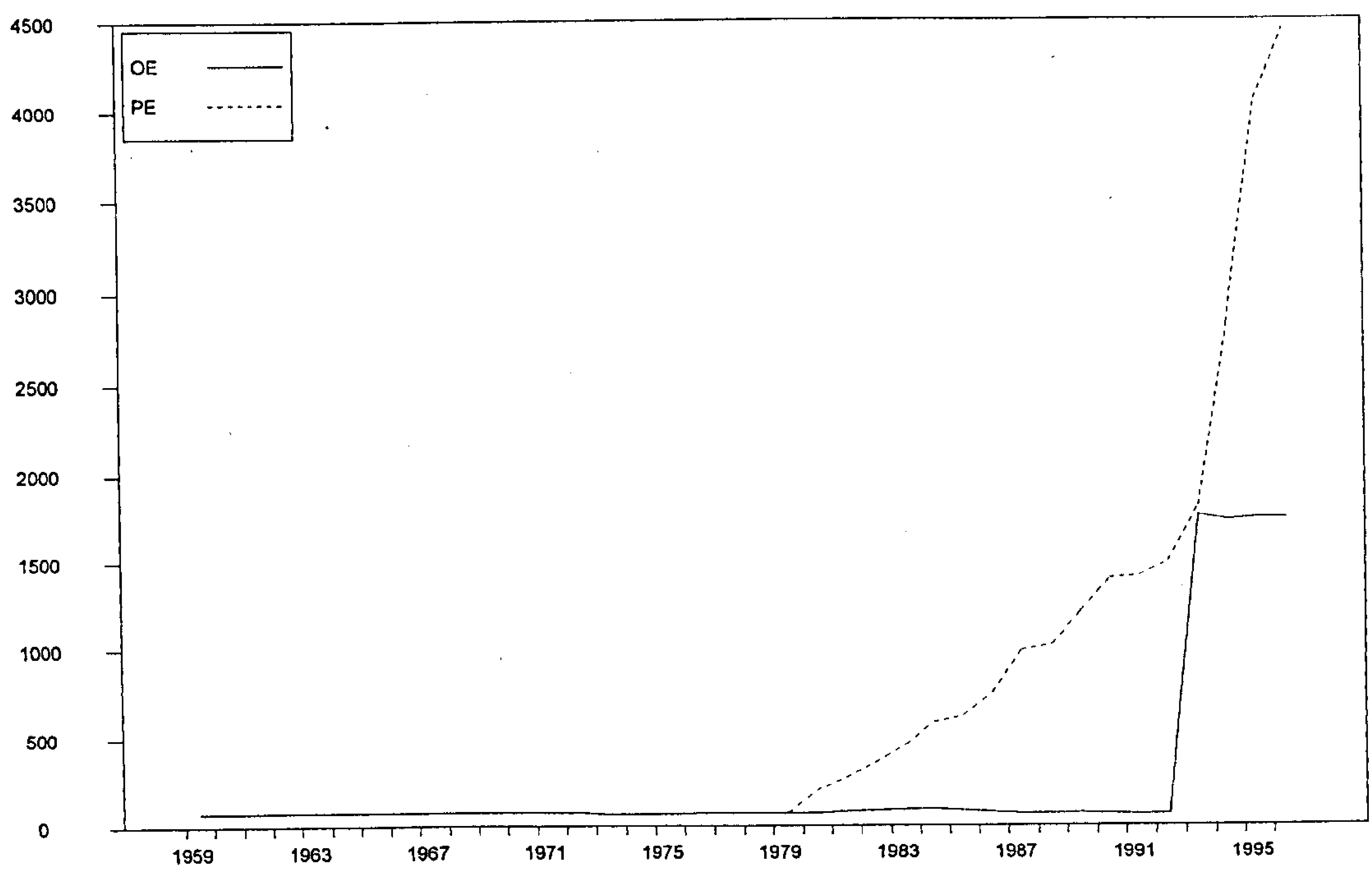


Figure 2.14 Exchange Rate Premium

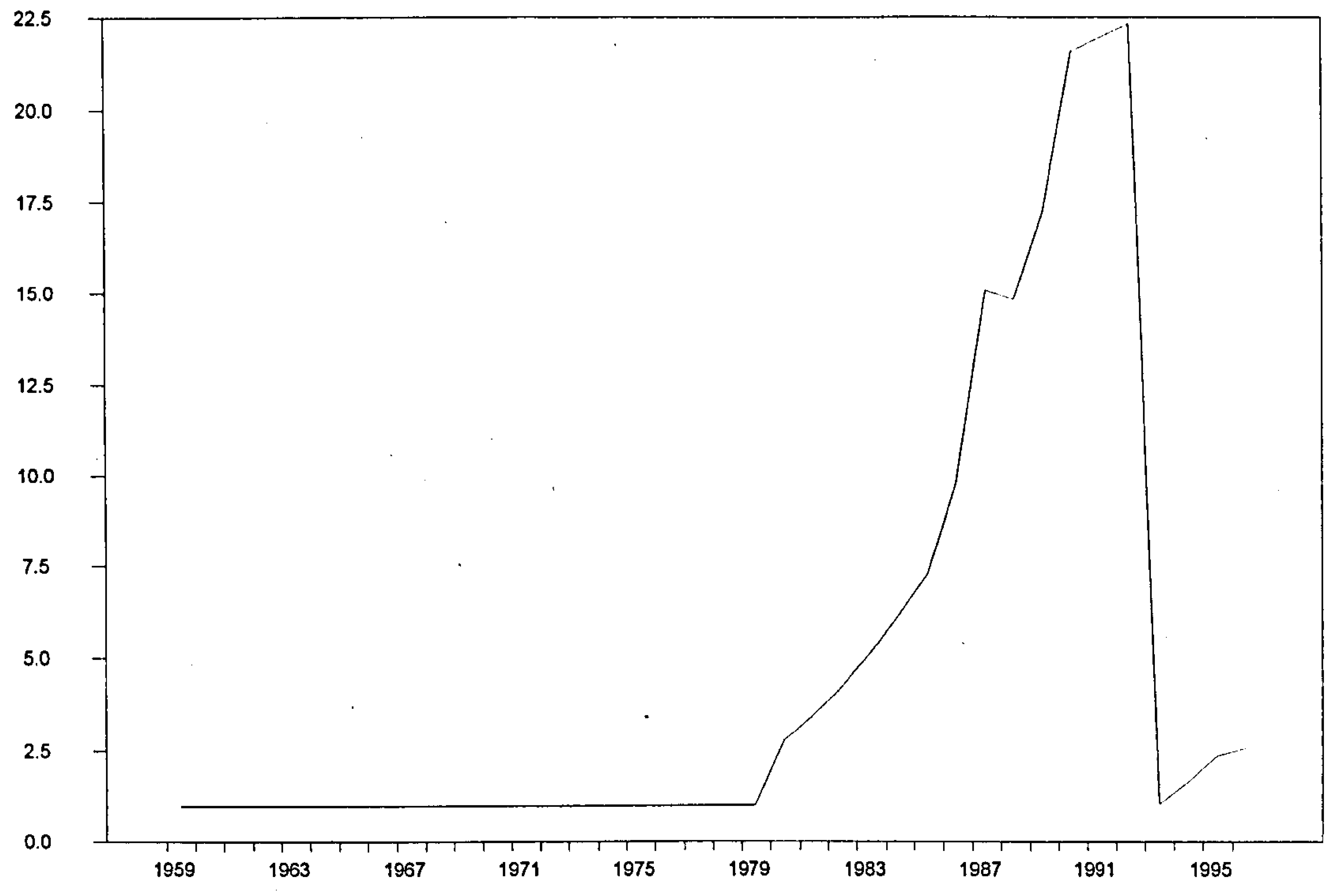


Figure 2.15 Total Real Imports and Exports of Goods and Services (thousands millions of rials at 1990 Prices)

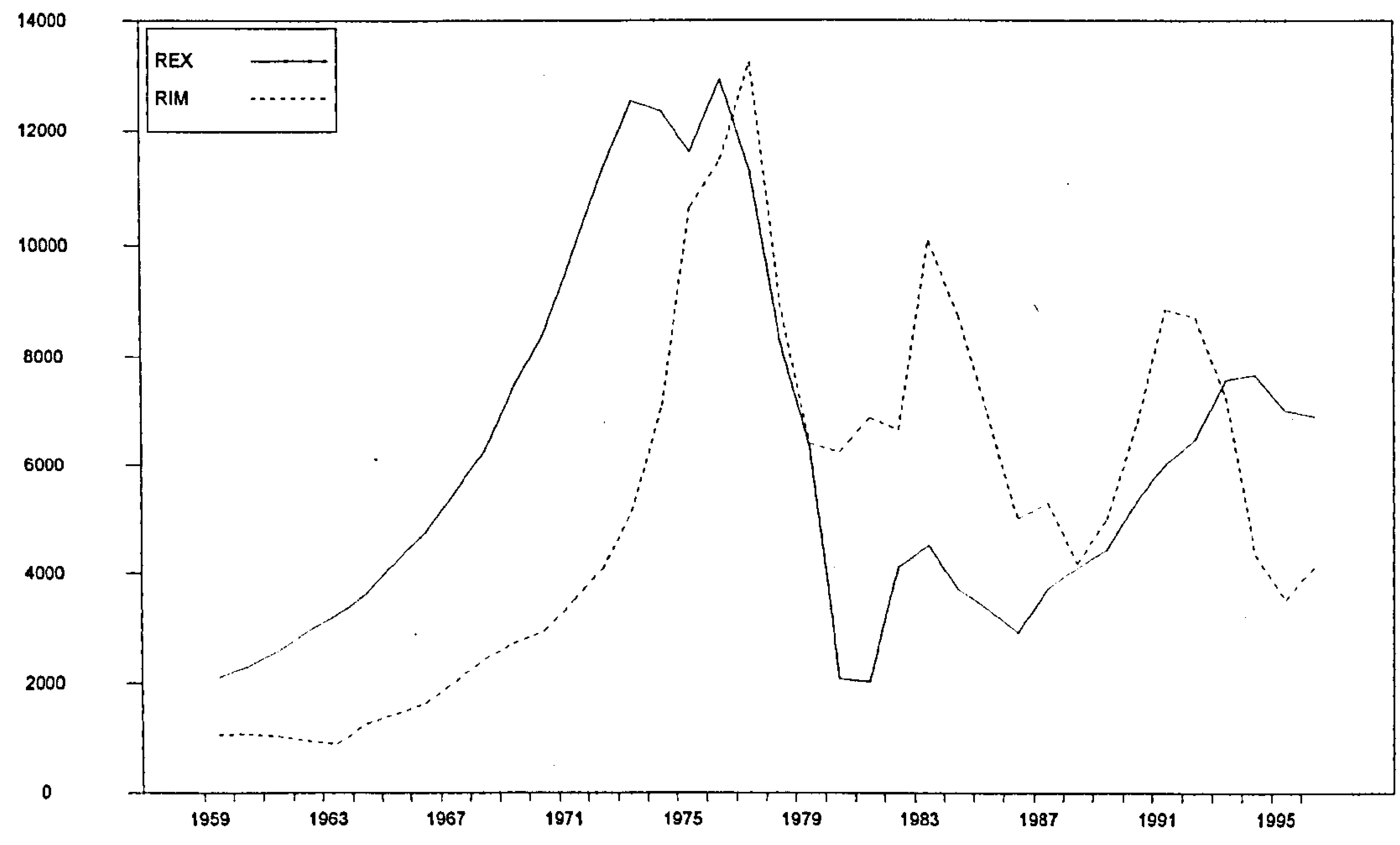


Figure 2.16a Trade Balance over the Period 1959 – 1996 (thousands millions of rials at Current Prices)

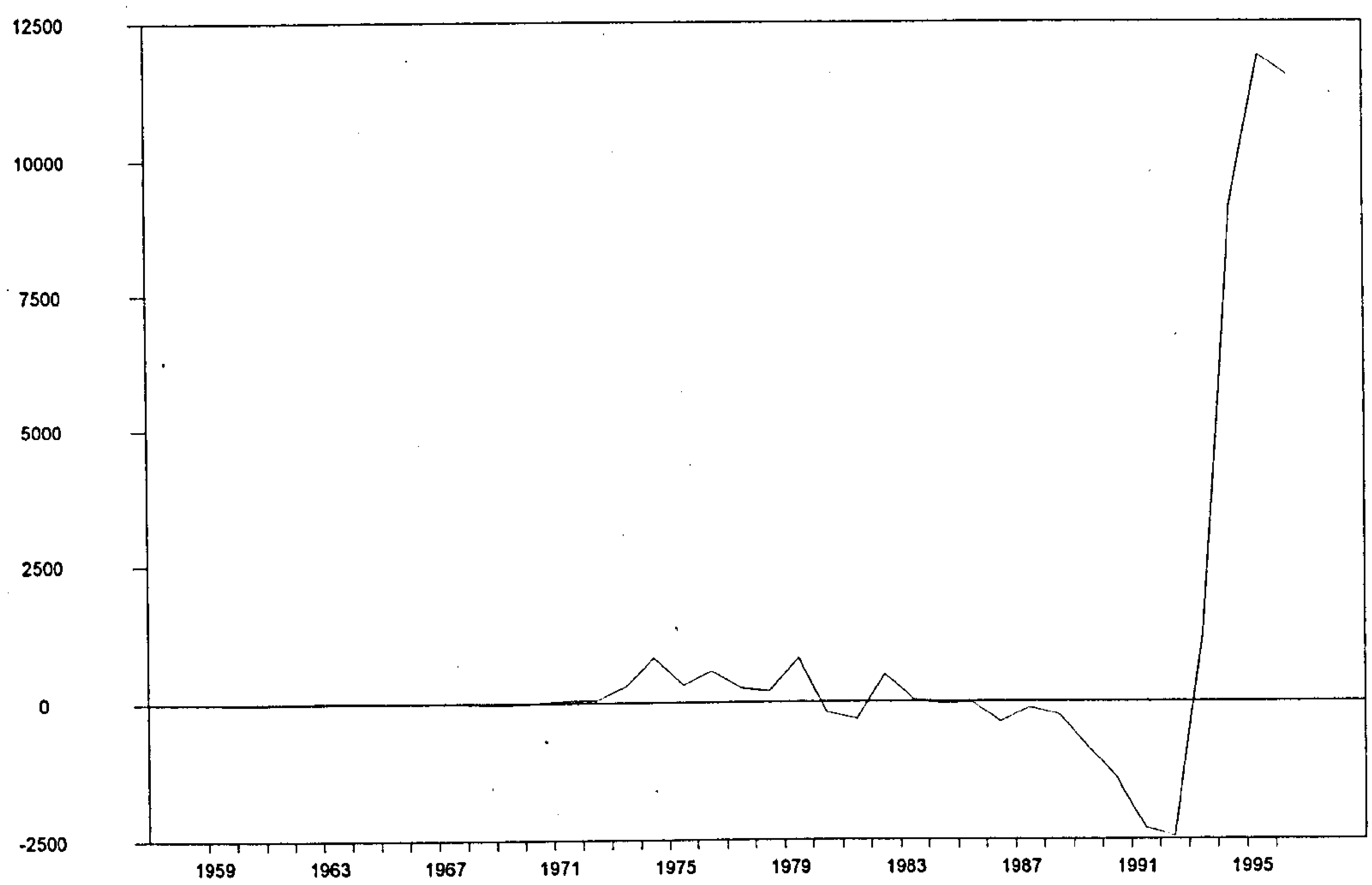
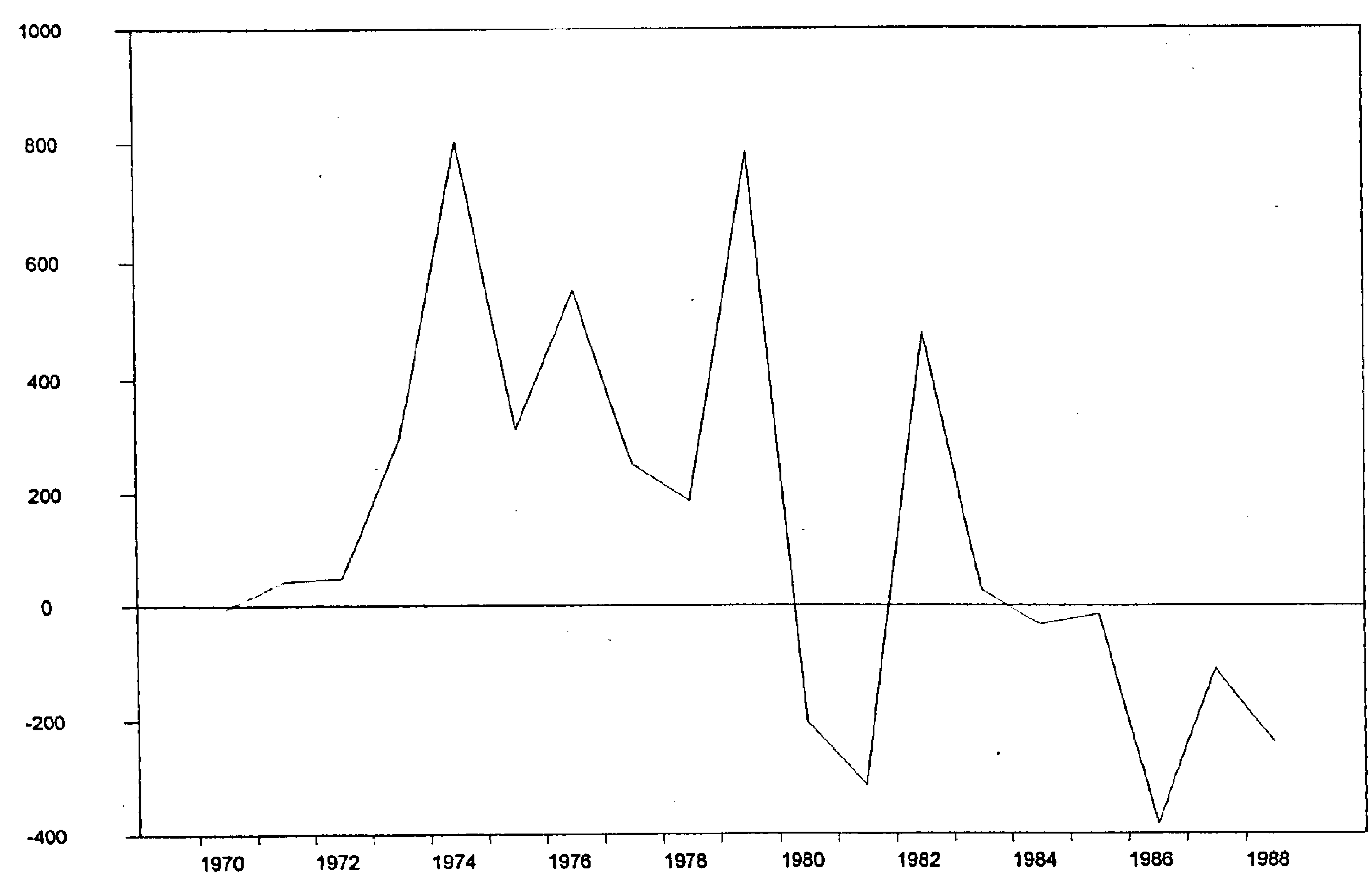


Figure 2.16b Trade Balance over the Sub-Period 1970 – 1988 (thousands millions of rials at Current Prices)



3 LINEAR TIME SERIES PROPERTIES OF INFLATION

3.1 Introduction

The objective of this chapter is to investigate some properties of the Iranian inflation measures using univariate models. Two inflation measures are considered calculated by using the difference of the log of the consumer price index (CPI) and the gross domestic product (GDP) deflator. This chapter attempts to answer a number of questions in this context as follows: are the effects of shocks on inflation temporary or permanent? do structural breaks exist in the time series? does the monthly series exhibit a seasonal pattern? how to best model seasonality?

Various univariate techniques are considered concerning the above questions. The different aspects of persistency and variability are investigated using annual and monthly data. To test the stationarity properties of the inflation measures, the autocorrelation function (ACF) is used along with more formal unit root tests. The Dickey–Fuller (DF) and augmented Dickey–Fuller (ADF) tests are commonly employed for this propose. These unit root tests do not take account of any break in the time series. Hence, if the time series has a structural break, the standard tests may not reject the unit root hypothesis (Perron, 1989). In the context of Iran, there have

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been some events (see chapter two, section 2.1) that possibly affect the time series. Consequently, the Perron procedure is considered to account for structural changes in the time series.

A time series can be modelled in a variety of ways. Autoregressive integrated moving average (ARIMA) models are specified using the ACF and partial ACF (PACF). The main characteristic that can be determined from these models is the length of its memory. In this context, with monthly data, a seasonal pattern can be identified if the ACF for the inflation rate shows spikes at lags 12, 24, 36, ...

This chapter is organised as follows: Section two discusses the standard DF and ADF tests of unit roots together with the Perron procedure (1989), which tests for the existence of unit roots under structural changes. Section three introduces linear models considering the effects of seasonality in monthly data, and reports the empirical results. Finally, in section four, the conclusions of this chapter are presented.

3.2 Unit Root Tests

In this section, the univariate properties of various inflation measures are considered based on unit root tests. Campbell and Perron (1991) point out that a macroeconomic time series, Y_t, consists of several components with different properties including a deterministic trend (TD_t) and a stochastic component or noise function (Z_t). They define the deterministic trend as linear in time t, and assume that the noise function can be described by an autoregressive moving average (ARMA) process. They may be written as follows:

$$Y_t = TD_t + Z_t \tag{3.1}$$

$$TD_t = k_0 + k_1 T \tag{3.2}$$

$$\phi(L)Z_t = \theta(L)\varepsilon_t \tag{3.3}$$

where $\varepsilon_t \sim$ i.i.d.(0, σ^2), and $\phi(L)$ and $\theta(L)$ are polynomials in the lag operator L of orders p and q, respectively. If the roots of $\phi(L)$ are strictly outside the unit circle, Z_t is a stationary process and Y_t is stationary around a trend. Such a series is referred to as I (0) and is called trend stationary (TS). If $\phi(L)$ has one unit root and all other roots are strictly outside the unit circle, then $\Delta Z_t \equiv (1-L)Z_t$ is a stationary process and ΔY_t is stationary around a fixed mean. In this case, Y_t is referred to as I (1), and is called difference stationary (DS).

Campbell and Perron consider two different types of shocks. Some shocks that can be called "big shocks" occur infrequently, and have a permanent effect on the trend function of a series. Other shocks, called "regular shocks", occur every period and may or may not affect the level of a series. The unit root issue concentrates on whether the "regular shocks" have a permanent effect on the level of a series.

Augmented Dickey–Fuller Test

Dickey–Fuller (1979) proposed an approach to test the null hypothesis that a series contains a unit root against the alternative of stationarity. To introduce this, the following unrestricted model is considered.

$$Y_t = \phi Y_{t-1} + \varepsilon_t \tag{3.4}$$

This equation can be estimated by OLS. If the coefficient of Y_{t-1} is equal one, then there is a unit root problem. A time series that contains a unit root is known as a random walk and is nonstationary. Subtracting Y_{t-1} from each side of equation (3.4) yields:

$$\Delta Y_t = \delta Y_{t-1} + \varepsilon_t \tag{3.5}$$

where $\delta = (\phi - 1)$, and then the null hypothesis is $\delta = 0$, and the alternative hypothesis is $\delta < 0$. Furthermore, Dickey and Fuller consider two modified regression equations by adding constant and time trend to test for the presence of a unit root as follows:

$$\Delta Y_t = \mu + \delta Y_{t-1} + \varepsilon_t \tag{3.6}$$

$$\Delta Y_t = \mu + \alpha T + \delta Y_{t-1} + \varepsilon_t \tag{3.7}$$

The parameter of interest in the above regression equations is δ. The DF test is based on the assumption that ε_t is white noise. But, when the true process is AR (p), p > 1, the error term will be autocorrelated to compensate for the misspecification of the dynamic structure of Y_t. Assuming that Y_t follows the p^{th}–order autoregressive process

$$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \cdots + \phi_p Y_{t-p} + \varepsilon_t \tag{3.8}$$

then equation (3.5) is replaced by the following

$$\Delta Y_t = \delta Y_{t-1} + c_1 \Delta Y_{t-1} + \cdots + c_k \Delta Y_{t-k} + \varepsilon_t \tag{3.9}$$

where $\delta = \phi_1 + \phi_2 + \cdots + \phi_p - 1$; and $k = p - 1$. The null hypothesis of a unit root now is $\delta = 0$ against the alternative $\delta < 0$.

Equation (3.9) needs to be extended to allow for the possibility that the data generation process contains deterministic components. The test for the null hypothesis of a stochastic trend (nonstationarity) against the alternative of a deterministic trend (stationarity) is based on the following models:

$$\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^{k} c_i \, \Delta Y_{t-i} + \varepsilon_t \tag{3.10}$$

$$\Delta Y_t = \mu + \delta Y_{t-1} + \sum_{i=1}^{k} c_i \, \Delta Y_{t-i} + \varepsilon_t \tag{3.11}$$

$$\Delta Y_t = \mu + \alpha T + \delta Y_{t-1} + \sum_{i=1}^{k} c_i \, \Delta Y_{t-i} + \varepsilon_t \tag{3.12}$$

To choose the number of lags in the equation of unit root test, Campbell and Perron suggest starting with some upper bound on k. If the last included lag is significant based on the standard normal distribution, the k is optimum. If not, the lag must be reduced until the coefficient on the last included lag is significant. If none is significant, $k = 0$, i. e. p = 1. An alternative procedure would be to select the order by starting from a parsimonious specification, including additional lags as long as they are significant. They emphasise that this is not asymptotically valid, and leads to serious size distortion in finite samples.

Since the augmented statistic does not follow a standard t–distribution, Dickey and Fuller computed critical values on the basis of Monte Carlo simulations. Using the related critical values, if $\delta = 0$ cannot be rejected, then Y_t contains a unit root. Consequently, the series has to be differenced once. Under this assumption, the original series is integrated of order 1, denoted I (1). If the original series has to be differenced twice before it becomes stationary, the original series is integrated of order 2, called I (2). Generally, if the original time series has to be differenced d times before it becomes stationary, the original series is integrated of order d or I (d). Obviously, if d = 0, the original time series is stationary.

Perron's Procedure

Perron (1989) points out that some important events such as the Great Crash in 1929 and the oil price shock in 1973 were not a realisation of the underlying data generation process of the various series. Therefore, he considers these shocks as exogenous and removes their influence from the noise function.

Perron extends the Dickey–Fuller methodology by allowing for a one–time change in the structure occurring at a time T_B ($1<T_B<T$). To test for a structural break, Perron introduces three possible null hypotheses for a given time series $\{Y_t\}_0^T$. One that permits an exogenous change in the level of the series (model A), one that allows an exogenous change in the slope (model B), and finally, one that allows both (model C). These are parameterised below:

Null hypotheses:

model A: $Y_t = \mu + Y_{t-1} + dTB_t + \varepsilon_t$, (3.13)

model B: $Y_t = \mu_1 + Y_{t-1} + (\mu_2 - \mu_1)D_t + \varepsilon_t$, (3.14)

model C: $Y_t = \mu_1 + Y_{t-1} + dTB_t + (\mu_2 - \mu_1)D_t + \varepsilon_t$, (3.15)

Alternative hypotheses:

model A: $y_t = \mu_1 + \alpha T + (\mu_2 - \mu_1)D_t + \varepsilon_t$, (3.16)

model B: $y_t = \mu + \alpha_1 T + (\alpha_2 - \alpha_1)DT_t^* + \varepsilon_t$, (3.17)

model C: $y_t = \mu_1 + \alpha_1 T + (\mu_2 - \mu_1)D_t + (\alpha_2 - \alpha_1)DT_t + \varepsilon_t$, (3.18)

where $TB_t = 1$ if $t = T_B + 1$, and 0 otherwise;

$D_t = 1$ if $t > T_B$, and 0 otherwise;

$DT_t^* = t - T_B$ if $t > T_B$ and 0 otherwise; and

$DT_t^{*} = t$ if $t > T_B$ and 0 otherwise.

Perron (1989) presents a Monte Carlo experiment to assess the effects of the presence of a shift in the level or in the slope of a series on unit root tests. He uses the residuals from regressions (3.16) to (3.18), denoted by y_t^i (i = A, B, C), and estimates the following ADF regression by OLS:

$$y_t^i = \hat{\gamma}^i y_{t-1}^i + \sum_{j=1}^{k} \hat{c}_j^i \Delta y_{t-j}^i + \hat{\varepsilon}_t^i \qquad (3.19)$$

He also applies ADF tests for the full sample and for two split samples (pre–breakpoint and post–breakpoint periods) on the original series Y_t. He finds that the estimate of γ from (3.19) is markedly superior to any of the split sample estimates. The split sample regressions are not powerful enough to reject the unit root hypothesis.

Perron's results confirm that under structural break, the Dickey–Fuller test suffers from considerable loss of power. Hence, he extends the Dickey–Fuller regression to allow for a breakpoint in a time series. He adds dummy variables in the ADF regression and constructs the following nested regressions corresponding to models (A), (B), and (C), respectively.

$$Y_t = \hat{\mu}^A + \hat{\alpha}^A T + \hat{\beta}^A D_t + \hat{d}^A TB_t + \hat{\gamma}^A Y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta Y_{t-i} + \hat{\varepsilon}_t \qquad (3.20)$$

$$Y_t = \hat{\mu}^B + \hat{\alpha}^B T + \hat{\beta}^B D_t + \hat{\delta}^B DT_t^{*} + \hat{\gamma}^B Y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta Y_{t-i} + \hat{\varepsilon}_t \qquad (3.21)$$

$$Y_t = \hat{\mu}^C + \hat{\alpha}^C T + \hat{\beta}^C D_t + \hat{d}^C TB_t + \hat{\delta}^C DT_t + \hat{\gamma}^C Y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta Y_{t-i} + \hat{\varepsilon}_t \qquad (3.22)$$

Under the null hypothesis of a unit root, the following restrictions are imposed on the parameters of each model:

model A: $\alpha^A = 0$, $\beta^A = 0$, $\gamma^A = 1$

model B: $\alpha^B = 0$, $\delta^B = 0$, $\gamma^B = 1$

model C: $\alpha^C = 0$, $\delta^C = 0$, $\gamma^C = 1$

Under the alternative hypothesis of a trend stationary process, it is expected that

α^A, α^B, $\alpha^C \neq 0$; γ^A, γ^B, $\gamma^C \prec 1$; and β^A, δ^B, $\delta^C \neq 0$

Also, under the null hypothesis, d^A, d^C, and β^B are expected to be different from zero, while under the alternative hypothesis they should be zero.

Perron notes that the asymptotic distribution of the t statistics in models (A) and (C) in equations (3.20) and (3.22) are the same as the asymptotic distribution of the t statistic in equation (3.19), while this correspondence does not hold for the t statistic of model (B) in (3.21). He emphasises that the unit root test based on equation (3.21) has less power than the test based on equation (3.19). Consequently, to test for a unit root where there is a change in the slope of a time series, he suggests using equation (3.19) rather than (3.21).

Perron also obtains the critical values of the relevant t statistics [$t_{\hat{\gamma}^i}(\lambda)$, i = A, B, C]. In each case, he considers nine values of the parameter λ (the ratio of pre–break sample size to total sample size).

Empirical Analysis

The data consists of monthly and annual data for the Iranian inflation measures calculated based on the consumer price index (CPI) and gross domestic product (GDP) deflator over the period 1959 – 1996. The source of the data is the Iranian central bank (see Appendix B).

As discussed in chapter two, the Iranian economy has experienced some big shocks and major government interventions over recent decades. Possible structural breaks include:

- first oil price shock in 1972 – 1973
- the revolution in 1978
- second oil price shock in 1979
- the eight–year war from 1980 to 1988
- third oil shock in 1986
- the economic reform programme during the period 1989 – 1993

To examine the structural breaks in the CPI and the GDP deflator, the plot of these series is first considered. Figure 3.1 shows the log of the CPI (Pc_t) using monthly data and Figure 3.3 plots Pc_t and the log of the GDP deflator (Pd_t) using annual data.[1] In addition, the changes of these series, $(1 - L^{12})\ Pc_t$ for the monthly series and $(1 - L)\ P_t$ for the annual series, are graphed in Figure 3.2 and Figure 3.4. The evidence from those figures shows that there is a break in the slope of both series after 1972. Estimation of equations (3.17) and (3.18) confirms that a break exists in the slope of Pc_t and Pd_t.[2] The coefficient on the break dummy is significant for the monthly data of Pc_t and also for the two annual series.

The sample autocorrelation function (ACF) and partial autocorrelation function (PACF) are used to identify the behaviour of the variable using both monthly and annual data (see Figure 3.5 through Figure 3.20).[3] The ACF for the level

[1] Monthly data are available only for the CPI.

[2] Bahmani-Oskooee (1995) finds a structural break in the level of Pc_t in 1978, but this break is not visible from Figure 3.1 or Figure 3.3.

[3] The ACF and PACF will be used to build the best linear and nonlinear models later.

of all series does not tail off quickly, suggesting nonstationary behaviour. Similar behaviour is observed if the ACF for the two sub–sample periods is examined (results not shown).

For the monthly series of Pc_t, $(1 - L)\ Pc_t$ has high and persistent autocorrelations at lags around multiples of 12 (see Figure 3.7). They seem to be dying out very slowly, suggesting the need for seasonal differencing. As can be seen from Figure 3.9, the ACF for $(1 - L^{12})\ Pc_t$ dies out very slowly, suggesting the need for further differencing. When the series $(1 - L)(1 - L^{12})\ Pc_t$ is considered, the pattern of the ACF in Figure 3.11 suggests that this series is stationary.

For the annual data, the ACF of Pc_t and Pd_t also fail to damp out quickly, suggesting that differencing is needed. For the differenced series, the ACF for $(1 - L)\ Pd_t$ decays to zero quickly, so that no further differencing is indicated. However, for $(1 - L)\ Pc_t$ the decay is much slower, suggesting that the CPI measure of inflation is probably nonstationary as indicated by the monthly data.

As mentioned before, due to the breakpoint in the time series, the Perron procedure is applied to test for a unit root in the inflation measures.[4] The number of lags in the equations of unit root tests is determined by starting with some upper bound on k suggested by Campbell and Perron (1991). First we deal with the monthly data. Table 3.1 presents the results of the univariate Perron test of unit roots for Pc_t, $(1 - L)\ Pc_t$, $(1 - L^{12})\ Pc_t$, and $(1 - L)(1 - L^{12})\ Pc_t$. Model (C) is used for the level while model (A) is used for the differenced series. To evaluate the significance of the t–statistic for the null hypothesis $\gamma = 1$, the critical values in Perron's Tables

[4] Some formal unit root tests such as Perron (1989) and Zivot and Andrews (1992) which consider one breakpoint in time series were used in this study. Although there is possibility of the presence of

IV.A and VI.C are used. The null hypothesis of a unit root for Pc_t cannot be rejected. Although the test suggests that the first difference of Pc_t is stationary, the ACF shows a strong seasonal pattern in this variable (see Figure 3.7). To eliminate seasonality, $(1 - L^{12})\ Pc_t$ is considered, which represents the annualised inflation rate. The result indicates a unit root in this variable. Finally, for the series $(1 - L)(1 - L^{12})\ Pc_t$, the null hypothesis of a unit root is rejected so that this series is stationary.

In the presence of a unit root, it is important to test whether this feature is stable in the two sub–periods. The standard Augmented Dickey–Fuller procedure is employed for two sub–periods, pre–1972.8 and post–1972.8 for the monthly data, with the results presented in Table 3.2. For both pre and post breakpoint the null hypothesis of a unit root in Pc_t and $(1 - L^{12})\ Pc_t$ cannot be rejected, while it is rejected for the series of $(1 - L)\ Pc_t$ and $(1 - L)(1 - L^{12})\ Pc_t$. These results are identical to those obtained for the whole period using the Perron procedure.

Next the annual data are considered. The Perron results in Table 3.3 suggest that there is a unit root in the level of both series, but the differenced series are stationary. The ADF results in Table 3.4 for the two sub–periods confirm these findings (given the value $\hat{\delta}$ = -1.03 in the test for ΔPd_t in the first period, the insignificance of $t_{\hat{\delta}} = -3.01$ must be attributed to the very small number of observations).

To summarise, for the annual data it is found that inflation is stationary irrespective of whether the CPI or GDP deflator is used. For the monthly data of the CPI, the results suggest that the monthly changes (ΔP) are stationary while the

more than one breakpoint in the Iranian macroeconomic time series, here only the results of the Perron tests are reported.

annualised changes ($\Delta_{12}P$) are not. These findings are consistent with those of Tabebeian and Souri (1995) who employ the Phillips–Perron (1988) test and find P ~ I (1) using data over 1959 – 1993 for the CPI. Bahmani–Oskooee (1995) also uses annual data for the CPI and concludes that P ~ I (1), although when he allows for a break in 1978 the Perron test suggests that P ~ I (2).

3.3 Linear Univariate Models

An integrated I (d) series may be represented by an autoregressive integrated moving average or ARIMA (p, d, q) process as follows:

$$\phi_p(L)(1-L)^d Y_t = \theta_0 + \theta_q(L)\varepsilon_t \tag{3.23}$$

where $\phi_p(L) = 1 - \phi_1 L - \cdots - \phi_p L^p$; $\theta_q(L) = 1 - \theta_1 L - \cdots - \theta_q L^q$; and ε_t is zero–mean white noise.

For the differenced series $\Delta^d Y_t$ to be stationary, the roots of $\phi(L)$ must be outside the unit circle. The roots of $\theta(L)$ also should be outside the unit circle for the invertibility condition to hold.

The model building approach of Box and Jenkings (1976) consists of three stages. Model identification, which is the determination of the values of p, d, and q on the basis of the ACF and PACF; model estimation, which provides estimates of the ϕ's and θ's and variance of ε_t; and diagnostic checking, which evaluates the estimated model. If the diagnostic tests reject the model, then another model is specified and estimated.

For seasonal time series the model is extended to the following multiplicative ARIMA $(p,d,q)(P,D,Q)_s$ model:

$$\phi_p(L)\Phi_P(L^s)(1-L)^d(1-L^s)^D Y_t = \theta_0 + \theta_q(L)\Theta_Q(L^s)\varepsilon_t \quad (3.24)$$

where $\Phi_P(L^s) = 1 - \Phi_1 L^s - \cdots - \Phi_P L^{Ps}$; $\Theta_Q(L^s) = 1 - \Theta_1 L^s - \cdots - \Theta_Q L^{Qs}$; and s = 12 for monthly data. The specification of P and Q is based on the patterns of seasonal lags of the ACF and PACF.

Results

The unit root tests for the monthly CPI in the previous section show that the series $\Delta\Delta_{12}P$ is stationary so that d = D = 1. From the ACF and PACF, the ARIMA (1, 1, 0)(0, 1, 2)$_{12}$ model for Pc_t seems appropriate for the whole period and also the second sub–period, while the simple model ARIMA(0, 1, 0)(0, 1, 1)$_{12}$ model is suggested for the first sub–period. The estimated models are reported in Table 3.5.[5] It can be seen that there is no residual autocorrelation, although there is strong evidence of ARCH for the second period and the whole period. The Chow test does not indicate a structural break.

For the annual data, the unit root tests show that ΔP_t is stationary while the ACF and PACF indicate an AR (1) model for this series. This is the same for both the CPI and the GDP deflator, so that an ARIMA (1, 1, 0) model is estimated for each series. It can be seen from Table 3.6 that the estimate of ϕ is higher for ΔPc_t than for ΔPd_t, which is what would be expected given that the ACF for ΔPc_t decays more slowly. While there is no residual autocorrelation, there is evidence of ARCH for both models. Also the hypothesis of no structural change after 1972 is rejected for both models.

3.4 Conclusion

Univariate properties of inflation are examined by looking at the plots of the series and their ACFs and PACFs, applying unit root tests and estimating ARIMA models. The evidence from the annual data is that inflation is a stationary process but the linear model suffers from a break in 1972 and also the presence of ARCH. For the monthly data, the evidence is less clearcut. While the monthly changes (ΔP) are stationary, there is evidence of a persistent seasonal pattern. When the series is seasonally differenced, $\Delta_{12}P$ is found to be nonstationary. For the stationary series $\Delta\Delta_{12}P$, the linear model again exhibits ARCH effects. The presence of ARCH and structural breaks in the models may be an indication of nonlinear behaviour, and this issue is examined in the next chapter.

[5] The estimation process has been done by using Regression Analysis of Time Series (RATS) and Microfit statistical packages.

Table 3.1 Univariate Perron Test for Unit Roots [Models (A) and (C)] Using Monthly Data

Regressions: Model (A) $Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\beta}D_t + \hat{d}TB_t + \hat{\gamma}Y_{t-1} + \sum_{i=1}^{k}\hat{c}_i\Delta Y_{t-i} + \hat{\varepsilon}_t$

Model (C) $Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\beta}D_t + \hat{d}TB_t + \hat{\delta}DT_t + \hat{\gamma}Y_{t-1} + \sum_{i=1}^{k}\hat{c}_i\Delta Y_{t-i} + \hat{\varepsilon}_t$

	Pc_t	ΔPc_t	$\Delta_{12}Pc_t$	$\Delta\Delta_{12}Pc_t$
n	389	389	389	378
k	48	62	50	60
$\hat{\mu}$	0.01	-0.9E-3	0.5E-3	0.3E-3
$t_{\hat{\mu}}$	(1.17)	(-0.54)	(0.27)	(0.19)
$\hat{\alpha}$	0.3E-4	0.1E-4	-0.2E-5	-0.2E-5
$t_{\hat{\alpha}}$	(0.53)	(1.57)	(-0.19)	(-0.24)
$\hat{\beta}$	-0.02	0.003	0.01	-0.8E-3
$t_{\hat{\beta}}$	(-1.14)	(1.34)	(0.61)	(-0.32)
$\hat{d}$	0.005	0.002	0.4E-3	0.004
$t_{\hat{d}}$	(0.36)	(0.16)	(0.03)	(0.28)
$\hat{\delta}$	0.1E-3	-	-	-
$t_{\hat{\delta}}$	(1.12)	-	-	-
$\hat{\gamma}$	0.99	0.41	1.002	0.37
$t_{\hat{\gamma}-1}$	(-1.45)	(-11.63)***	(0.15)	(-12.73)***

Notes:

- Pc_t is the log of the CPI; and Δ is the difference operator.
- 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 $t^* = 1972.8$. The ratio of pre–break sample size to total sample size is $\lambda = 0.35$.
- n is the number of observations; and k is the number of lags.
- *** indicates statistical significance at the 1% level, according to the critical values of the Perron test (1989, Table IV.A and Table VI.C).

Table 3.2 Univariate Augmented Dickey–Fuller Test for Unit Roots Using Monthly Data

Regression: $\Delta Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\delta}Y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta Y_{t-i} + \hat{\varepsilon}_t$

	n	k	$\hat{\mu}$	$t_{\hat{\mu}}$	$\hat{\alpha}$	$t_{\hat{\alpha}}$	$\hat{\delta}$	$t_{\hat{\delta}}$
(i) Pc_t								
1959.4 –1972.7	110	49	-0.010	-0.13	.2E-4	.33	0.01	0.10
1972.8 –1996.11	292	48	-0.004	-0.55	.1E-3	1.11	-0.01	-1.05
(ii) ΔPc_t								
1959.4 –1972.7	132	26	0.001	0.56	-.5E-5	-.28	-0.25	-3.36*
1972.8 –1996.11	292	38	0.002	0.54	.2E-4	1.86	-0.53	-7.97***
(iii) $\Delta_{12}Pc_t$								
1959.4 –1972.7	99	48	-0.005	-1.65	.5E-4	1.86	-0.01	-0.06
1972.8 –1996.11	292	50	0.002	0.69	-.1E-4	-.83	0.02	1.16
(iv) $\Delta\Delta_{12}Pc_t$								
1959.4 –1972.7	122	24	-	-	-	-	-0.58	-3.81***
1972.8 –1996.11	292	60	-	-	-	-	-0.51	-9.45***

Notes:

- Pc_t is the log of the CPI; and Δ is the difference operator.
- n is the number of observations; and k is the number of lags.
- *** and * indicate statistical significance at the 1% and 10 % level, respectively, according to the critical values of the ADF test.

Table 3.3 Univariate Perron Test for Unit Roots Using Annual Data

Regressions: Model (A) $Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\beta}D_t + \hat{d}TB_t + \hat{\gamma}Y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta Y_{t-i} + \hat{\varepsilon}_t$

Model (C) $Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\beta}D_t + \hat{d}TB_t + \hat{\delta}DT_t + \hat{\gamma}Y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta Y_{t-i} + \hat{\varepsilon}_t$

	Pc_t	ΔPc_t	Pd_t	ΔPd_t
n	36	35	36	35
k	1	1	1	0
λ	0.35	0.35	0.35	0.35
$\hat{\mu}$	-0.47	-0.02	-0.60	-0.02
$t_{\hat{\mu}}$	(-1.06)	(-1.10)	(-1.49)	(-0.69)
$\hat{\alpha}$	0.01	0.01	0.004	0.003
$t_{\hat{\alpha}}$	(1.12)	(2.97)	(0.60)	(1.27)
$\hat{\beta}$	-0.32	0.07	-0.32	0.08
$t_{\hat{\beta}}$	(-0.93)	(1.88)	(-0.98)	(1.51)
$\hat{d}$	0.04	-0.02	0.11	0.13
$t_{\hat{d}}$	(0.58)	(-0.30)	(1.22)	(1.58)
$\hat{\delta}$	0.02	-	0.03	-
$t_{\hat{\delta}}$	(1.06)	-	(1.21)	-
$\hat{\gamma}$	0.85	-0.11	0.82	0.25
$t_{\hat{\gamma}-1}$	(-1.07)	(-5.29)***	(-1.38)	(4.41)***

Notes:

- Pc_t is the log of the CPI; Pd_t is the log of the GDP deflator; and Δ is the difference operator.
- 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 $t^* = 1973$.
- n is the number of observations; k is the number of lags; and λ denotes the ratio of pre-break sample size to total sample size.
- *** indicates statistical significance at the 1% level, according to the critical values of the Perron test (1989, Table IV.A and Table VI.C).

Table 3.4 Univariate Augmented Dickey-Fuller Test for Unit Roots Using Annual Data

Regression: $\Delta Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\delta}Y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta Y_{t-i} + \hat{\varepsilon}_t$

	n	k	$\hat{\mu}$	$t_{\hat{\mu}}$	$\hat{\alpha}$	$t_{\hat{\alpha}}$	$\hat{\delta}$	$t_{\hat{\delta}}$
Pc_t								
1959 – 1972	13	0	-1.76	-1.52	0.012	1.61	-0.57	-1.54
1973 – 1996	24	0	0.05	0.08	0.005	0.25	0.01	0.05
ΔPc_t								
1959 – 1972	12	0	-0.01	-0.54	0.003	2.16	-0.86	-3.57*
1973 – 1996	24	1	0.03	0.61	0.006	2.76	-1.17	-4.65***
Pd_t								
1959 – 1972	13	0	0.65	0.66	0.007	2.31	0.22	0.71
1973 – 1996	24	1	-1.08	-1.27	0.040	1.46	-0.22	-1.42
ΔPd_t								
1959 – 1972	12	0	-0.05	-1.89	0.010	2.19	-1.03	-3.01
1973 – 1996	24	0	0.12	1.52	0.001	0.49	-0.80	-3.82**

Notes:

- Pc_t is the log of the CPI; Pd_t is the log of the GDP deflator; and Δ is the difference operator.
- n is the number of observations; and k is the number of lags.
- ***, **, and * indicate statistical significance at the 1%, 5 %, and 10% level, respectively, according to the critical values of the ADF test.

Table 3.5 ARIMA (p, 1, q)(P, 1, Q)s Models for Pc_t

	Model1		Model2		Model3	
	(1959.4 –1996.11)		(1959.4 –1972.7)		(1972.8 –1996.11)	
Constant	0.0004 (3.31)		-		0.0007 (3.13)	
$\hat{\phi}_1$	0.32 (7.10)		-		0.33 (5.82)	
$\hat{\Theta}_1$	0.71 (14.48)		0.61 (8.54)		0.69 (11.49)	
$\hat{\Theta}_2$	0.19 (3.82)		-		0.19 (3.11)	
n	438		147		292	
R^2	0.409		0.254		0.420	
s	0.0126		0.0081		0.0145	
DW	2.00		1.83		2.01	
Q(24)	29.91	[0.053]	20.16	[0.385]	24.92	[0.163]
Q(48)	49.35	[0.234]	40.40	[0.585]	43.35	[0.456]
$\chi^2_{ARCH}(3)$	27.66	[0.000]	2.37	[0.500]	10.35	[0.015]
$\chi^2_{ARCH}(12)$	38.26	[0.000]	17.45	[0.133]	18.02	[0.115]
F (4, 431)	0.73			-		-

Notes:

- n is the number of observations; s is the standard error of estimate; R^2 is the proportion of variation in dependent variable explained by the model; DW is the value of Durbin–Watson statistic; Q (k) is the Ljung–Box statistic for residual autocorrelation up to order k; χ^2_{ARCH} (k) is the Engle (1982) test for ARCH up to order k; and F is the Chow test for structural break.
- the numbers in brackets below the coefficients are t–statistics; and the numbers in square brackets are p–values.

Table 3.6 ARIMA (1, 1, 0) Models for Pc_t and Pd_t: Annual Data (1959 – 1996)

Dependent variables:	ΔPc_t		ΔPd_t	
Constant	0.14 (2.97)		0.14 (3.17)	
$\hat{\phi}_1$	0.77 (6.87)		0.67 (5.31)	
n	36		36	
R^2	0.581		0.453	
s	0.065		0.090	
DW	1.79		2.23	
Q(2)	2.72	[0.257]	0.68	[0.711]
$\chi^2_{ARCH}(1)$	4.94	[0.026]	7.88	[0.005]
F (2, 32)	4.43	[0.020]	5.97	[0.006]

Notes:

- ΔPc_t is the first difference of the log of the CPI; ΔPd_t is the first difference of the log the GDP deflator; and Δ is the difference operator.
- n is the number of observations; s is the standard error of estimate; R^2 is the proportion of variation in dependent variable explained by the model; DW is the value of Durbin–Watson statistic; Q (k) is the Ljung–Box statistic for residual autocorrelation up to order k; χ^2_{ARCH} (k) is the Engle (1982) test for ARCH up to order k; and F is the Chow test for structural break.
- The numbers in brackets below the coefficients are t–statistics; and the numbers in square brackets are p–values.

Figure 3.1 The Plot of Pc_t: Monthly Data (1959.4 – 1996.11)

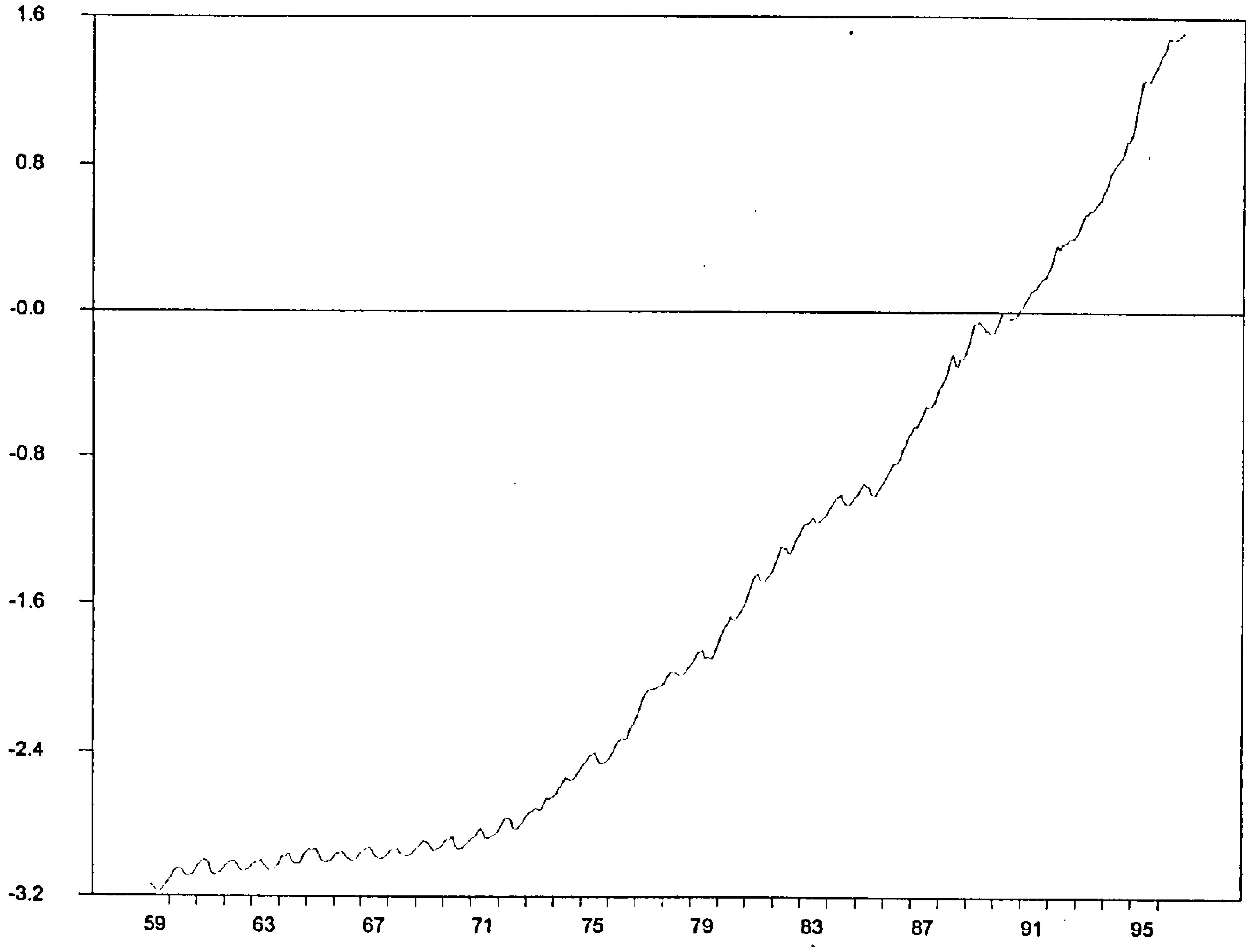


Figure 3.2 The Plot of $\Delta_{12}Pc_t$: Monthly Data (1960.4–1996.11)

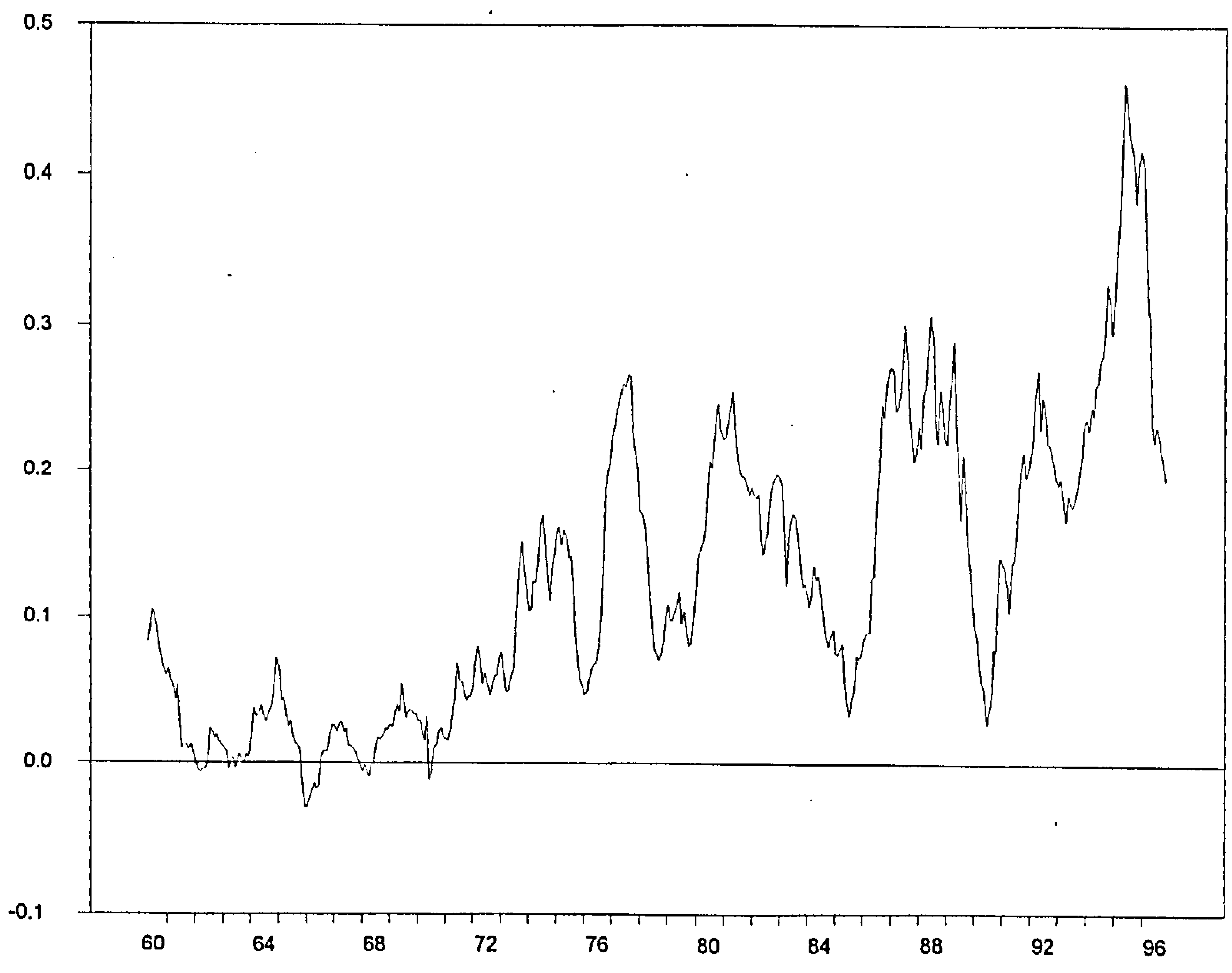


Figure 3.3 The Plot of Pc and Pd: Annual Data (1959 – 1996)

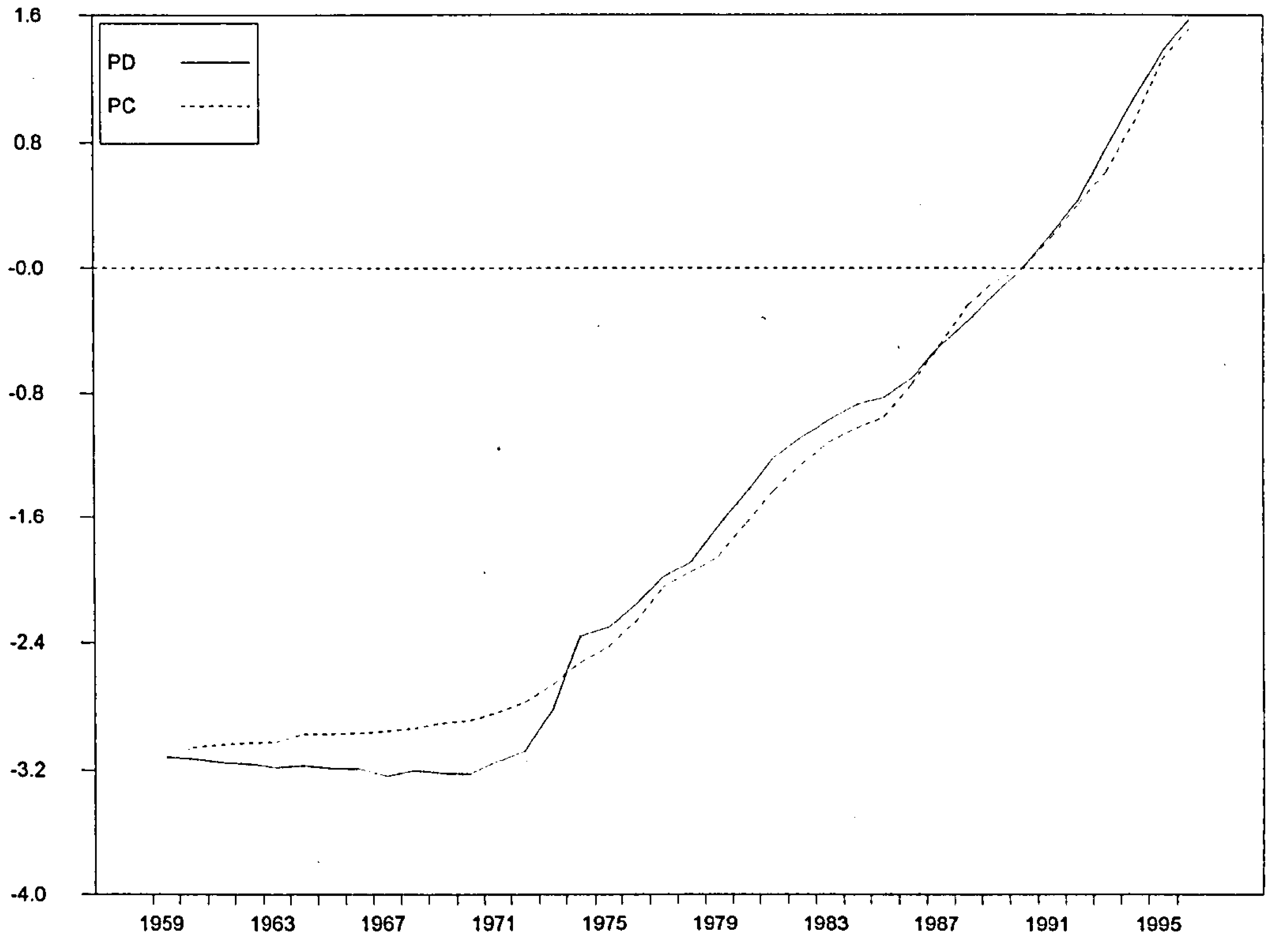


Figure 3.4 The Plot of ΔPc_t and ΔPd_t: Annual Data (1960 – 1996)

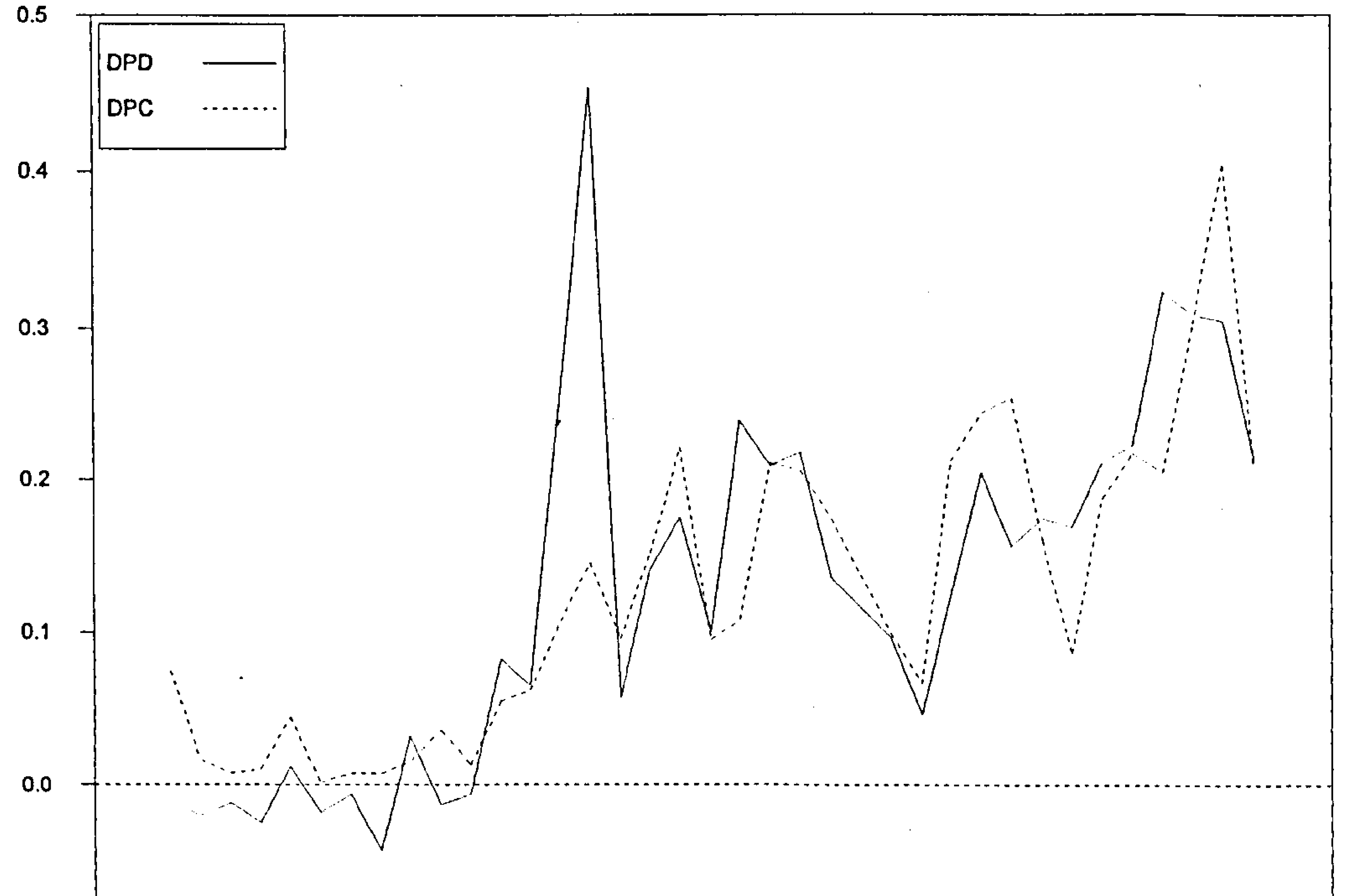


Figure 3.5 Correlogram for Pc_t: Monthly Data (1959.4 –1996.11)

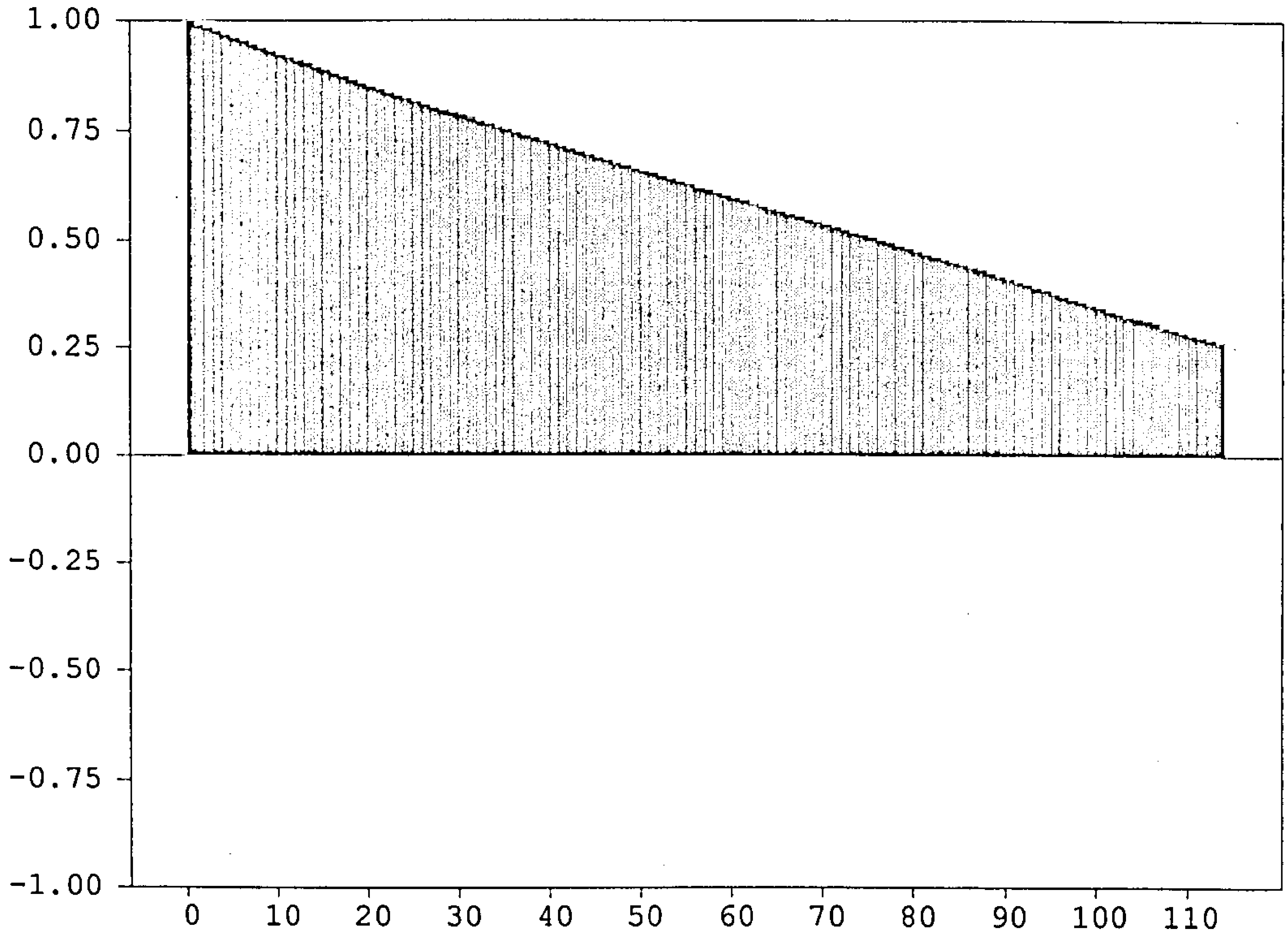


Figure 3.6 Partial Correlogram for Pc_t: Monthly Data (1959.4 –1996.11)

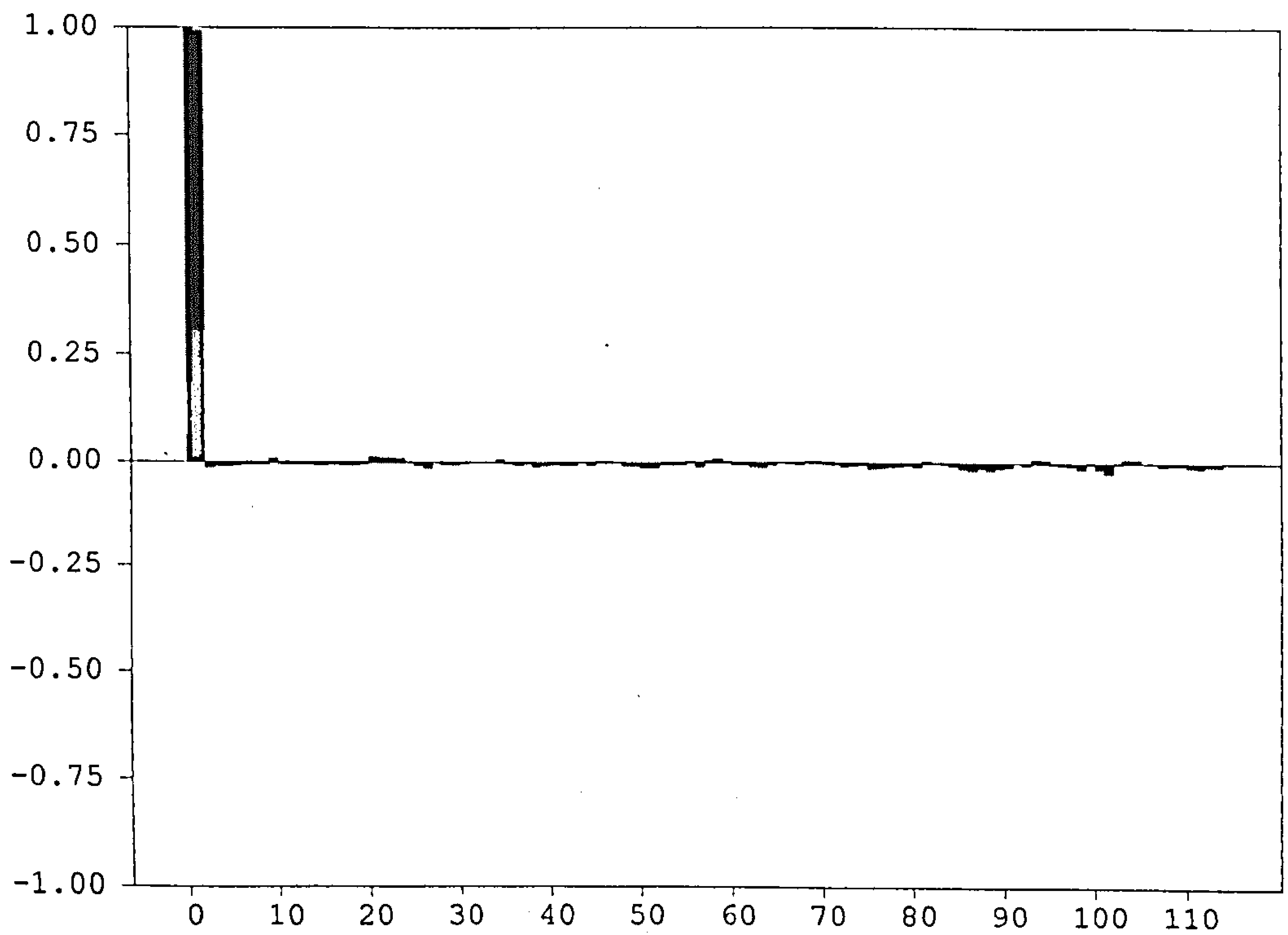


Figure 3.7 Correlogram for ΔPc_t: Monthly Data (1959.5 –1996.11)

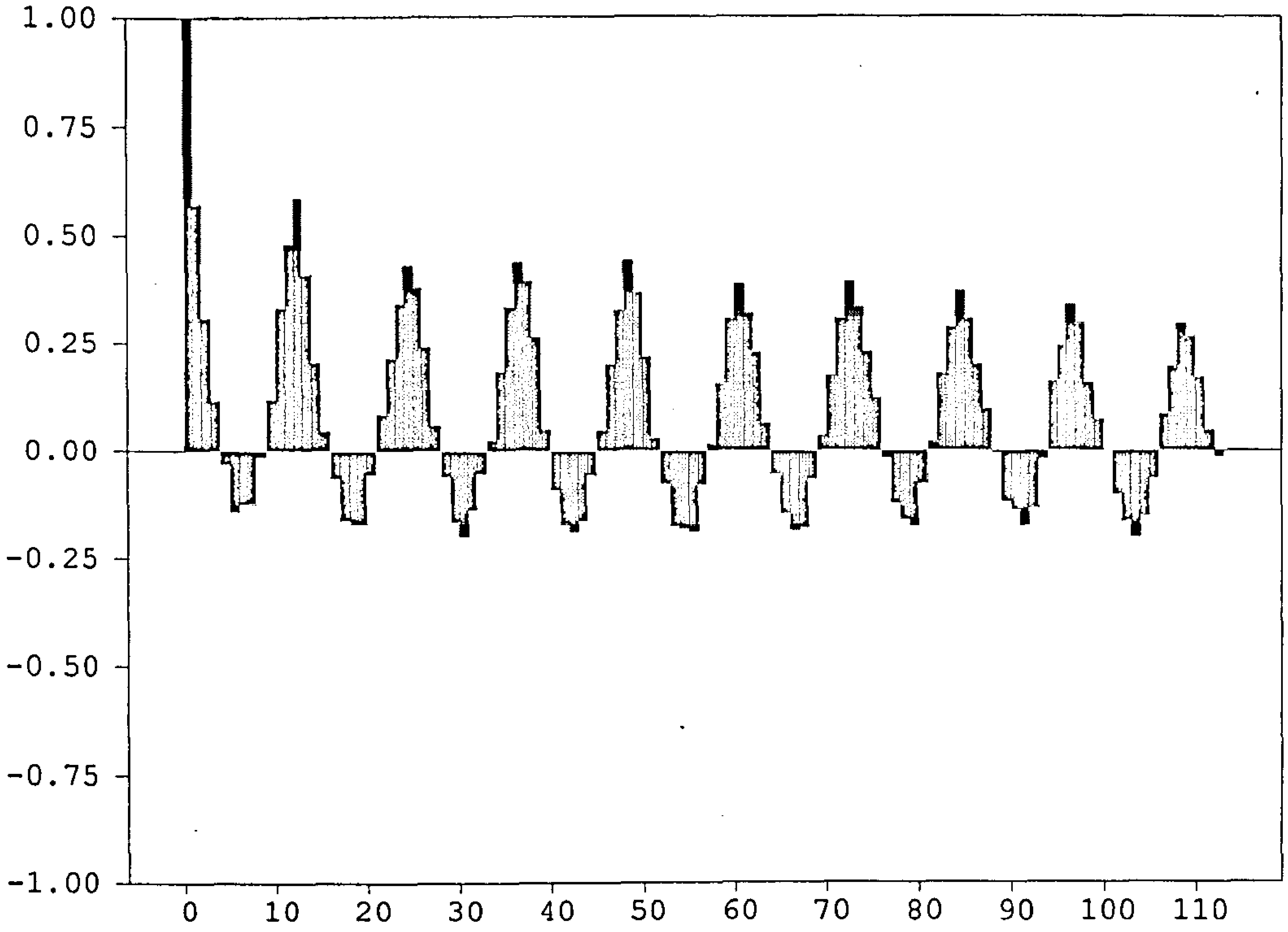


Figure 3.8 Partial Correlogram for ΔPc_t: Monthly Data (1959.5 –1996.11)

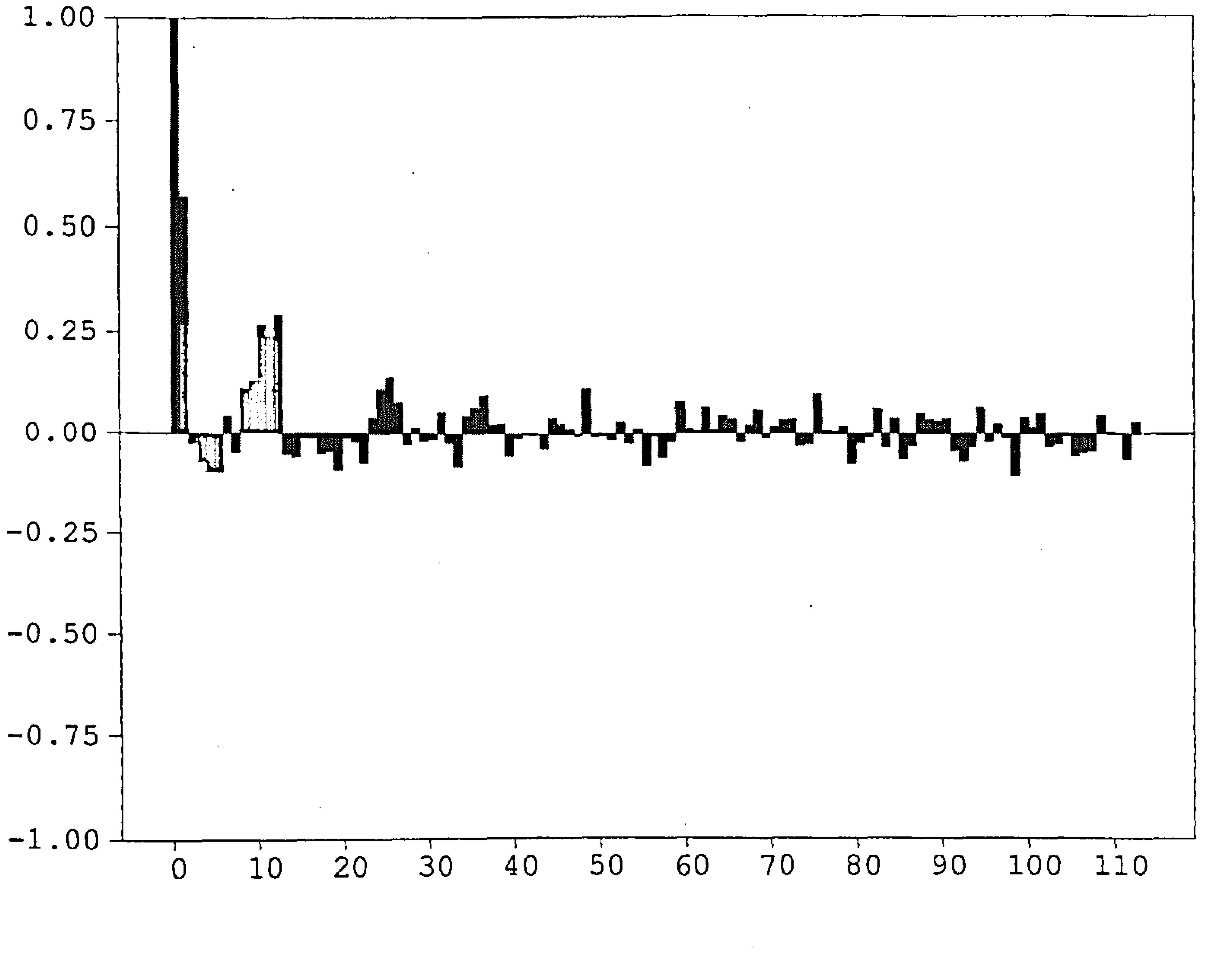


Figure 3.9 Correlogram for $\Delta_{12}Pc_t$: Monthly Data (1960.4 –1996.11)

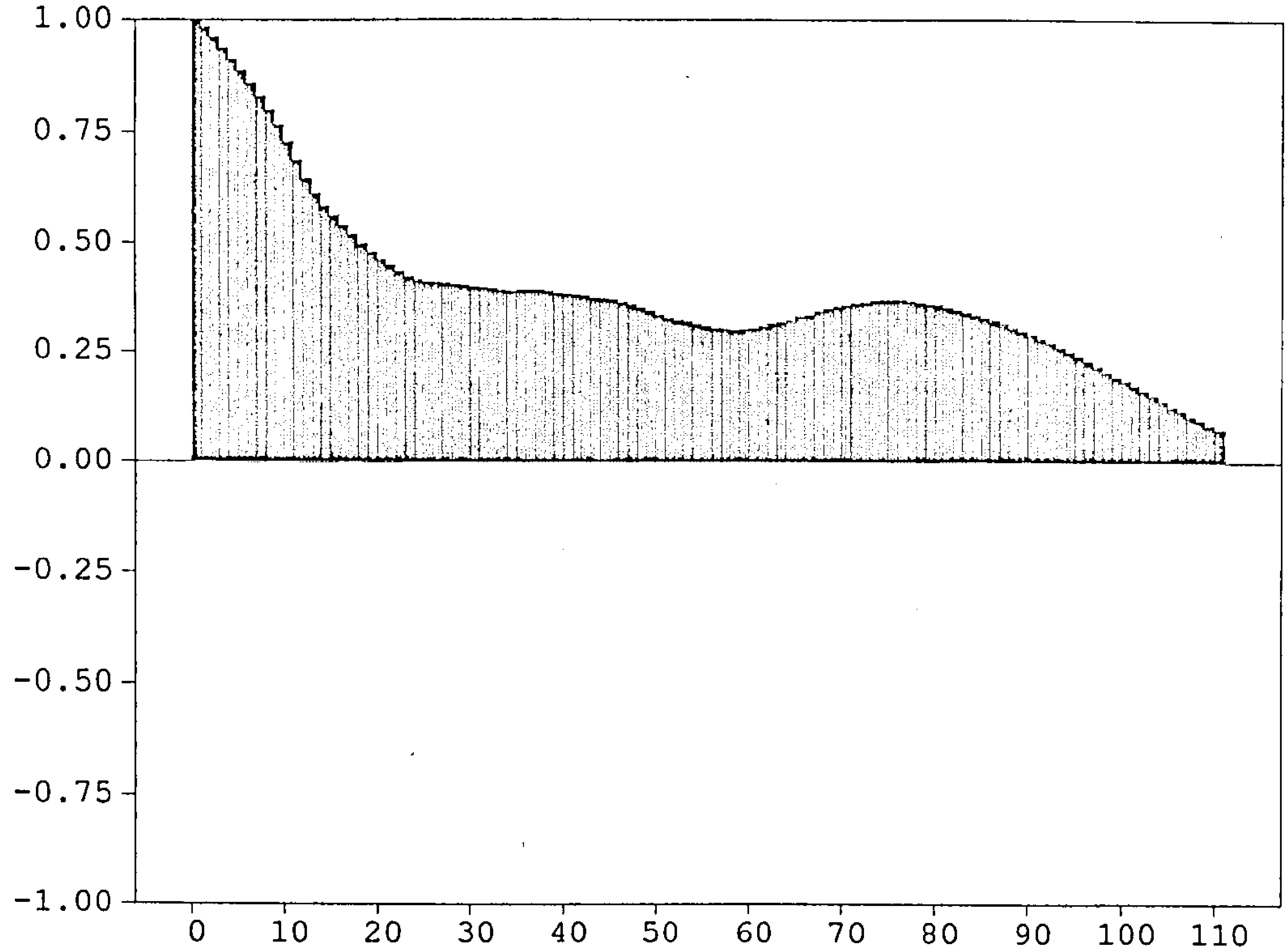


Figure 3.10 Partial Correlogram for $\Delta_{12}Pc_t$: Monthly Data (1960.4 –1996.11)

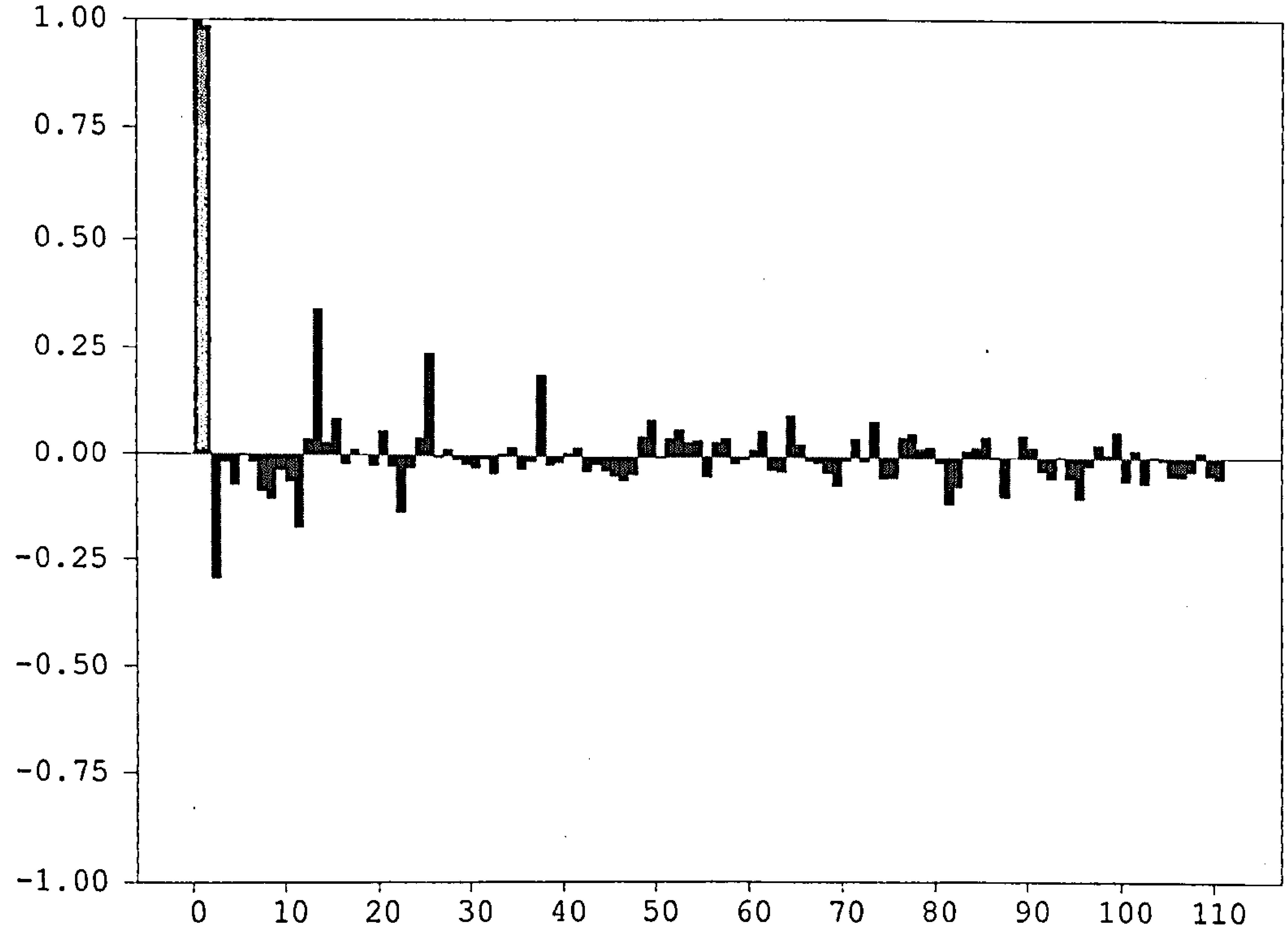


Figure 3.11 Correlogram for $\Delta\Delta_{12}Pc_t$: Monthly Data (1960.5 –1996.11)

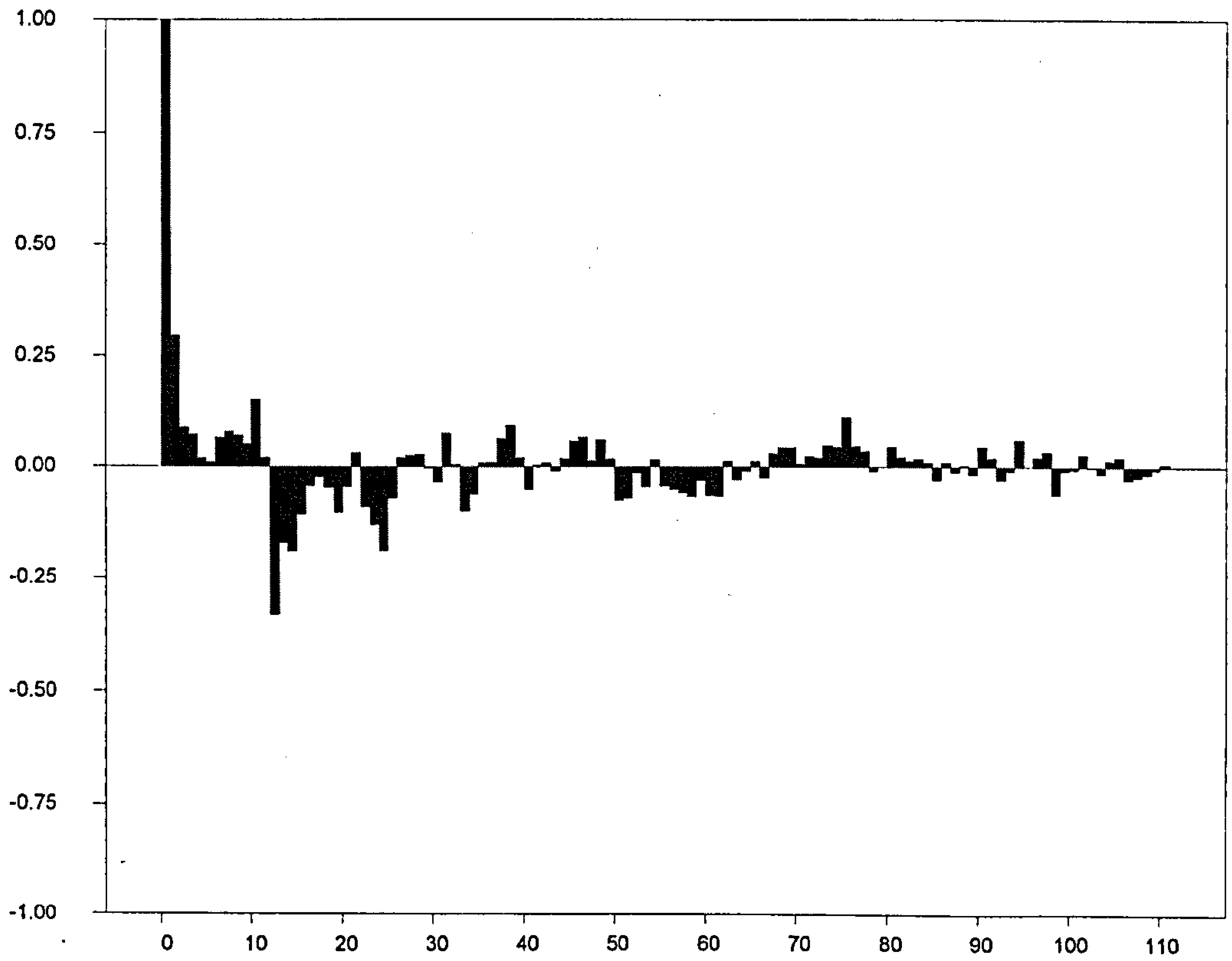


Figure 3.12 Partial Correlogram for $\Delta\Delta_{12}Pc_t$: Monthly Data (1960.5 –1996.11)

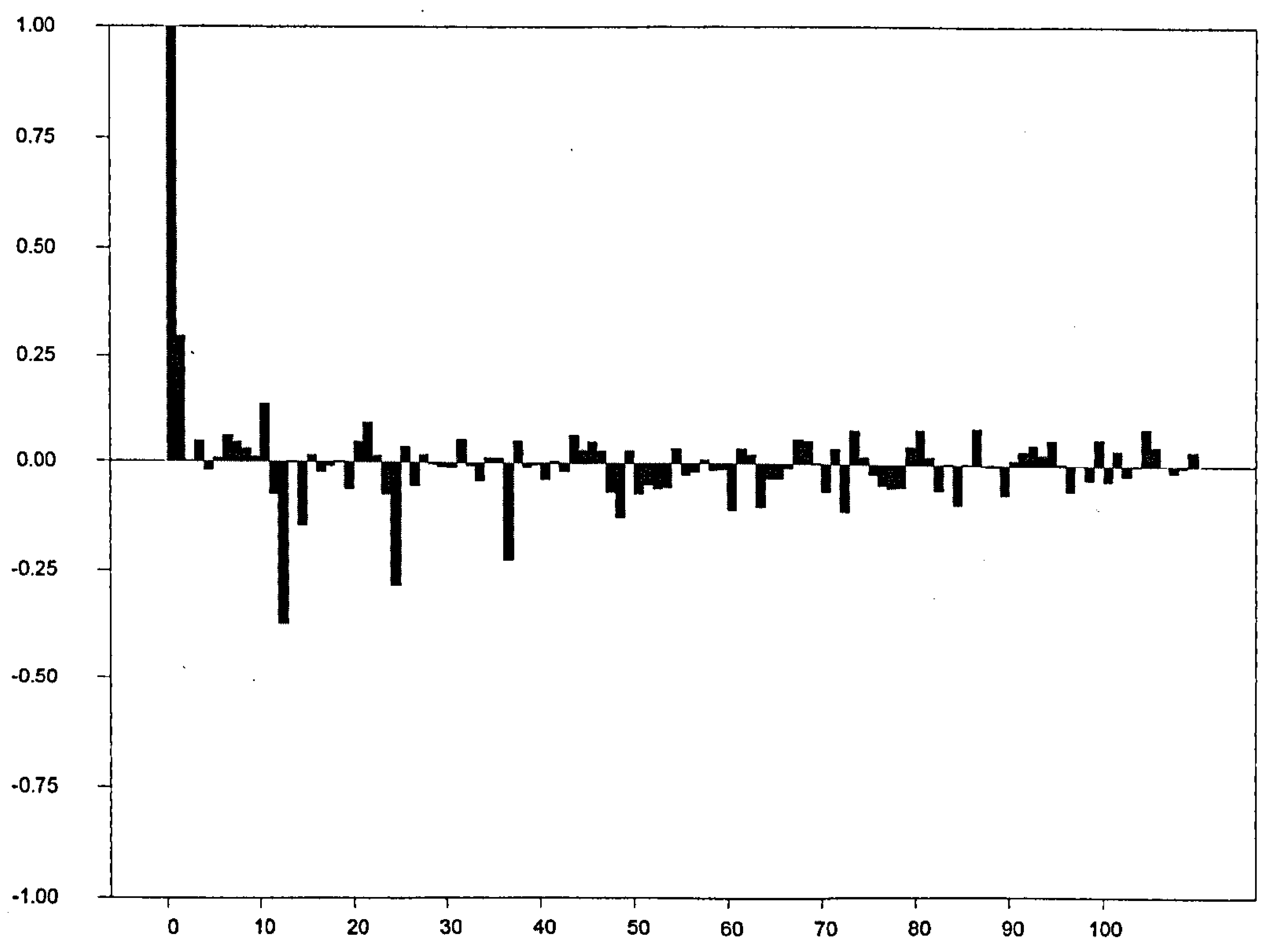


Figure 3.13 Correlogram for Pc_t: Annual Data (1959 –1996)

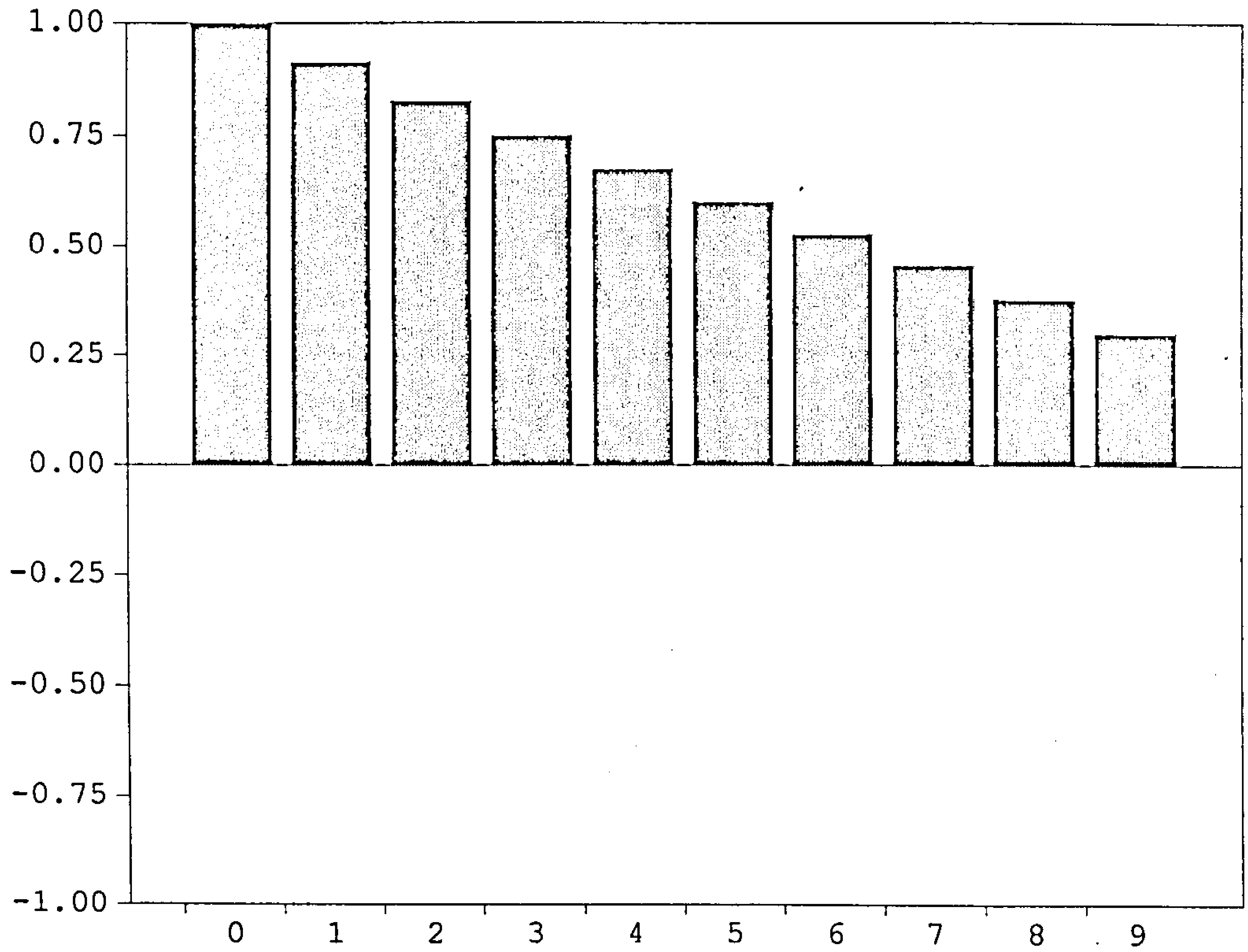


Figure 3.14 Partial Correlogram for Pc_t: Annual Data (1959 –1996)

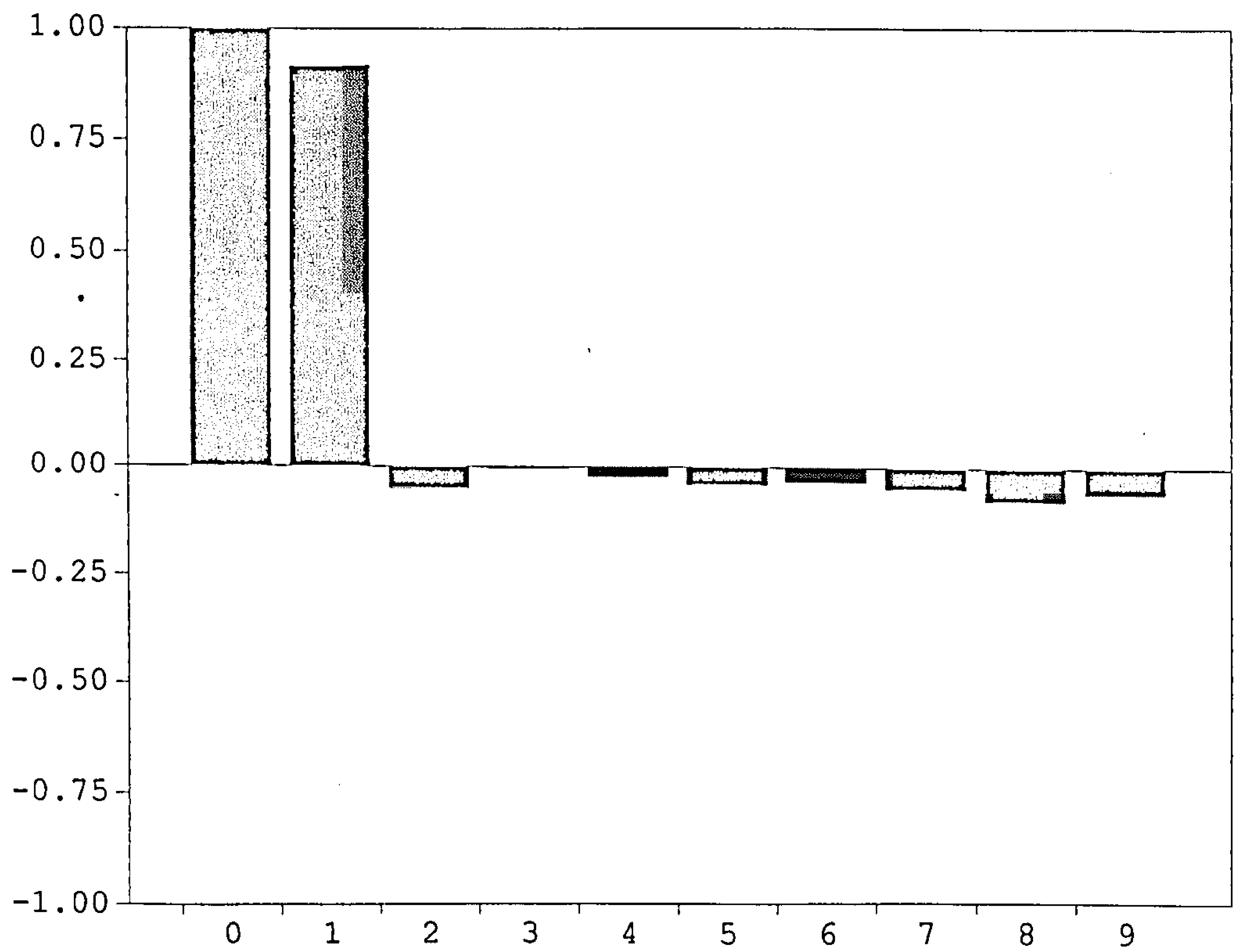


Figure 3.15 Correlogram for ΔPc_t: Annual Data (1960 –1996)

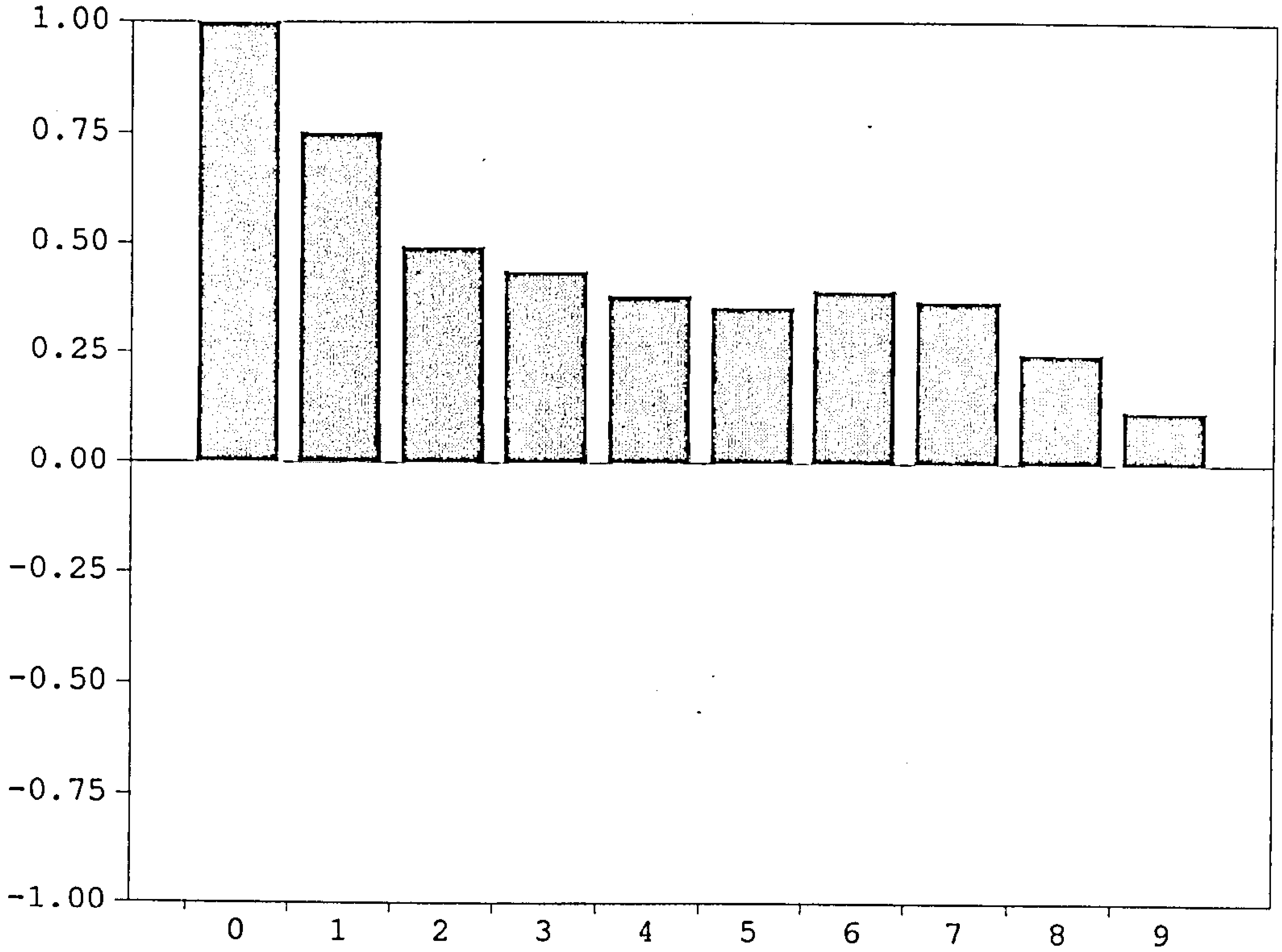


Figure 3.16 Partial Correlogram for ΔPc_t: Annual Data (1960 –1996)

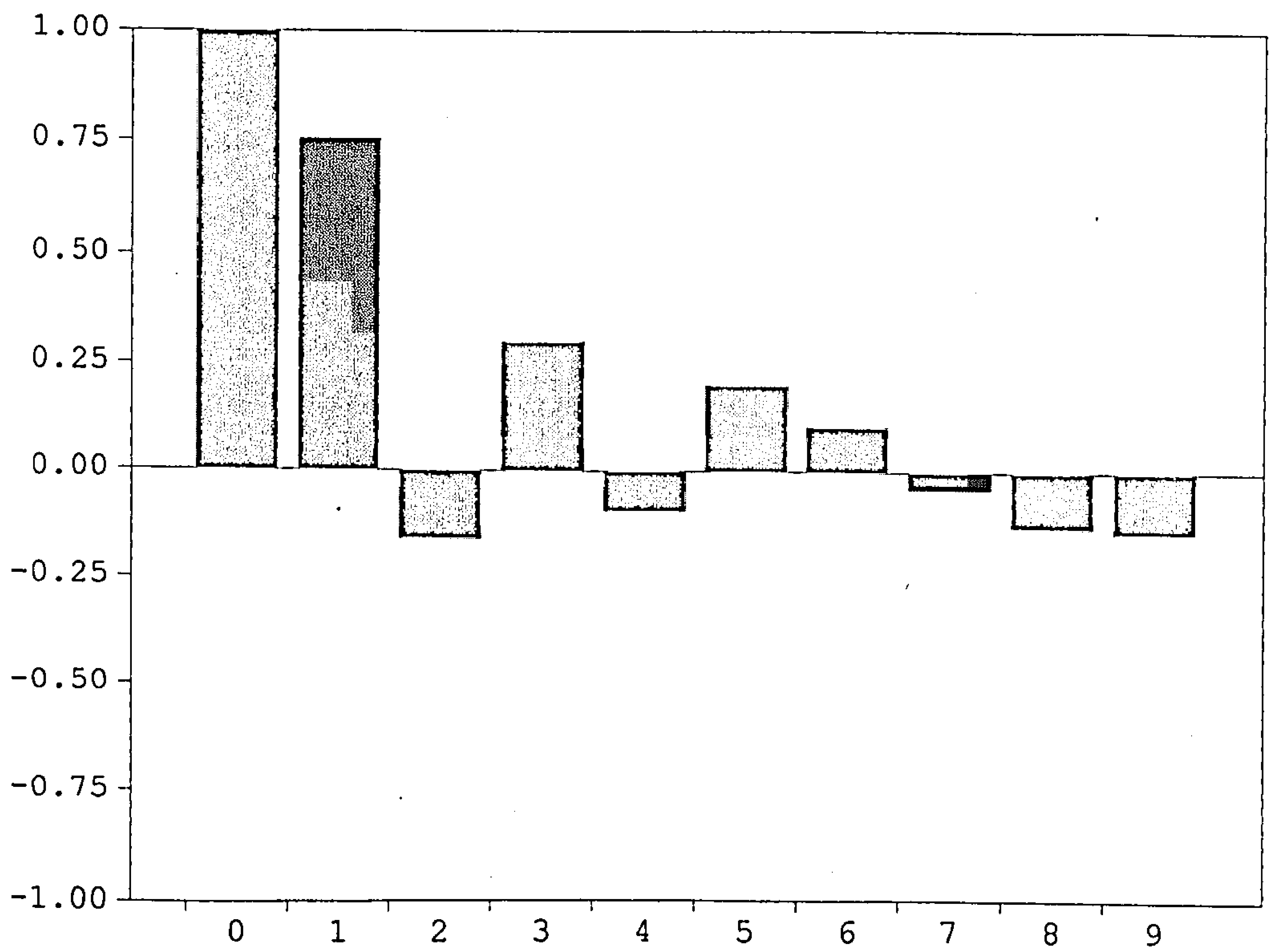


Figure 3.17 Correlogram for Pd_t: Annual Data (1959 –1996)

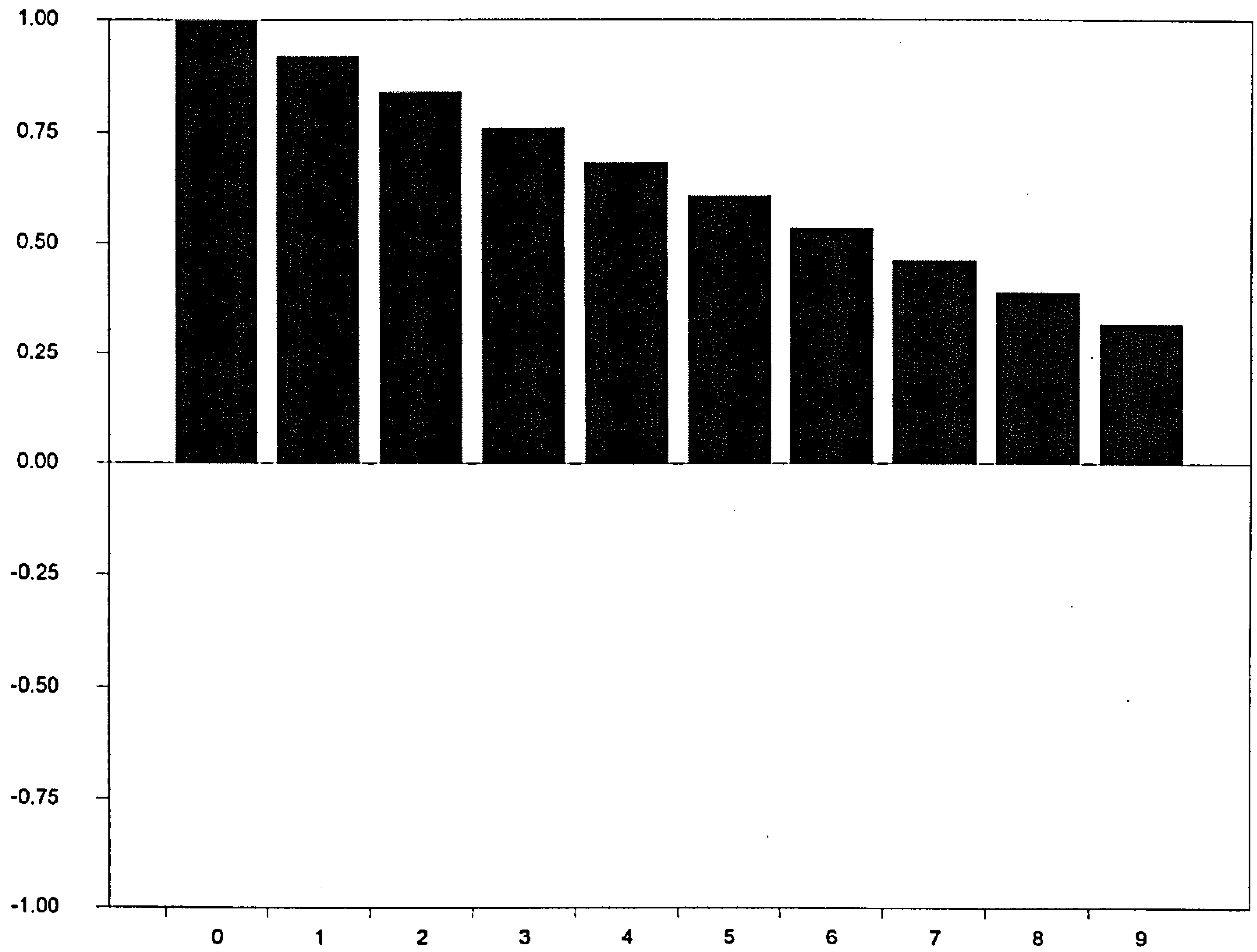


Figure 3.18 Partial Correlogram for Pd_t: Annual Data (1959 –1996)

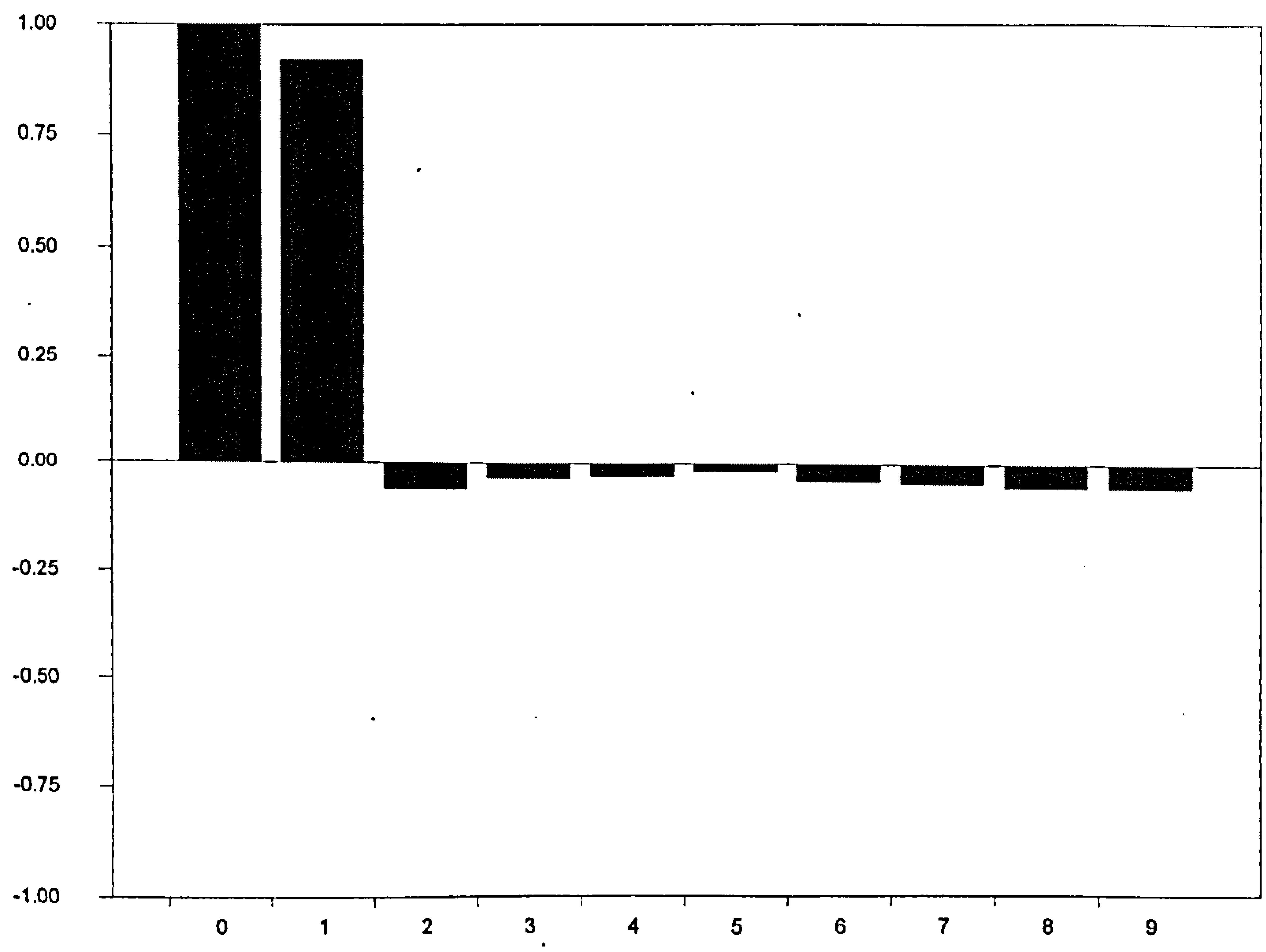


Figure 3.19 Correlogram for ΔPd_t: Annual Data (1960 –1996)

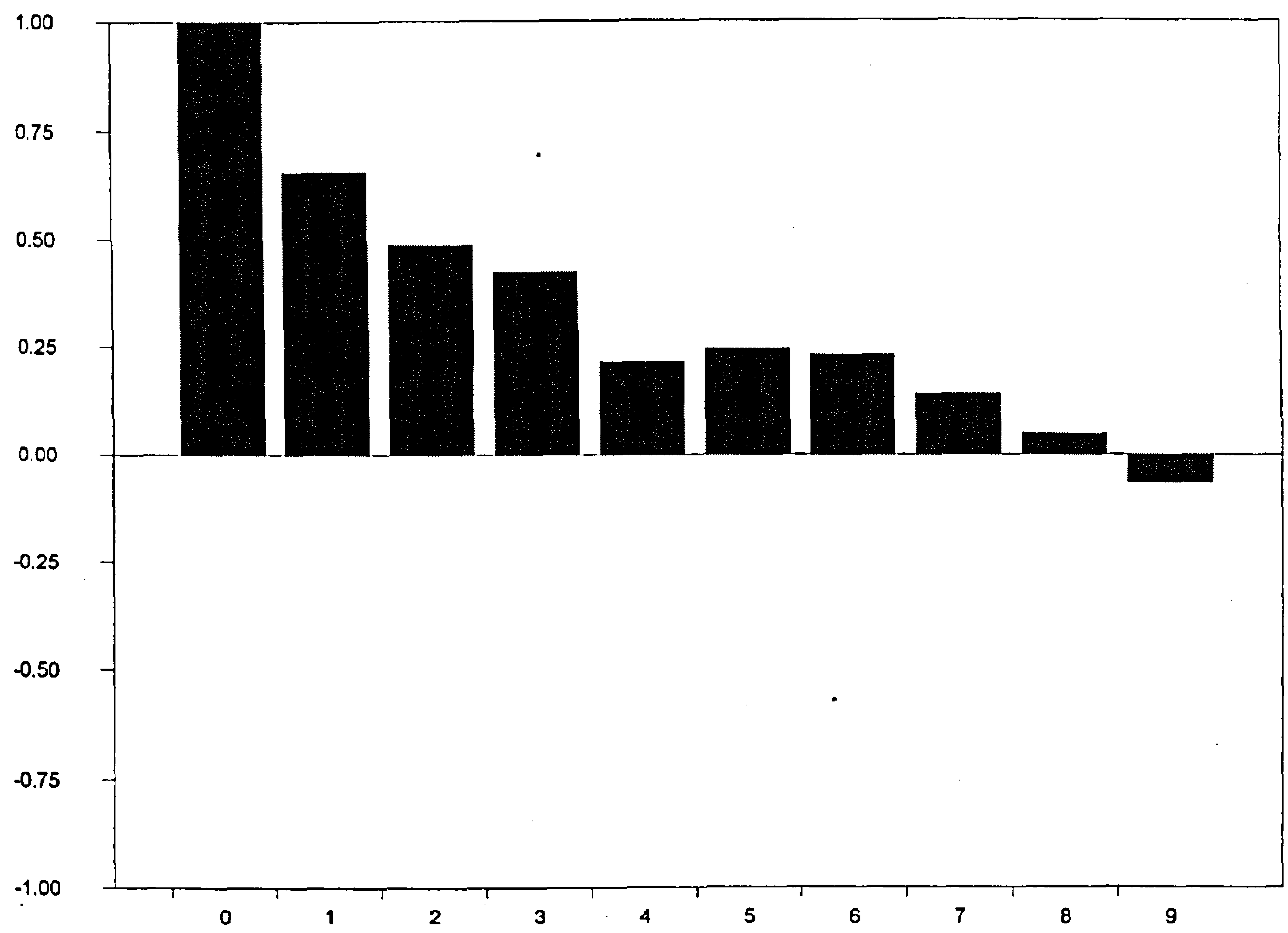
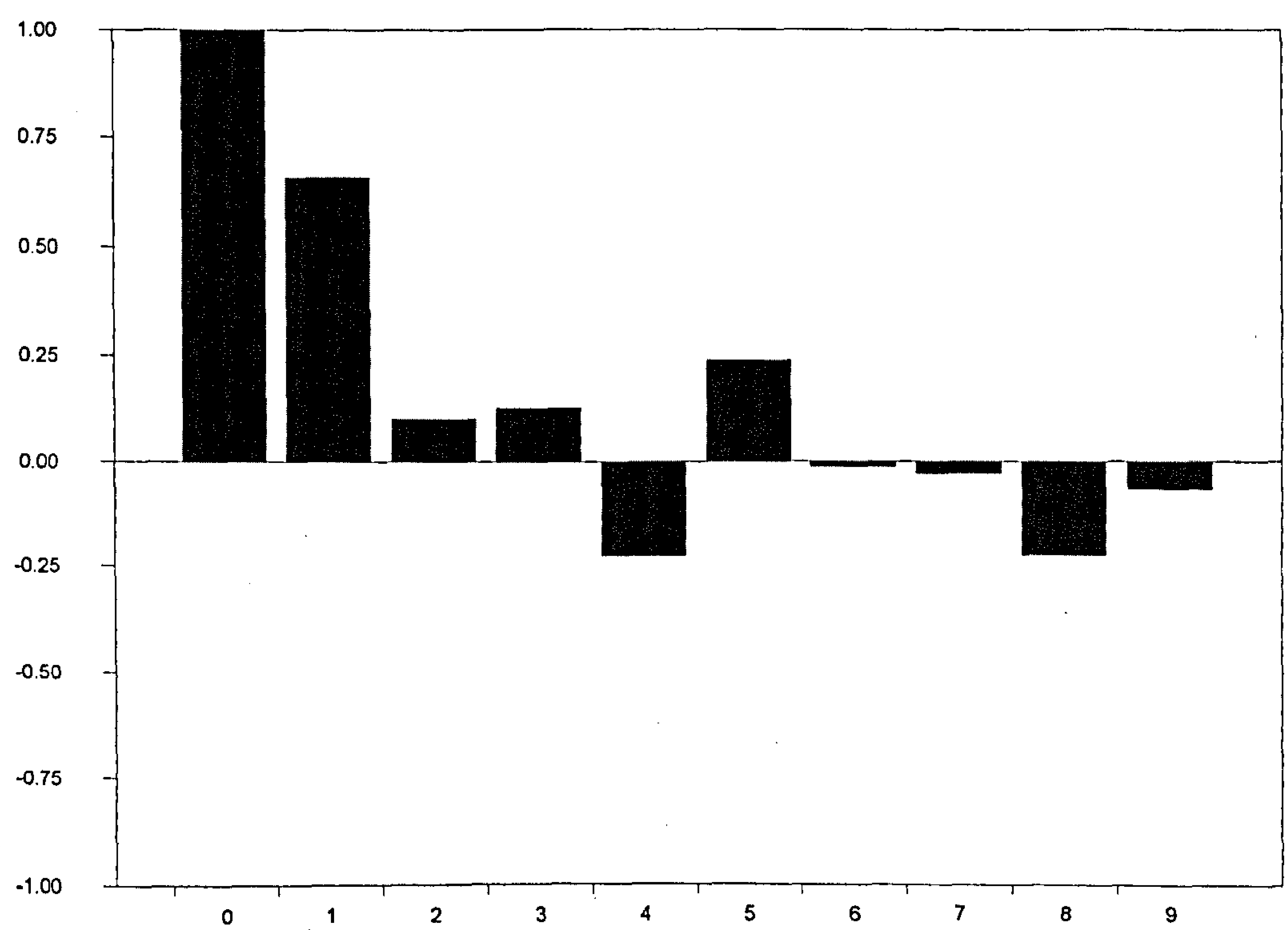


Figure 3.20 Partial Correlogram for ΔPd_t: Annual Data (1960 –1996)



4 NONLINEAR TIME SERIES PROPERTIES OF INFLATION

4.1 Introduction

The aim of this chapter is to explore some nonlinear properties of the Iranian inflation measures using univariate models. The chapter attempts to answer two questions in this context as follows: is higher inflation variance associated with higher inflation rates? and, are there nonlinear structures in the inflation measures?

The chapter uses nonlinear univariate techniques to answer the above questions. Following the studies of Friedman (1977), Engle (1982), Bollerslev (1986), Ball (1992), and Caporale and McKiernan (1997), autoregressive conditional heteroscedasticity (ARCH) and generalised ARCH (GARCH) models are considered to investigate the relationship between inflation measures and their variability or uncertainty. Moreover, the nonlinear structure of inflation is examined using the procedures of Terasvirta and Anderson (1992), and Granger and Terasvirta (1993). Since there is some evidence of nonlinear behaviour in the inflation measures, appropriate smooth transition autoregressive (STAR) models are specified and estimated using monthly and annual data.

The structure of this chapter is as follows: In the next section, the ARCH process and its extensions are described, and the relationship between inflation and its variability is investigated. Section three investigates the nonlinear behaviour in the inflation measures by testing linearity and estimating appropriate nonlinear models. Finally, section four summarises the results.

4.2 Inflation and Uncertainty: ARCH Models and Their Extensions

There are opposite views and contradictory evidence about the relationship between the inflation rate and the variance of inflation. Friedman (1977) argues that higher inflation variance is associated with higher inflation rates. Engle (1982) applies an autoregressive conditional heteroscedastic (ARCH) model, and fails to confirm a positive relationship between the conditional mean and variance of inflation for the United States. Bollerslev (1986) extends the ARCH (q) model, and suggests that the conditional variance can follow an ARMA process. The generalised ARCH model, called GARCH (p, q), contains both autoregressive and moving average components. Caporale and McKiernan (1997) employ a GARCH model and find a positive and significant relationship between the level and variability of inflation for the annualised US inflation rate.

In this section, ARCH models and their extensions (GARCH models) are applied to analyse the relationship between inflation and its variability. The functional form of an ARCH (q) process is formally given by

$$\varepsilon_t | \Psi_{t-1} \sim N(0, h_t^2) \tag{4.1}$$

$$h_t^2 = \alpha_0 + \sum_{j=1}^{q} \alpha_j \varepsilon_{t-j}^2 \qquad (4.2)$$

where ε_t is the innovation in the ARMA model for a stationary series y_t; and h_t^2 is the conditional variance of ε_t with respect to the information set, Ψ_{t-1}. Since h_t^2 is strictly positive for all realisations of ε_t, $\alpha_0 > 0$ and $\alpha_j \geq 0$ for j = 1, 2, ..., q. Bollerslev (1986) extends ARCH (q) process to GARCH (p, q) process, defined as:

$$h_t^2 = \alpha_0 + \sum_{j=1}^{q} \alpha_j \varepsilon_{t-j}^2 + \sum_{j=1}^{p} \delta_j h_{t-j}^2 \qquad (4.3)$$

Where $p \geq 0$; $q > 0$; and $\delta_j \geq 0$, for j = 1, 2, ..., p

To test for the presence of ARCH effects, the best AR (p) model for y_t is first estimated, and then the squares of the residuals, e_t^2, are obtained. In the next stage, the following equation is estimated:

$$e_t^2 = \alpha_0 + \sum_{j=1}^{q} \alpha_j e_{t-j}^2 + u_t \qquad (4.4)$$

Under the assumption of normality, the test statistic

$$\xi_{LM} = T.R^2 \qquad (4.5)$$

where T is the sample size; and R^2 is the coefficient of determination obtained from (4.4), is asymptotically distributed as χ_q^2.

In the empirical analysis, the GARCH model is extended by including the lagged level of the inflation rate, y_{t-1}, as follows:

$$h_t^2 = \alpha_0 + \sum_{j=1}^{q} \alpha_j \varepsilon_{t-j}^2 + \sum_{j=1}^{p} \delta_j h_{t-j}^2 + \gamma y_{t-1} \qquad (4.6)$$

In this model, y_{t-1} is assumed to influence the conditional error variance in addition to the past squared errors. This enables us to test whether the inflation rate affects its variability.

Empirical Analysis

To identify the presence of ARCH effects in the inflation measures, the best fitting AR models of inflation are estimated for both monthly and annual data. The differenced annualised inflation rate ($\Delta\Delta_{12}Pc_t = y_t$) is first considered. Table 4.1 shows the estimated AR (49) model for the whole period and the second sub–period, and AR (12) for the first sub–period. The Engle test confirms that there are ARCH effects in the whole sample, 1959.4 – 1996.11, with weaker evidence of ARCH in the second sub–period, 1972.8 – 1996.11. However, for the first sub–period, the test confirms that there is no ARCH.

In the next step, the aim is to determine appropriate values of p and q and estimate the resulting GARCH models. For both the whole period and the second sub–period, the GARCH (1, 1) model is preferred among several alternatives considered. The estimates are shown in Table 4.2. Comparing with the estimates in Table 4.1, it can be seen that the presence of ARCH does not affect the OLS estimates of the linear AR model. The estimates of the GARCH parameters satisfy the stationarity condition $\alpha_1 + \delta_1 \prec 1$. The estimate of γ is positive and significant, suggesting that there is a positive relationship between the differenced annualised inflation rate and its variability in both periods. This evidence supports the Friedman hypothesis that high inflation leads to more variable inflation. To account for the effect of a structural break in 1972:8, a dummy variable is included in the models, which takes a value of 1 from 1972.8 and 0 otherwise. The coefficient of this dummy variable was not significant and was excluded. This is consistent with the result of the previous chapter where the presence of a structural break was rejected on the basis of the ARIMA models for the monthly data.

For the annual data, the Engle test rejects the null of no ARCH effects for both inflation measures (see Table 3.6 in the previous chapter). An ARCH (1) process is specified and estimated for both measures in the following form:

$$h_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \gamma y_{t-1} \tag{4.7}$$

with the results reported in Table 4.3. The AR model includes a dummy variable for the first oil shock, which takes a value of 1 from 1973 and 0 otherwise. The coefficient $\hat{d}$ of the dummy variable is significant in both models and substantially improves the fit of the models. When a second dummy is included to allow the autoregressive parameter β_1 to shift after 1973, its coefficient is not significant.

As can be seen, there is a positive relationship between the rate of inflation and its variance in both models, again supporting the Friedman hypothesis, although the coefficient $\hat{\gamma}$ in the case of the GDP deflator is not statistically significant.

4.3 Smooth Transition Autoregressive Models

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 Peteuccelli (1990) for details]. The basic STAR model of order p is

$$y_t = \beta_0 + \sum_{j=1}^{p} \beta_j y_{t-j} + (\beta_0^* + \sum_{j=1}^{p} \beta_j^* y_{t-1}) F(y_{t-d}) + u_t \tag{4.8}$$

where $\{y_t\}$ is assumed stationary; $u_t \sim$ i.i.d. $(0, \sigma^2)$; and F is a transition function which by convention is bounded by zero and one. The form of the logistic function is

$$F(y_{t-d}) = (1 + \exp\{-\gamma(y_{t-d} - c)\})^{-1}, \ \gamma > 0 \tag{4.9}$$

and the form of the exponential function is

$$F(y_{t-d}) = (1 - \exp\{-\gamma(y_{t-d} - c)^2\}) \ , \ \gamma > 0 \tag{4.10}$$

Model (4.8) with (4.9) is called the LSTAR model, while (4.8) with (4.10) is called the ESTAR model.

When $\gamma \to \infty$ in equation (4.9), then $F(y_{t-d}) = 0$ if $y_{t-d} \leq$ c, while $F(y_{t-d})$ = 1 if y_{t-d}> c, consequently, equation (4.8) becomes a threshold AR (p) model:

$$y_t = \begin{cases} \beta_0 + \sum_{j=1}^{p} \beta_j y_{t-j} + u_t & y_{t-d} \leq c \\ \beta_0 + \sum_{j=1}^{p} \beta_j y_{t-j} + (\beta_0^* + \sum_{j=1}^{p} \beta_j^* y_{t-1}) + u_t & y_{t-d} \succ c \end{cases} \tag{4.11}$$

When $\gamma \to 0$ or $\beta_j^* = 0$ (j = 0, 1, ..., p), then model (4.8) becomes a linear AR (p) model:

$$y_t = \beta_0 + \sum_{j=1}^{p} \beta_j y_{t-j} + u_t \tag{4.12}$$

Testing Linearities

Terasvirta and Anderson consider three stages to specify a STAR model as follows:

- specification of a linear AR model.
- testing linearity for different values of the delay parameter d, and if it is rejected, determining d.
- choosing between LSTAR and ESTAR models using a sequence of tests of nested hypotheses.

The first stage forms the basis of the linearity testing. Since the order p is usually unknown, it has to be determined from the data. The order of AR model is specified based on the partial autocorrelation function [see, for example, Michael, Nobay, and Peel (1997)].

The second stage is to test linearity. 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: $\beta_{2j} = \beta_{3j} = \beta_{4j} = 0$, $(j = 1, ..., p)$

in the artificial regression

$$y_t = \beta_0 + \sum_{j=1}^{p} \beta_{1j} y_{t-j} + \sum_{j=1}^{p} \beta_{2j} y_{t-j} y_{t-d} + \sum_{j=1}^{p} \beta_{3j} y_{t-j} y_{t-d}^2 + \sum_{j=1}^{p} \beta_{4j} y_{t-j} y_{t-d}^3 + \upsilon_t \tag{4.13}$$

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:

$$H_{04}: \beta_{4j} = 0, \quad (j = 1, ..., p) \tag{4.14}$$

$$H_{03}: \beta_{3j} = 0 \mid \beta_{4j} = 0, \quad (j = 1, ..., p) \tag{4.15}$$

$$H_{02}: \beta_{2j} = 0 \mid \beta_{3j} = \beta_{4j} = 0, \quad (j = 1, ..., p) \tag{4.16}$$

If the model is an ESTAR model, then $\beta_{4j} = 0$, j =1, ..., 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 (4.14) is rejected we choose the LSTAR model. If (4.14) is accepted and (4.15) is rejected, the ESTAR model is selected. Moreover, if (4.14) and (4.15) are accepted and (4.16) is rejected, then the LSTAR model is chosen.

Empirical Analysis

a) Monthly Data

Linearity tests are first applied to the differenced annualised inflation rate ($\Delta\Delta_{12}Pc_t = y_t$). AR models are specified and estimated for the pre– and post–breakpoint periods as well as the whole period. As discussed in the previous chapter, the breakpoint accounts for the first oil boom. The appropriate AR models were reported in Table

4.1, and a maximum delay of six periods (D = 6) is considered. Table 4.4 shows that the null of linearity is rejected for the second period as well as the full sample period, but not for the first period. This suggests that the source of nonlinearities is the second period. The minimum P–values when linearity is rejected are where the delay parameter is equal to three $(\hat{d} = 3)$.

In the next step, the null hypotheses (4.14) through (4.16) are tested in order to choose between ESTAR and LSTAR. From Table 4.5 he null that $\beta_{4j} = 0$ is rejected so that the LSTAR model is selected for both the second period and full sample period.

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

$$F(y_{t-d}) = (1 + \exp\{-\gamma(y_{t-d} - c)/\hat{\sigma}_{(y)}\})^{-1}, \qquad \gamma > 0 \qquad (4.17)$$

where $\hat{\sigma}_{(y)}$ is the sample standard deviation of y_t. A reasonable starting value for iterative nonlinear least squares estimation then is $\gamma = 1$.

The same model is deliberately considered for the whole sample and the second sub–sample. In both cases the same set of restrictions was acceptable by the data. In the linear part of the model, the coefficient of lag 49 is zero, and in the nonlinear part, the constant and the coefficients at lags 1, 12, 24, 25, 37, 48, and 49 are all zero, so the following restricted models are estimated by nonlinear least–squares:

whole sample

$$y_t = 0.001 + 0.29y_{t-1} - 0.63y_{t-12} + 0.17y_{t-13} - 0.55y_{t-24} + 0.15y_{t-25} - 0.24y_{t-36} + 0.10y_{t-37}$$

(1.79) (6.24) (–12.74) (2.59) (–9.54) (2.59) (–3.94) (1.83)

$$- 0.13y_{t-48} + (- 0.27y_{t-13} - 0.69y_{t-36}) (1 + \exp\{- 41.20 (y_{t-3} - 0.022)\})^{-1}$$

(–2.62) (–1.94) (–5.30) (0.43) (20.18)

$s = 0.0130$ $\gamma^* = 0.70$ $s^2_{NL} / s^2_L = 0.96$

second sub–period

$$y_t = 0.007 + 0.27y_{t-1} - 0.62y_{t-12} + 0.18y_{t-13} - 0.58y_{t-24} + 0.18y_{t-25} - 0.27y_{t-36} + 0.11y_{t-37}$$

(0.78) (4.45) (–9.66) (2.39) (–7.3) (2.45) (–3.26) (1.59)

$$- 0.15y_{t-48} + (- 0.30y_{t-13} - 0.72y_{t-36}) (1 + \exp\{- 28.59 (y_{t-3} - 0.021)\})^{-1}$$

(–2.33) (–1.62) (–4.45) (0.68) (17.79)

$s = 0.0150$ $\gamma^* = 0.56$ $s^2_{NL} / s^2_L = 0.95$

where the numbers in brackets are t–statistics; s is the standard error of estimate; γ^* is the standardised value of γ ($\gamma^* = \hat{\gamma} \times s_{(y)}$); and finally s^2_{NL} / s^2_L is the ratio of the residual variances from the nonlinear and linear models. The value of this ratio shows that, in both cases, the nonlinear models produce a slightly smaller standard error compared to the corresponding linear models. The values of γ^* show that the speed of transition between regimes is slightly higher in the whole period than the second sub–period. However, the two models are essentially the same and, overall, provide little improvement over the linear models.

b) Annual Data

Linearity is tested for the two inflation measures (ΔPc_t and ΔPd_t) using annual data over the whole sample period. The best fitting AR (1) models were reported in Table 3.6 in the previous chapter. The linearity tests are reported in Table 4.6 where a maximum delay of three periods is considered. It can be seen that linearity is strongly rejected for the GDP deflator, while the result is marginal for the CPI. The minimum P–values for both inflation measures are where the delay parameter is equal to one.

From the model selection tests in Table 4.7 it can be seen that the strongest rejection is for H_{02} in the case of ΔPd_t and H_{04} in the case of ΔPc_t. Hence, for both measures of inflation a LSTAR model is suggested. After eliminating insignificant coefficients, the following models are obtained:

CPI inflation

$$\Delta Pc_t = \underset{(3.31)}{0.53}\, \Delta Pc_{t-1} + \underset{(2.68)}{0.08}\, (1 + \exp\{-\underset{(0.15)}{73.40}\, (\Delta Pc_{t-1} - \underset{(5.66)}{0.055})\})^{-1}$$

$$s = 0.0623 \qquad \gamma^* = 7.19 \qquad s^2_{NL} / s^2_L = 0.93$$

GDP deflator inflation

$$\Delta Pd_t = \underset{(1.59)}{0.03} + \underset{(6.56)}{0.91}\Delta Pd_{t-1} + (\underset{(4.03)}{0.76} - \underset{(-4.59)}{2.53}\Delta Pd_{t-1})\, (1 + \exp\{-\underset{(0.002)}{101.49}\, (\Delta Pd_{t-1} - \underset{(0.08)}{0.25})\})^{-1}$$

$s = 0.066 \qquad \gamma^* = 12.2 \qquad s_{NL}^2 / s_L^2 = 0.527$

The ratio of the residual variances (s_{NL}^2 / s_L^2) shows that the nonlinear model for the GDP deflator inflation provides a substantial improvement over the linear model. In the case of the CPI inflation the improvement is marginal, as would be expected from the fact that linearity was not strongly rejected. The high values of γ^* imply that the transition between the two extreme regimes of low and high inflation is instantaneous, implying a threshold AR model of the form (4.11).

In the case of CPI, only the intercept differs between the two regimes; while in the case of GDP deflator, the two regimes are very different as shown below:

$$\Delta P_t = \begin{cases} 0.03 + 0.91\Delta P_{t-1}, & \Delta P_{t-1} < 0.25 \\ 0.79 - 1.62\Delta P_{t-1}, & \Delta P_{t-1} > 0.25 \end{cases}$$

This threshold model is probably the result of the sharp fluctuations in inflation, in particular the large spike in 1974. The model implies that very high inflation rates cannot persist. For example, a value of 40 % in one period will be followed by a value of 14 % ± noise in the next period (and then the low inflation process, which is a stationary AR (1) model, switches on).

4.4 Conclusion

It was found that ARCH effects are present in the inflation measures for both the monthly and annual data. The results also suggested that there is a positive relationship between inflation and its variability. The presence of ARCH could be the result of nonlinear behaviour in inflation.

The null hypothesis of linearity is clearly rejected for both the monthly and annually data. The tests also suggested that the LSTAR model is more appropriate. Further investigation with the monthly data is necessary to examine the case of fitting an LSTAR model for $\Delta_{12}P$ rather than $\Delta\Delta_{12}P$. For the annual data, the estimated LSTAR models seem quite plausible. They imply a threshold model describing the different processes generating low and high inflation rates.

Table 4.1 AR (p) Models for the Differenced Annualised Inflation Rate ($\Delta\Delta_{12}Pc_t = y_t$)

	Model1 (1959.4 –1996.11)	Model2 (1959.4 –1972.7)	Model3 (1972.8 –1996.11)
$\hat{\beta}_0$	0.001 (1.77)	-0.2E-4 (-0.03)	0.002 (1.77)
$\hat{\beta}_1$	0.32 (6.46)	-	0.33 (5.94)
$\hat{\beta}_{12}$	-0.64 (-12.41)	-0.48 (-6.28)	-0.63 (-10.47)
$\hat{\beta}_{13}$	0.15 (2.44)	-	0.15 (2.14)
$\hat{\beta}_{24}$	-0.57 (-9.61)	-	-0.69 (-8.53)
$\hat{\beta}_{25}$	0.15 (2.27)	-	0.16 (2.11)
$\hat{\beta}_{36}$	-0.39 (-6.41)	-	-0.40 (-5.76)
$\hat{\beta}_{37}$	0.15 (2.34)	-	0.17 (2.33)
$\hat{\beta}_{48}$	-0.17 (-3.14)	-	-0.19 (-3.00)
$\hat{\beta}_{49}$	0.07 (1.32)	-	0.08 (1.27)
n	390	135	292
R^2	0.368	0.229	0.375
s	0.0136	0.0084	0.0149
Q(36)	43.15 [0.190]	44.96 [0.150]	37.15 [0.420]
$\chi^2_{ARCH}(3)$	18.94 [0.000]	0.80 [0.851]	8.80 [0.032]
$\chi^2_{ARCH}(12)$	30.56 [0.003]	12.46 [0.409]	14.15 [0.291]

Notes:

- y_t is the differenced annualised CPI inflation rate.
- n is the number of observations; s is the standard error of estimate; R^2 is the proportion of variation in dependent variable explained by the model; Q(k) is the Ljung–Box statistic for residual autocorrelation up to order k; and $\chi^2_{ARCH}(k)$ is the Engle (1982) test for ARCH up to order k.
- the numbers in brackets under the coefficients are t–values; and the numbers in square brackets are P–values.

Table 4.2 GARCH (1, 1) Models for the Differenced Annualised Inflation Rate ($\Delta\Delta_{12}Pc_t = y_t$)

	Model1 (1959.4 –1996.11)	Model2 (1972.8 –1996.11)
$\hat{\beta}_0$	0.6E-3	0.8E-3
	(1.05)	(1.09)
$\hat{\beta}_1$	0.30	0.34
	(6.04)	(6.24)
$\hat{\beta}_{12}$	-0.66	-0.63
	(-13.39)	(-11.75)
$\hat{\beta}_{13}$	0.14	0.16
	(2.31)	(2.41)
$\hat{\beta}_{24}$	-0.56	-0.61
	(-9.21)	(-9.34)
$\hat{\beta}_{25}$	0.16	0.22
	(2.35)	(3.07)
$\hat{\beta}_{36}$	-0.36	-0.44
	(-5.47)	(-6.07)
$\hat{\beta}_{37}$	0.12	0.19
	(1.80)	(2.72)
$\hat{\beta}_{48}$	-0.18	-0.25
	(-3.61)	(-4.2)
$\hat{\beta}_{49}$	0.08	0.1
	(1.76)	(1.82)
$\hat{\alpha}_0$	0.4E-5	0.8E-5
	(.45)	(1.19)
$\hat{\alpha}_1$	0.07	0.04
	(1.75)	(2.56)
$\hat{\delta}_1$	0.91	0.92
	(24.86)	(70.77)
$\hat{\gamma}$	0.0013	0.002
	(14.11)	(213.99)
n	390	292
R^2	0.378	0.389
s	0.0137	0.0151

Notes:

- y_t is the differenced annualised CPI inflation rate.
- n is the number of observations; s is the standard error of estimate; and R^2 is the proportion of variation in dependent variable explained by the model.
- the numbers in brackets under the coefficients are the t–values.

Table 4.3 ARCH (1) Models for the Annual Data

	ΔPc_t	ΔPd_t
$\hat{\beta}_0$	0.02 (2.84)	0.001 (0.11)
$\hat{d}$	0.08 (3.45)	0.13 (4.12)
$\hat{\beta}_1$	0.43 (2.56)	0.30 (1.77)
$\hat{\alpha}_0$	0.2E-4 (0.36)	0.001 (2.11)
$\hat{\alpha}_1$	0.24 (0.65)	0.49 (0.89)
$\hat{\gamma}$	0.02 (2.11)	0.01 (0.78)
n	36	36
R^2	0.668	0.599
s	0.0602	0.0805

Notes:

- ΔPc_t and ΔPd_t are the CPI and GDP deflator inflation rates, respectively.
- n is the number of observations; s is the standard error of estimate; and R^2 is the proportion of variation in dependent variable explained by the model.
- the numbers in brackets under the coefficients are t–values.

Table 4.4 P–Values of the Linearity Test for Different Values of Delay Parameter (d): Differenced Annualised Inflation Rate (y_t)

d	1959.4 – 1972.7	1972.8 – 1996.11	1959.4 – 1996.11
1	0.308	0.0197	0.0016
2	0.690	0.0098	0.000045
3	0.51	0.00499	0.000018
4	0.158	0.153	0.0049
5	0.56	0.0056	0.0001
6	0.686	0.43	0.06

Table 4.5 P–Values of the Model Selection Tests: Differenced Annualised Inflation Rate (y_t)

Null Hypothesis	1972.8 – 1996.11	1959.4 – 1996.11
d	3	3
p	49	49
H_{04}	0.029	0.004
H_{03}	0.027	0.0028
H_{02}	0.169	0.0225

Notes:

- the hypotheses H_{04}, H_{03}, and H_{02} correspond to the null hypotheses of (4.14), (4.15), and (4.16), respectively.
- the value of d is determined from Table 4.4, and p is the order of the linear model.

Table 4.6 P–Values of the Linearity Test for Different Values of Delay Parameter (d): Annual Data

d	ΔPc_t	ΔPd_t
1	0.059	0.0007
2	0.072	0.0145
3	0.076	0.0032

Note:

- ΔPc_t and ΔPd_t are the CPI and GDP deflator inflation rates, respectively.

Table 4.7 P–Values of the Model Selection Tests: Annual Data

Null Hypothesis	ΔPc_t	ΔPd_t
d	1	1
p	1	1
H_{04}	0.056	0.283
H_{03}	0.626	0.051
H_{02}	0.059	0.0004

Notes:

- ΔPc_t and ΔPd_t are the CPI and GDP deflator inflation rates, respectively.
- the hypotheses H_{04}, H_{03}, and H_{02} correspond to the null hypotheses of(4.14), (4.15), and (4.16), respectively.
- the value of d is determined from Table 4.6, and p is the order of the linear model.

5 THE MONEY DEMAND FUNCTION AND INFLATION

5.1 Introduction

The objective of this chapter is to design and estimate a per capita demand function for money in order to shed new light on both the theoretical and empirical ground. A theoretical demand function for money is constructed based on the characteristics of the Iranian economy in the framework of the cash–in–advance model. This provides the ground for the empirical results of the models in chapters seven and eight.

To evaluate the per capita money demand function, cointegration analysis is carried out, and the long–run and short–run relationships among variables included in the models estimated using annual data for the 1959 – 1996 period. Structural breaks are considered 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. It is shown that there is a long–run relationship between per capita real balances, inflation, and per capita real income after accounting for a break point in 1978.

The direction of causality between variables considered in the per capita money demand function is examined using error correction model (ECM) analysis and

the constancy of parameters is examined by evaluating the effects of structural breaks.

This chapter is organised as follows: Section two reviews previous studies on money demand in Iran. Section three deals with the per capita demand function for money derived in Appendix A and also describes the data employed. Section four presents the empirical analysis and section five offers a summary.

5.2 Previous Studies on Money Demand

There are a number of studies of the money demand function in Iran. Most of these [Nazemzadeh (1984), Emadzadeh (1990), Noferesti (1995), and Esmaeel–Nia (1996)] have investigated the demand for money without using modern cointegration techniques and so their results must be viewed with some scepticism. Liu (1996), Tavakoli (1996), and Bahmani–Oskooee (1996) use cointegration analysis to estimate an aggregate money demand function for Iran.

Here only the recent studies, which use cointegration techniques, are examined. Liu employs quarterly data over the period 1974 – 1994 and finds that real balances and real income are I (1) and the rate of inflation is I (0). Her estimation results show that there is a long–run relationship between real balances (broad money, M2), real income (GDP), and the rate of inflation calculated using the consumer price index. The long–run income elasticity of the demand function is 0.51 and the long–run semi–elasticity of the rate of inflation is -4.00 on an annual basis. Tavakoli estimates a similar money demand function using similar procedures and finds very similar results.

Bahmani–Oskooee specifies the demand for money in the following form:

$$M_t = -\alpha \Delta P + \gamma Y_t + \delta E_t + \varepsilon_t \tag{5.1}$$

where M_t denotes the log of real balances; Δ is the difference operator; P_t is the log of the consumer price index (CPI); Y_t denotes the log of real GDP; and E_t is the log of the parallel market exchange rate defined as the number of Iranian rials per US dollar. Ever since the seminal article of Friedman (1956), empirical studies of the demand for money have considered various measures of income, wealth, and opportunity cost as important explanatory variables. In Bahmani–Oskooee's study, the first difference of the log of the CPI is used as an appropriate measure for the opportunity cost of holding money. The interest rate is not used as an alternative or additional measure of opportunity cost due to the lack of well–developed financial markets and stock markets in Iran. Furthermore, since the Iranian government sets interest rates, they are not an appropriate measure for the opportunity cost of holding money (see also chapter two for a discussion of the role of the interest rate in Iran).

The inclusion of the exchange rate requires further discussion. Arango and Nadiri (1981) have argued that an increase in the exchange rate (or depreciation of the domestic currency) may have either positive or negative effects on real balances. They assume that wealth holders evaluate their portfolios based on domestic currency. When the value of the foreign currency increases, domestic residents find that the value of their holding of foreign securities increases, while domestic holdings of foreigners, as valued in their own currency, decrease. This implies an increase in the domestic monetary base. So, domestic interest rates decrease and the demand for money increases. Concerning the negative effects of the exchange rate on money demand, Bahmani–Oskooee and Pourheydarian (1990) have argued that when the domestic currency depreciates, individuals may expect further depreciation, so they demand more foreign currency and less domestic currency.

Bahmani–Oskooee uses two alternative measures for real balances, real M1 and real M2.[1] Using annual data for 1959 – 1990, he finds that all variables included in equation (5.1) are I (1) and there is a stable money demand function when real M2 is used as the dependent variable but not when M1 is used. The estimated equation for real M2 is as follows:

$$M_t = -1.3\Delta P_t + 1.39Y_t + 0.25E_t + \hat{\varepsilon}_t \tag{5.2}$$

The signs of the coefficients of inflation and real income are consistent with the theory, while the positive effect of the parallel market exchange rate[2] supports the wealth effect argument.

The study at hand adds to the literature by designing a microfoundation model of the demand function for money [see Appendix A] as well as making use of an extended data period. It uses two alternative measures of money (monetary base and M2) for the dependent variable. M2 is used to analyse inflation in this chapter and chapter seven, while monetary base is used to analyse the relationship between seigniorage and inflation in chapter eight. The first difference of the log of the

[1] M1 is the sum of notes and coins held by agents plus sight deposits of the private sector with the banking system; M2 is the sum of M1 plus quasi-money; quasi-money is defined as the sum of time and saving deposits of the private sector with the banking system. The value of real balances is calculated using the consumer price index.

implicit deflator of GDP at market prices is used as an appropriate measure for the opportunity cost of holding money. The GDP deflator is preferred because there have been considerable government subsidies on consumer goods (more specifically, foods, fuel, and electricity), which means that the CPI does not reflect the true inflation rate in the economy. Pesaran (1998) also estimates a demand function for money using the GDP deflator as an appropriate measure of inflation for Iran.

5.3 A Per Capita Demand Function for Money and Data Description

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. Using a cash–in–advance framework, the above predictions emerge [see Appendix A]. The following model is used for empirical estimation:

$$PMPi_t = c - \alpha \Delta P_t^e + \gamma PY_t + u_t \qquad i = B, 2 \qquad (5.3)$$

where $PMPB_t$ and $PMP2_t$ are the logs of the real per capita balances using monetary base and M2, respectively, i.e. PMPi = log [Mi/(population × GDP deflator)] for i = B, 2; PY_t is the log of per capita GDP at 1990 prices; P is the log of the implicit GDP deflator; ΔP_t^e is the expected rate of inflation, used as the opportunity cost of holding money.

The empirical money demand specification differs from the theoretical model

[2] He also considered the official exchange rate, but could not find a stable long-run relationship.

derived in Appendix A. First consider real per capita income. When the variables included in the model are cointegrated, PY_{t-1} can be replaced by PY_t, since in the long–run the difference between PY_{t-1} and PY_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:

$$\Delta P_t = \Delta P_t^e + \omega_t \tag{5.4}$$

where ω_t is normally distributed with a mean of zero and a constant variance of σ^2. Provided the expectation error ω_t is stationary, it does not matter whether expectations are rational or adaptive. Substituting ΔP_t from the above equation into equation (5.3) yields:

$$PMPi_t - \gamma PY_t = c - \alpha\Delta P_t + \upsilon_t \qquad \text{i} = \text{B}, 2 \tag{5.5}$$

where $\upsilon_t = u_t + \alpha\omega_t$. Since ω_t is I (0), υ_t is also I (0) provided the original error u_t is I (0). Hence, if the original equation (5.3) is cointegrated then equation (5.5) will also be cointegrated.

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

$$PMPi_t = c - \alpha\Delta P_t + \gamma PY_t + \Phi D_t + \varepsilon_t \qquad \text{i} = \text{B}, 2 \tag{5.6}$$

where c is intercept; α and γ are the semi–elasticity of the rate of inflation and income elasticity, respectively; 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:

- first oil boom (DO_t)

- revolution ($D78_t$)
- second oil boom and start of the eight–year war ($D79_t$)
- war period (DW_t)
- third oil boom ($D86_t$)
- 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 ($D91_t$).

The data are annual over the 1959 – 1996 period. Population and official exchange rate (which is period average rate) were collected from International Financial Statistics of IMF, various issues. The source of other data is the central bank of Iran [see Appendix B].

Below the movements of the time series used in the chapter are graphically examined. Figure 5.1 plots the log of the implicit deflator (P) and the log of the nominal values of MB and M2. This shows a huge change in the nominal values of P and the monetary measures (MB and M2) over the sample period. More specifically, prices rise about 110–fold, from 0.044 in 1959 to 4.86 in 1996. The actual level of MB increases from 30.8 thousands millions of rials in 1961 to 47343.2 thousands millions of rials in 1996, and the actual level of M2 increases from 51.6 thousands millions of rials in 1959 to 116552.6 thousand millions rials in 1996. Over the sample period, MB and M2 rise about 1537–fold and 2259–fold, respectively. Figure 5.2 plots the log of the real per capita monetary measures (PMPB and PMP2). The graphical evidence shows that these series increase sharply until 1978; for the period after, the series slow down markedly and even show a decrease.

Figure 5.3 shows the rate of inflation and the growth rate of nominal MB and M2. As can be seen, these time series move relatively closely together over the period. The spike in 1974 corresponds to the huge increase in the oil price, which affected the amount of coins and notes in circulation; while that of 1978 corresponds to the revolution when individuals took out their deposits from the banking system and held them as cash. Figure 5.4 shows real per capita GDP. This variable increased 2.3–fold (by taking into account of 2.9–fold increase in the population) over the sample period, which compares with a 6.7–fold increase in aggregate real GDP. Finally, Figure 5.5 plots the log of the parallel market exchange rate, which shows a clear break in 1979.

5.4 Empirical Analysis

5.4.1 Testing for Unit Roots

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

Table 5.1 presents the results of the ADF test for the levels of the series over the period 1959 – 1996. The ADF test fails to reject the null of nonstationarity for the level of any time series. Next, the first differences of all sequences are tested using the ADF test. Table 5.2 shows that the first differences of all these series are stationary.

Due to the presence of structural breaks in some time series, the Perron procedure is also used to check the robustness of the ADF results. Inspection of the plots indicates the presence of structural breaks in the following series (see Figure 5.1, Figure 5.2, and Figure 5.5.

- GDP deflator
- the per capita real balances (PMPB and PMP2)
- parallel market 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 5.3 and Table 5.4 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.

5.4.2 Cointegration Tests

The Johansen–Juselius (1990) cointegration technique is used to estimate the per capita money demand function as specified in equation (5.6). 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. From Table 5.5, the SBC and AIC suggest one and two lags, respectively. Since the likelihood ratio (LR) test suggested VAR (1) at 5 percent level for PMPB and PMP2, p = 1 is chosen for both models.

Table 5.6 reports the results of two likelihood ratio statistics, λ_{max} statistic and λ_{trace} statistic, in order to determine the number of cointegrated vectors. The λ_{max} confirms the presence of one cointegrating vector at 10 percent level in PMPB while both λ_{max} statistic and λ_{trace} statistic suggest the cointegrating rank of one for PMP2 at 5 percent level. 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.[3]

The long–run money demand function is estimated and the results are reported in Table 5.7, where the estimates are normalised to represent the per capita demand function for money. As can be seen, the signs of all coefficients are consistent with the theory. The semi–elasticity of inflation is 4.31 and 3.40 for PMPB and PMP2, respectively, while the income elasticity is 2.37 and 2.09 for PMPB and PMP2, respectively.

[3] It should be noted that time trend is not significant in the models and so it is excluded.

5.4.3 The Dynamics of the Models

Granger (1986), and Engle and Granger (1987) propose the use of an error correction model in order to investigate the short–run relationship among the variables included in the models. The following error correction models, where the order of VAR = 1[4], are estimated:

$$\Delta PMPi_t = \beta_0 + \beta_1 D78_t + \beta_2 TB78_t + \beta_3 \Delta P_t + \lambda ECi_{t-1} + \varepsilon_t, \quad \text{i} = \text{B}, 2 \tag{5.7}$$

$$\Delta PY_t = \beta_0 + \beta_1 D78_t + \beta_2 TB78_t + \beta_3 \Delta P_t + \lambda ECi_{t-1} + \varepsilon_t \;, \quad \text{i} = \text{B}, 2 \tag{5.8}$$

where $ECi_t = PMPi_t - \hat{\gamma} PY_t$ is the error correction term with $\hat{\gamma}$ obtained from the corresponding cointegrating regression.

The estimates of the error correction models are reported in Table 5.8. As can be seen, all models appear to be statistically well specified, although there is weak evidence of autocorrelation in both models for ΔPY, at 5 percent but not at 1 percent level. The error correction terms are significant and have the correct signs in all models. It should be noted that the magnitudes of the error correction coefficients in all regressions are rather small. This has an important policy implication concerning the collection of revenue through seigniorage, since any deviation from long–run equilibrium can be expected to persist for a relatively long period of time. Based on the Granger causality test [see Granger and Newbold (1988)], the significance of the error correction terms confirms bi–directional causality between per capita real balances and income for both measures of real balances.

[4] The order of VAR is suggested by the SBC, AIC, and LR test.

5.4.4 Money Market and Dynamics of Inflation

This section analyses the determinants of inflation in the money market for the Iranian economy by estimating the following model:

$$\Delta P_t = \beta_0 + \beta_1 D_t + \beta_2 \Delta PMP2_{t-1} + \beta_3 \Delta P_{t-1} + \beta_4 \Delta PY_{t-1} + \lambda EC_{t-1} + \varepsilon_t \quad (5.9)$$

where D_t is a set of relevant dummy variables as well as outliers. EC_t represents the excess money supply, which is basically derived using the cointegration relationship in the previous section to obtain:

$$EC_t = PMP2_t + 3.40\Delta P_t - 2.09PY_t + 8.18 - 1.11D78_t - 0.30TB78_t.$$

The model in the general form is estimated and after simplification, the following parsimonious model is obtained:

$$\Delta P_t = 0.16DO_t + 0.11D91_t + 0.26TB74_t - 0.18TB75_t \quad (5.10)$$

(13.95) (4.33) (5.32) (-3.05)

$$+0.15\Delta PMP2_{t-1} + 0.09EC_{t-1}$$

(1.86) (2.32)

n = 36 $\bar{R}^2 = 0.852$ s = 0.0461 $\chi^2_{SC}(1) = 0.09$ [0.76]

$\chi^2_{FF}(1) = 0.71$ [0.40] $\chi^2_N(2) = 1.30$ [0.52] $\chi^2_{ARCH}(1) = 0.002$ [0.97]

$F_1(2, 28) = 0.40$ [0.67] $F_2(2, 28) = 2.21$ [0.13]

where n is the number of observations; $\bar{R}^2$ is the adjusted squared multiple correlation coefficient; s is the standard error of regression; χ^2_{SC} is Lagrange

Multiplier (LM) test statistic for residual autocorrelation; χ^2_{FF} is RESET statistic for misspecification; χ^2_N is Jarque–Bera test statistic for normality; χ^2_{ARCH} is test statistic for autoregressive conditional heteroscedasticity; F_1 is F–statistic for the significance of ΔP_{t-1} and ΔPY_{t-1}; and F_2 is F–statistic for the significance of $D78_t$ and $TB78_t$, where $D78_t$ takes the value of 1, if t ≥ 1979 and 0 otherwise and $TB78_t$ takes the value of 1, if t = 1978 and 0 otherwise. The numbers in brackets below the coefficients are t–statistics; and the numbers in square brackets next to diagnostic test statistics are P–values.

Two dummy variables and two outliers are included in the model. DO_t accounts for the first oil boom and takes the value of 1, if t ≥ 1973 and 0 otherwise. $D91_t$ accounts for the effects of the economic reform programme (which included the exchange rate devaluation, price control removal, and trade and tariffs deregulation) and takes the value of 1, if t ≥ 1992 and 0 otherwise. $TB74_t$ and $TB75_t$ are outliers to account for the effects of the oil boom in 1974 and 1975 and take the value of 1, if t = 1974 and t = 1975, respectively, and 0 otherwise.

The final form of the model is obtained by removing insignificant variables. The two F–statistics are insignificant and the standard error of regression declined from 0.0476 in the general model to 0.0461 in the simplified model. All coefficients are statistically significant and the signs are consistent with the theory. Moreover, all the diagnostic tests confirm that the model is well specified.

As can be seen, the error correction coefficient has the correct sign. This means that the excess supply of money affects inflation in the long–run. Moreover, money supply raises inflation in the short–run as well, since the coefficient of the per capita real balances is significant. Considering the positive long–run and short–run effects of money supply on inflation, the monetary authorities should bring the money supply into its consideration and use it as a nominal anchor to control inflation. However, because of the slow rate of adjustment towards equilibrium the effectiveness of the policy may be questioned. The slow rate of adjustment is consistent with the positive relationship between higher inflation and uncertainty suggested by ARCH and GARCH models.

5.4.5 The Robustness of Estimates

Evaluation of Exchange Rate Effects

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.

Table 5.9 reports the results for determining the order of VAR. As can be seen, the SBC and AIC suggest one lag for PMPB and PMP2.[5] The LR test also suggests the same order for both models. Consequently, VAR (1) is used for determining the cointegration rank in the VAR models. Table 5.10 presents the cointegration test results based on the likelihood ratio statistics, λ_{max} statistic, and λ_{trace} statistic. λ_{trace} suggests that the cointegrating rank for PMPB is one at 10 percent level, while both λ_{max} and λ_{trace} determine the rank of PMP2 is at least one at the 5 % level, with λ_{max} indicating a rank of two at the 10 % level. Although these results are

[5] Due to the small sample size, a maximum of two lags is employed.

not very clear, they are not inconsistent with the expectation of one cointegrating vector.

The estimated equations of the per capita functions are normalised and presented in Table 5.11.[6] As can be seen, the coefficient of the parallel market exchange rate is insignificant in both models.[7] An ECM was also estimated, with ΔPMPB or ΔPMP2 as the dependent variable, but the exchange rate was again insignificant.

However, although the coefficient of parallel market exchange rate is statistically insignificant, t–values of 1.39 and 1.33 for PMPB and PMP2, respectively, The negative sign of the variable indicate a weak evidence of currency substitution hypothesis. Policy implication of this evidence is described in chapter nine.

Other Checks

The robustness of estimates is also investigated using other procedures. In the Johansen method, VAR (2), which is selected by the AIC, is used to estimate the long–run coefficients. The elasticity of real income is 2.46 and 1.96 for PMPB and PMP2, respectively, and the semi–elasticity of the rate of inflation is 4.23 and 3.29 for PMPB and PMP2, respectively. 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

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[6] Since the trend was not significant in the models, the case of no trend is considered.

[7] 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.

models. The t–values of the trend are 1.19 and 0.30 for PMPB and PMP2, respectively. Finally, a per capita demand function for M1 is also estimated but not reported, since the estimates are very similar to those for PMPB and PMP2.

The autoregressive distributed lag (ARDL) method is also 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 4.64 and 3.26 for PMPB and PMP2, respectively, and the income elasticity is 2.64 and 2.33 for PMPB and PMP2, respectively, which are very similar to the estimates reported in previous sections. 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.[8]

Finally, the cointegrating regressions are also estimated using both OLS and the fully modified Phillips–Hansen (1990) methods.[9] The results again confirm that the signs of coefficients are consistent with the theory, provided the models allow for the break in 1978.

5.5 Conclusion

After removing the effects of shocks through the inclusion of dummy variables in the

[8] 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.

[9] 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.

model, a stable money demand function is found. Using cointegration analysis, a stable long–run relationship is found between per capita real balances, inflation, and per capita real income after allowing for a break in 1978. Moreover, the ECMs confirm the presence of this relationship. The empirical estimates support the theoretical model of the demand function for money that is constructed for the Iranian economy using the cash–in–advance models. The high value of the elasticity of income implies the rejection of the hypothesis of unitary income elasticity. Furthermore, the exchange rate (either parallel or official rate) does not play a significant role in the demand function for money.

The model for inflation suggests that the money supply affects inflation in both the long–run and the short–run. Therefore, the monetary authorities could bring the money supply into its consideration and use it as a nominal anchor to control inflation.

The magnitudes of the error correction coefficients in all regressions are rather small. This means that any deviation from long–run equilibrium can be expected to persist for a relatively long period of time, which has important policy implications concerning the collection of revenue through seigniorage.

Table 5.1 Univariate Augmented Dickey–Fuller Test for Unit Roots in the Level of Time Series

Regression: $\Delta Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\delta}Y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta Y_{t-i} + \hat{\varepsilon}_t$								
	n	k	$\hat{\mu}$	$t_{\hat{\mu}}$	$\hat{\alpha}$	$t_{\hat{\alpha}}$	$\hat{\delta}$	$t_{\hat{\delta}}$
P_t	36	1	-0.30	-1.85	0.010	2.64	-0.06	-1.78
$PMPB_t$	35	0	0.17	1.03	-0.005	-1.69	-0.01	-0.09
$PMP2_t$	37	0	0.42	2.54	-0.001	-0.55	-0.07	-1.66
PY_t	36	1	0.54	2.08	0.4E-3	0.29	-0.08	-1.98
OE_t	37	0	0.23	0.53	0.010	1.78	-0.10	-0.92
E_t	37	0	0.13	0.79	0.010	2.37	-0.06	-1.20

Notes:

- P_t is the log of the implicit deflator of GDP at market prices; $PMPB_t$ is the log of the per capita real monetary base; $PMP2_t$ is the log of the per capita real M2; PY_t is the log of the per capita real GDP; OE_t is the log of the official exchange rate; and E_t is the log of the parallel market exchange rate.
- n is the number of observations; and k is the number of lags.

Table 5.2 Univariate Augmented Dickey–Fuller Test for Unit Roots in the First Difference of Time Series

Regression: $\Delta Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\delta}Y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta Y_{t-i} + \hat{\varepsilon}_t$

	n	k	$\hat{\mu}$	$t_{\hat{\mu}}$	$\hat{\alpha}$	$t_{\hat{\alpha}}$	$\hat{\delta}$	$t_{\hat{\delta}}$
ΔP_t	36	0	-.016	-0.5	0.005	2.64	-0.640	-3.91**
$\Delta PMPB_t$	34	0	0.15	2.98	-0.005	-2.53	-0.910	-4.94***
$\Delta PMP2_t$	36	0	0.14	3.46	-0.004	-2.93	-0.830	-4.79***
ΔPY_t	36	0	0.01	0.77	-	-	-0.420	-3.03*
ΔOE_t	36	0	-0.16	-0.85	0.012	1.44	-0.997	-5.7***
ΔE_t	36	0	-0.10	-0.65	0.007	2.02	-0.840	-4.82***

Notes:

- P_t is the log of the implicit deflator of GDP at market prices; $PMPB_t$ is the log of the per capita real monetary base; $PMP2_t$ is the log of the per capita real M2; PY_t is the log of the per capita real gross domestic product (GDP); OE_t is the log of the official exchange rate; E_t is the log of the parallel market exchange rate; and Δ 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.

Table 5.3 Univariate Perron Tests for Unit Roots in Levels: 1959 – 1996

Regression: $Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\beta}D_t + \hat{d}TB_t + \hat{\delta}DT_t + \hat{\gamma}Y_{t-1} + \sum_{i=1}^{k}\hat{c}_i\Delta Y_{t-i} + \hat{\varepsilon}_t$				
	$PMPB_t$	$PMP2_t$	P_t	E_t
n	35	36	36	36
k	0	0	1	1
λ	0.47	0.50	0.35	0.54
$\hat{\mu}$	0.87	2.67	-0.60	1.69
$t_{\hat{\mu}}$	(2.22)	(4.20)	(-1.49)	(2.89)
$\hat{\alpha}$	0.040	0.080	0.004	-0.002
$t_{\hat{\alpha}}$	(2.57)	(4.00)	(0.60)	(-0.71)
$\hat{\beta}$	0.003	-0.100	-0.320	-0.930
$t_{\hat{\beta}}$	(.03)	(-2.25)	(-0.98)	(-2.36)
$\hat{d}$	-0.85	0.07	0.11	0.47
$t_{\hat{d}}$	(-0.93)	(1.06)	(1.22)	(2.63)
$\hat{\delta}$	-0.05	-0.09	0.03	0.07
$t_{\hat{\delta}}$	(-2.61)	(-3.88)	(1.21)	(2.87)
$\hat{\gamma}$	0.72	0.31	0.82	0.61
$t_{\hat{\gamma}-1}$	(-2.15)	(-4.06)	(-1.38)	(-2.90)

Notes:

- $PMPB_t$ is the log of the per capita real monetary base; $PMP2_t$ 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 λ denotes the ratio of pre–break sample size to total sample size.

Table 5.4 Univariate Perron Tests for Unit Roots in First Differences: 1959 – 1996

Regression: $Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\beta}D_t + \hat{d}TB_t + \hat{\gamma}Y_{t-1} + \sum_{i=1}^{k}\hat{c}_i\Delta Y_{t-i} + \hat{\varepsilon}_t$

	$\Delta PMPB_t$	$\Delta PMP2_t$	ΔP_t	ΔE_t
n	34	36	36	35
k	0	0	0	1
λ	0.47	0.50	0.35	0.54
$\hat{\mu}$	0.080	0.120	-0.020	-0.001
$t_{\hat{\mu}}$	(1.54)	(3.16)	(-0.68)	(-0.01)
$\hat{\alpha}$	0.002	0.001	0.003	-0.020
$t_{\hat{\alpha}}$	(0.52)	(0.14)	(1.29)	(-0.06)
$\hat{\beta}$	-0.15	-0.14	0.08	1.01
$t_{\hat{\beta}}$	(-2.19)	(-2.61)	(1.51)	(3.66)
$\hat{d}$	-0.04	0.07	0.13	-0.02
$t_{\hat{d}}$	(-0.34)	(0.93)	(1.58)	(-2.07)
$\hat{\gamma}$	0.13	-0.04	0.25	-0.44
$t_{\hat{\gamma}-1}$	(-3.95)*	(-5.78)***	(-4.41)***	(-6.26)***

Notes:

- $PMPB_t$ is the log of the per capita real monetary base; $PMP2_t$ 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 Δ is the difference operator.
- 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, 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 λ 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).

Table 5.5 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)

A. Results for PMPB

List of variables included in the unrestricted VAR:
PMPB PY
List of deterministic and/ or exogenous variables:
ΔP D78 TB78

Order	LL	AIC	SBC	LR test	Adjusted LR test
2	93.9867	79.9867	69.3022	-	-
1	89.7273	79.7273	72.0955	CHSQ(4)= 8.5188[.074]	6.7649[.149]
0	-92.1042	-98.1042	-102.6833	CHSQ(8)= 372.1819[.000]	295.5562[.000]

B. Results for PMP2

List of variables included in the unrestricted VAR:
PMP2 PY
List of deterministic and/ or exogenous variables:
ΔP 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:

- $PMPB_t$ is the log of the per capita real monetary base; $PMP2_t$ is the log of the per capita real M2; PY_t is the log of the per capita real gross domestic product (GDP); and ΔP_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.

Table 5.6 Cointegration Tests Based on Johansen's Maximum Likelihood Procedure

A. Results for PMPB					
Null	Alternative	λ_{max} Statistic	Critical Value (95%)	λ_{trace} Statistic	Critical Value (95%)
r = 0	r = 1	14.24*	14.88	14.24	17.86
r<= 1	r = 2	0.003	8.07	0.003	8.07

B. Results for PMP2					
Null	Alternative	λ_{max} Statistic	Critical Value (95%)	λ_{trace} Statistic	Critical Value (95%)
r = 0	r = 1	19.48**	14.88	21.35**	17.86
r<= 1	r = 2	1.87	8.07	1.87	8.07

Notes:

- $PMPB_t$ is the log of the per capita real monetary base; and $PMP2_t$ is the log of the per capita real M2.
- Lags in the VAR = 1.
- ** and * indicate statistical significance at the 5%, and 10% levels, respectively.

Table 5.7 ML Estimates of Long–run Money Demand Functions

Regression: $PMPi_t = -\alpha \Delta P_t + \gamma PY_t + \varepsilon_t$ i = B, 2		
	$\hat{\alpha}$	$\hat{\gamma}$
PMPB	4.31	2.37
PMP2	3.40	2.09

Notes:

- $PMPB_t$ is the log of the per capita real monetary base; $PMP2_t$ is the log of the per capita real M2; ΔP_t is the rate of inflation; and PY_t is the log of the per capita real GDP.

Table 5.8 Error Correction Models

Model for	PMPB		PMP2	
	$\Delta PMPB_t$	ΔPY_t	$\Delta PMP2_t$	ΔPY_t
Explanatory Variables:				
Intercept	-1.20 (-3.30)	0.62 (1.50)	-1.00 (-2.52)	1.07 (2.37)
$D78_t$	0.04 (0.99)	-0.14 (-2.66)	0.02 (0.51)	-0.17 (-3.40)
$TB78_t$	0.21 (3.27)	-0.20 (-2.83)	-0.06 (-1.12)	-0.20 (-3.00)
ΔP	-0.52 (-4.11)	0.07 (0.47)	-0.46 (-4.34)	0.11 (0.87)
$EC1_{t-1}$	-0.12 (-3.62)	0.05 (1.33)	-	-
$EC2_{t-1}$	-	-	-0.14 (-2.86)	0.12 (2.22)
n	35	35	37	37
$\overline{R}^2$	0.685	0.337	0.629	0.390
s	0.060	0.068	0.055	0.063
DW	1.64	1.30	1.49	1.31
$\chi^2_{SC}(1)$	0.86 [0.35]	4.76 [0.03]	1.25 [0.26]	5.20 [0.02]
$\chi^2_{FF}(1)$	0.92 [0.34]	2.09 [0.15]	3.52 [0.06]	1.38 [0.24]
$\chi^2_N(2)$	1.95 [0.38]	0.99 [0.61]	1.72 [0.42]	0.56 [0.76]
$\chi^2_{ARCH}(1)$	0.10 [0.76]	0.17 [0.68]	0.88 [0.35]	0.48 [0.49]

Notes:

- Δ is the difference operator; $PMPB_t$ is the log of the per capita real monetary base; $PMP2_t$ is the log of the per capita real M2; PY_t is the log of the per capita real GDP; and P_t is the log of the GDP deflator.
- $D78_t$ is dummy variable for the revolution, which takes 1 if t > 1978 and 0 otherwise; $TB78_t = 1$ if t = 1978 and 0 otherwise.
- The error correction terms of PMPB and PMP2 are $EC1_t = PMPB_t - 2.37PY_t$ and $EC2_t = PMP2_t - 2.09PY_t$, respectively.
- The numbers in brackets next to regression coefficients are t–statistics; and the numbers in square brackets next to diagnostic test statistics are P–values.
- n is the number of observations; $\overline{R}^2$ is the adjusted squared multiple correlation coefficient; s is the standard error of regression; DW is the Durbin–Watson statistic; χ^2_{SC} is Lagrange Multiplier (LM) test statistic for residual autocorrelation; χ^2_{FF} is RESET statistic for misspecification; χ^2_N is Jarque–Bera test statistic for normality; and χ^2_{ARCH} is test statistic for autoregressive conditional heteroscedasticity.

Table 5.9 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)

A. Results for PMPB

List of variables included in the unrestricted VAR:
PMPB PY E
List of deterministic and/ or exogenous variables:
ΔP D78 TB78

Order	LL	AIC	SBC	LR test	Adjusted LR test
2	120.7466	93.7466	73.1407	-	-
1	112.8723	94.8723	81.1350	CHSQ(9)= 15.7487[.072]	11.5799[.238]
0	-127.5858	-136.5858	-143.4544	CHSQ(18)= 496.6648[.000]	365.1947[.000]

B. Results for PMP2

List of variables included in the unrestricted VAR:
PMP2 PY E
List of deterministic and/ or exogenous variables:
ΔP D78 TB78

Order	LL	AIC	SBC	LR test	Adjusted LR test
2	130.8345	103.8345	82.4570	-	-
1	127.8694	109.8694	95.6177	CHSQ(9)= 5.9303[.747]	4.4477[.880]
0	-134.2991	-143.2991	-150.4249	CHSQ(18)= 530.2672[.000]	397.7004[.000]

Notes:

- $PMPB_t$ is the log of the per capita real monetary base; $PMP2_t$ is the log of the per capita real M2; PY_t is the log of the per capita real gross domestic product (GDP); ΔP_t is the rate of inflation; and E_t is the log of the parallel market exchange rate.
- $D78_t$ is a 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.

Table 5.10 Cointegration Tests Based on Johansen's Maximum Likelihood Procedure

A. Results for PMPB

Null	Alternative	λ_{max} Statistic	Critical Value (95%)	λ_{trace} Statistic	Critical Value (95%)
r = 0	r = 1	17.04	21.12	29.54*	31.54
r<= 1	r = 2	12.03	14.88	8.34	17.86
r<= 2	r = 3	0.48	8.07	0.02	8.07

B. Results for PMP2

Null	Alternative	λ_{max} Statistic	Critical Value (95%)	λ_{trace} Statistic	Critical Value (95%)
r = 0	r = 1	21.23**	21.12	36.13**	31.54
r<= 1	r = 2	14.41*	14.88	14.89	17.86
r<= 2	r = 3	0.49	8.07	0.49	8.07

Notes:

- $PMPB_t$ is the log of the per capita real monetary base; and $PMP2_t$ is the log of the per capita real M2.
- Lags in the VAR = 1.
- ** and * indicate statistical significance at the 5% and 10% level, respectively.

Table 5.11 ML Estimates of Long–run Money Demand Functions

Regression: $PMPi_t = -\alpha \Delta P_t + \gamma PY_t + \delta E_t + \varepsilon_t$ i = B, 2			
	$\hat{\alpha}$	$\hat{\gamma}$	$\hat{\delta}$
PMPB	4.57	1.61	-0.32
PMP2	4.97	1.76	-0.12

Notes:

- $PMPB_t$ is the log of the per capita real monetary base; $PMP2_t$ is the log of the per capita real M2; ΔP_t is the rate of inflation; PY_t is the log of the per capita real gross domestic product (GDP); and E_t is the log of the parallel market exchange rate.
- t–values of the parallel market exchange rate are 1.39 and 1.33 for PMPB and PMP2, respectively.

Figure 5.1 The log of the GDP deflator and the log of Nominal MB and M2: 1959 – 1996

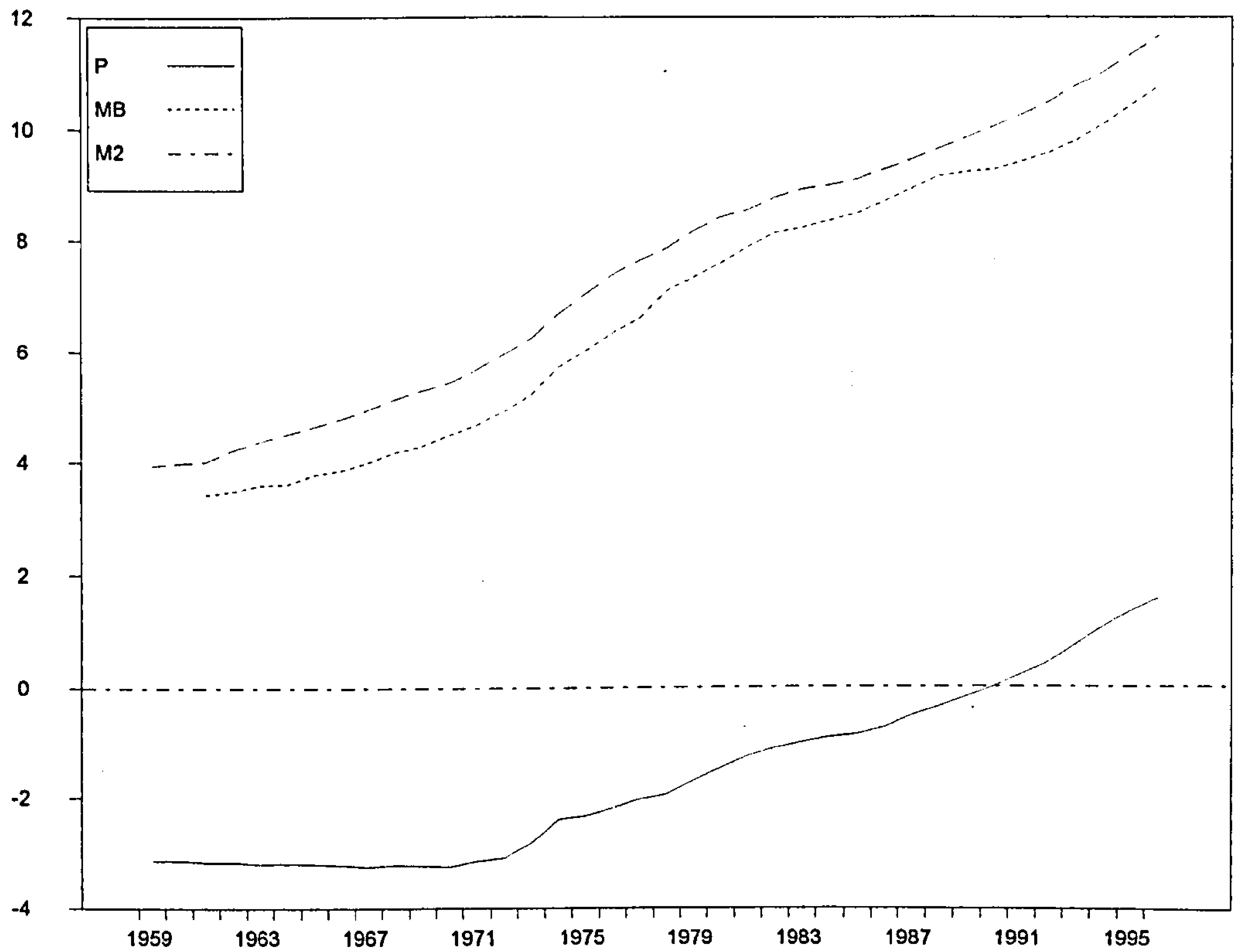


Figure 5.2 The log of the Real Per Capita Monetary Measures (PMPB and PMP2): 1959 – 1996

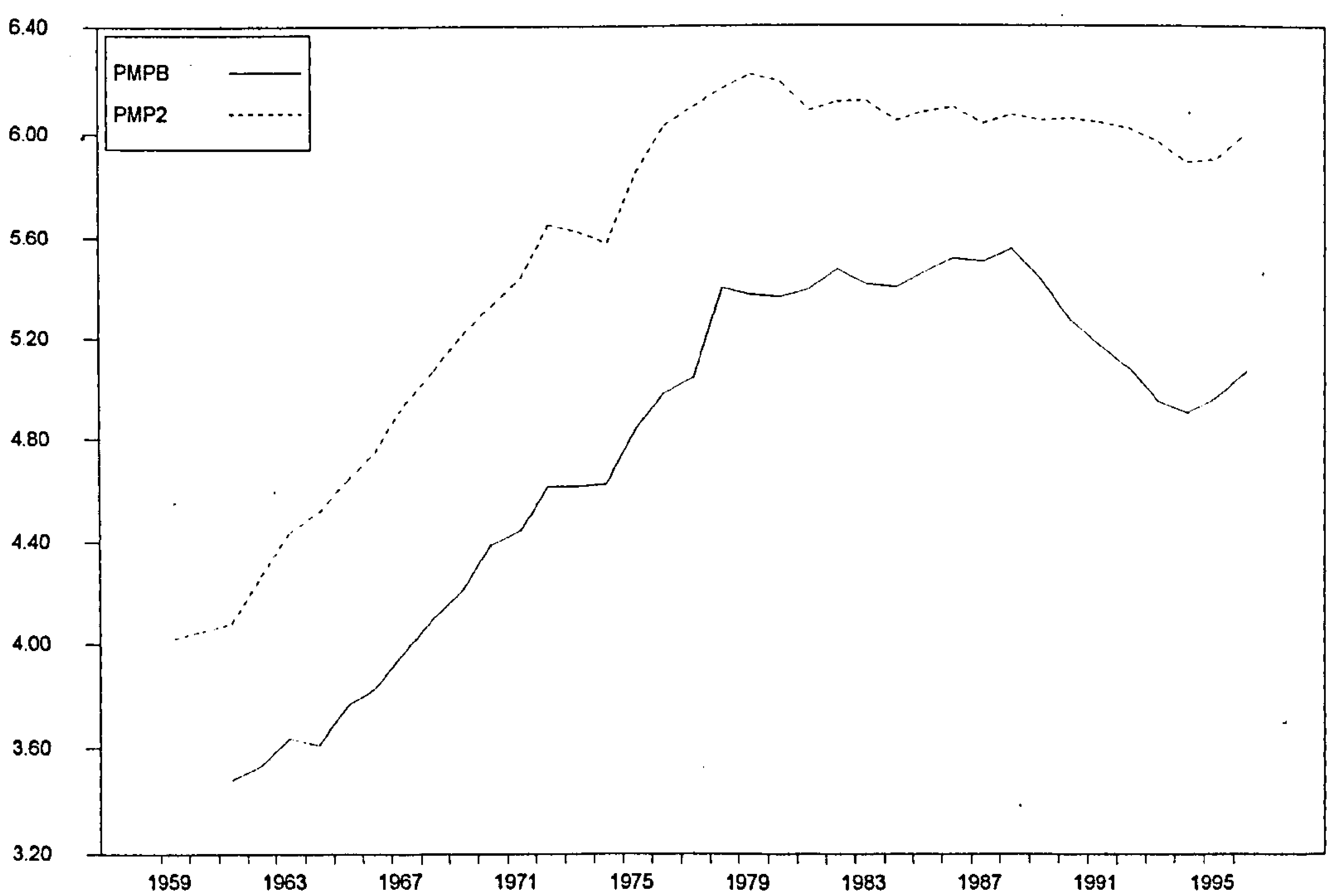


Figure 5.3 The Rate of Inflation and the growth Rate of Nominal MB, and M2: 1959 – 1996

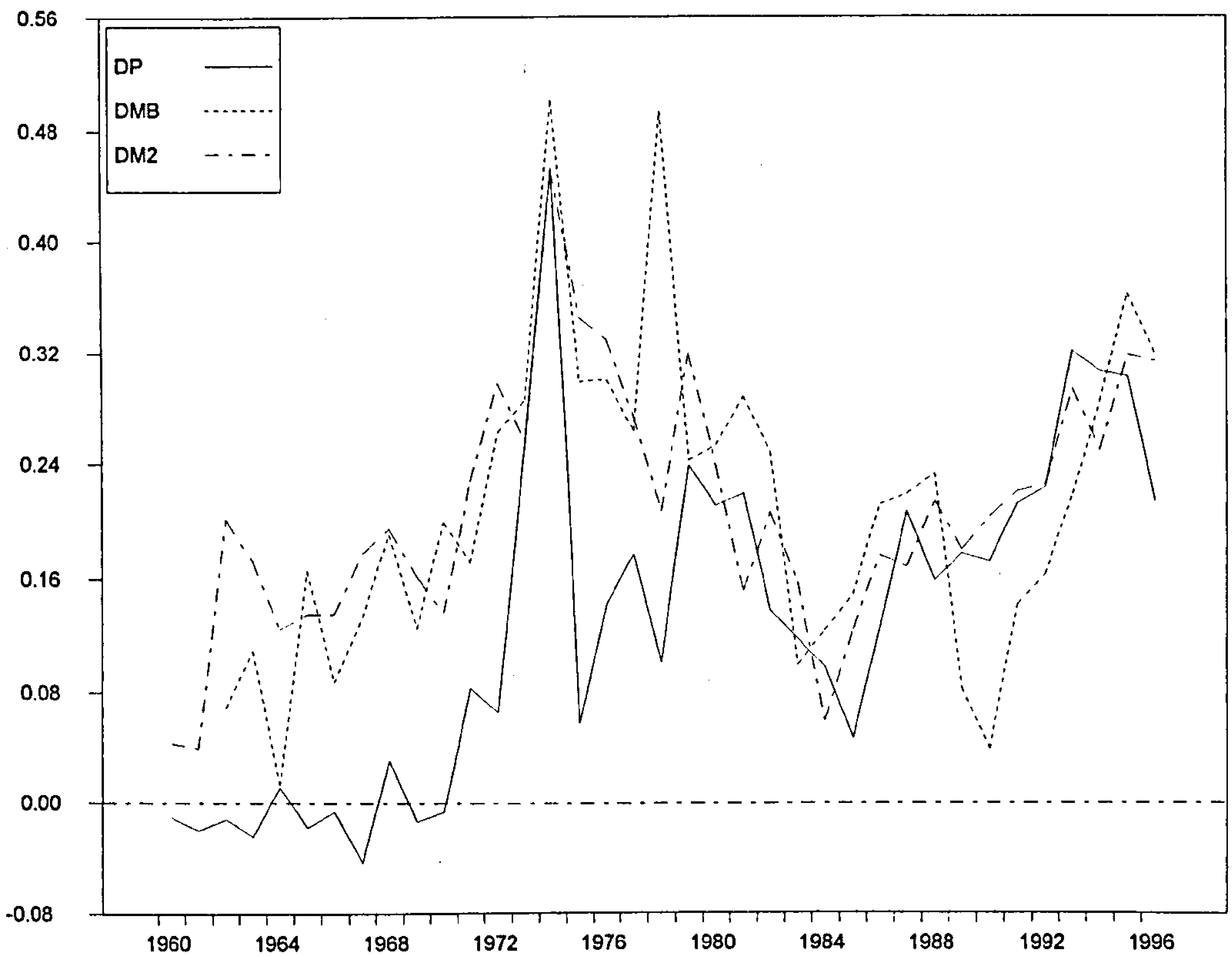


Figure 5.4 The Log of the Real Per Capita GDP in 1990 prices: 1959 – 1996

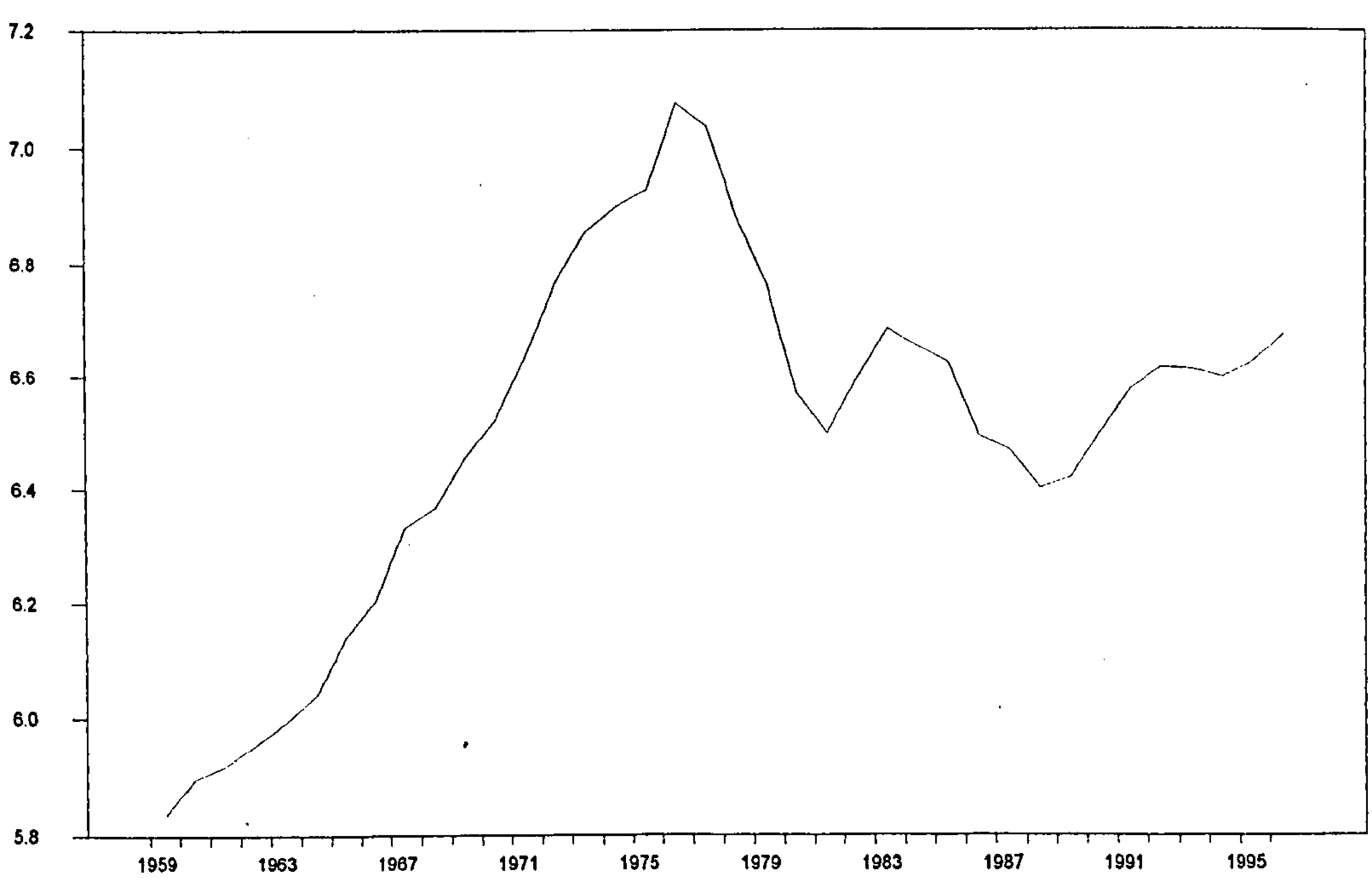
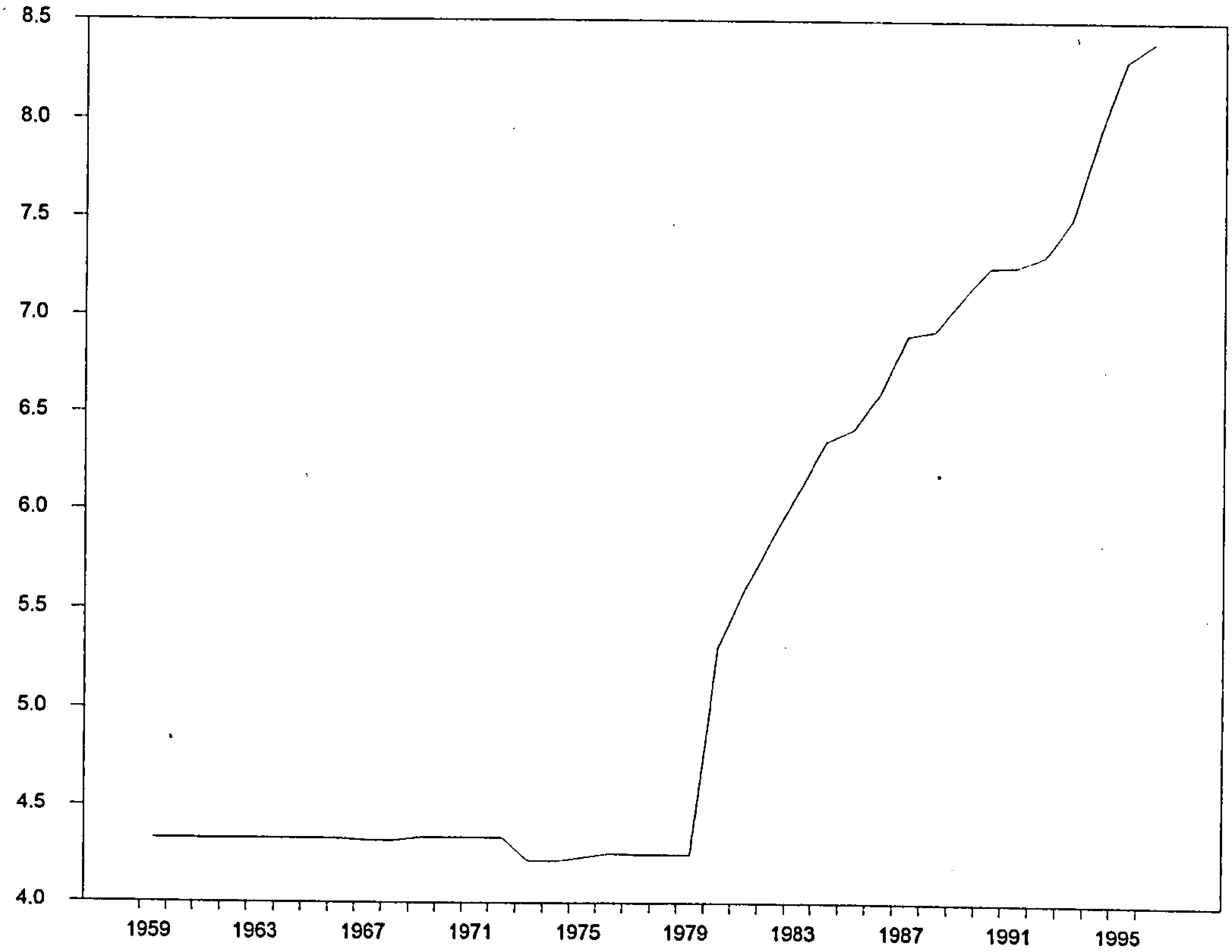


Figure 5.5 The Log of the Parallel Market Exchange Rate: 1959 – 1996



6 EXTERNAL SOURCE OF INFLATION

6.1 Introduction

The objective of this chapter is to examine the transmission of foreign price inflation into the Iranian economy by using a multivariate time–series model. The transmission channel, which happens through the goods market, is analysed by examining the long–run purchasing power parity (PPP) during the period 1959 – 1996. To investigate this, cointegration analysis is carried out based on the Johansen procedure and error correction models are used to analyse the short–run relationships of the variables. Moreover, due to the existence of the various government interventions as well as several internal and external shocks, appropriate dummy variables are included in the analysis. It is demonstrated that there is strong evidence in favour of long–run PPP when two dummy variables are included in the analysis.

The chapter is organised as follows: the next section discusses the theoretical aspects of the external source of inflation using PPP. Section three reviews previous studies concerning PPP in Iran. Section four describes the data and some stylised facts. Section five investigates the integration and cointegration properties of the relevant variables and presents the associated error–correction models. Finally, section six summarises the results.

6.2 External Source of Inflation and Purchasing Power Parity

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:

$$E_t = \gamma P_t + \delta P_t^f \tag{6.1}$$

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 $\delta = -1$.

6.3 Previous Studies of PPP in Iran

Bahmani-Oskooee (1993), Zonnoor and Amiri (1994), and Shiva and Khiabani (1997) have investigated the PPP relationship in Iran. Bahmani-Oskooee (1993) employs quarterly data over the 1973.1 – 1986.2 period, and applies the Engle and Granger (1987) methodology to test for cointegration in the following equation:

$$P = \alpha + \beta P^{FA} + \varepsilon \tag{6.2}$$

where P is the log of the Iranian CPI; and P^{FA} is the log of the weighted average of exchange rate adjusted price levels of trading partners given by:

$$p^{FA} = \sum_{i=1}^{n} w_i e_i p_i^f \tag{6.3}$$

where w_i is the weight given to trading partner i, obtained as the share of the domestic imports from that partner; e_i is the exchange rate defined as rials per unit of i's currency; p_i^f is the price level of trading partner i; and n is the number of trading partners.

His results do not support the presence of a long–run relationship between domestic inflation and exchange rate adjusted foreign inflation using both the parallel and official exchange rates. When a dummy variable, which takes the value of 1 if t > 1980 and 0 otherwise, is included in the cointegration relationship, PPP receives some support only when the parallel market exchange rate is used. Moreover, he estimates the following equation for seven major trading partners of Iran (Canada, France, Germany, Italy, Japan, the UK, and USA).

$$P = \alpha_i + \beta_i (E_i - P_i^f) + \varepsilon_i \qquad i = 1, 2, \ldots, 7 \tag{6.4}$$

where E_i is the log of the exchange rate defined as rials per unit of i's currency; and P_i^f is the log of the price level of trading partner i. The results support PPP for six countries when a dummy variable is included and the parallel market exchange rate is used.

Zonnoor and Amiri (1994) also use quarterly data for Iran during the period 1984.2 – 1992.2. They estimate equation (6.4) for six trading partners of Iran (Australia, Germany, Italy, Japan, Turkey, and the UK).

Since the residuals of the estimated model for each country are not stationary, they conclude that the PPP relationship does not hold in Iran using either parallel or official exchange rates. The contrast of this result to Bahmani–Oskooee's finding may be due to the different sample periods, or the inclusion of a dummy variable by Bahmani–Oskooee.

Shiva and Khiabani (1997) use the Johansen procedure to estimate the PPP relationship, given in equation (6.4), in Iran using monthly data for the period 1982.4 – 1995.3. Using the parallel market exchange rate, and the CPI of Iran and the US, they find two cointegration vectors. They interpret one of the vectors as representing the PPP relationship. They also use an ECM to investigate the causal relationship between the variables included in the model and find some evidence of causality from relative prices to the exchange rate but not in the other direction. These results are in contrast with the findings of Zonnoor and Amiri who find the opposite causal relationship.

In this study, an extended sample period is used and equation (6.1) is also generalised to consider the effects of other relevant variables such as terms of trade, oil prices, as well as the effects of various structural breaks. The set of dummy variables [DO_t, $D7379_t$, DR_t, $D79_t$, DW_t, $D86_t$, $D91_t$] is considered to account for the effects of the following shocks:

- first oil boom (DO_t)
- break in real exchange rate over the period 1973 – 1979 ($D7379_t$)
- revolution (DR_t)
- second oil boom and the start of the eight–year war ($D79_t$)
- eight–year war (DW_t)
- third oil boom ($D86_t$)
- the economic reform programme started in 1989 mainly comprising devaluation of the domestic currency, removal of price controls along with a reduction of government subsidies, and deregulation of trade and tariffs ($D91_t$).

6.4 Data Description and Stylised Facts

The basic data consists of annual observations over 1959 – 1996. In testing PPP, it is important to select appropriate definitions of the variables included in equation (6.1) as well as its generalised form. Concerning prices, three measures are available: wholesale price index, consumer price index, and GDP deflator. As noted in chapters two and five, 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. Figure 6.1 plots the real exchange rate, calculated using the following equation:

$$Z_t = E_t - P_t + P_t^f \tag{6.5}$$

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 eight–year war explain the second break in 1980. To account the effects of these breaks, two dummy variables are included in equation (6.1): $D7379_t$ 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.

Figure 6.2 shows that the growth 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.

6.5 Empirical Analysis

Unit Root Tests

Univariate Augmented Dickey–Fuller (ADF) tests and the Perron procedure are used to test for unit roots in the relevant series. Table 6.1 reports the results of the ADF unit roots tests. For the levels, the null of one unit root cannot be rejected for any of the series, including the real exchange rate. For the changes, the null hypothesis of a unit root is rejected at the 1 % level of significance for all series except foreign price inflation, ΔP_t^f, where the null is only rejected at the 10 % level.

The finding of a unit root in the real exchange rate may be due to the existence of breaks, as shown clearly in Figure 6.1. 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, as discussed before, since two shocks have had permanent effects on the series, 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 in Table 6.2 show the rejection of the null hypothesis at the 5 % level.[1] 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.

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., ΔP_t^f should be I (0) rather than I (1). Also, the ACF of ΔP_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

[1] The Perron critical values are not strictly appropriate, since two dummy variables are considered.

root in ΔP_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 6.1 would suggest.

Figure 6.2 shows that there are clear breaks in the GDP deflator and the exchange rate. To check the possibility that these breaks may affect the ADF tests, the Perron test procedure is employed to test for unit roots. The results in Table 6.2 show clearly that both series are I (1). Thus, only in the case of Z_t does the ADF test give misleading results because of the existence of breaks in the series.

Cointegration Analysis

The Johansen and Juselius (1990) procedure is employed to test for cointegration. To begin with, the number of lags in the autoregressive specification is selected based on the Akaike information criterion (AIC) and the Schwarz Bayesian criterion (SBC) along with the likelihood ratio tests. As can be seen from Table 6.3, all those criteria suggest the order of the VAR to be one. Table 6.4 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 included to account for breaks in PPP.

The cointegrating relationship is written as follows:

$$E_t = \beta_0 + \beta_1 D7379_t + \beta_2 D79_t + \gamma P_t + \delta P_t^f + u_t \qquad (6.6)$$

Table 6.5 reports the results of OLS, Phillips–Hansen, and ML estimation of this equation.[2, 3] 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.

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 (6.6) 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.

The Dynamics of the Model

This section considers error correction models (ECMs) in order to study the short–run relationships among the variables included in the PPP equation. A general ECM is estimated for each of the variables, ΔE_t, ΔP_t, and ΔP_t^f. In each case the list of

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[2] Since the standard errors of the OLS estimator are not valid, t–values of the coefficients are not reported.

[3] 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).

explanatory variables includes: intercept, trend, EC_{t-1}, ΔE_{t-1}, ΔP_{t-1}, and ΔP_{t-1}^{f}, where the error–correction term is calculated from the restricted PPP equation as follows:[4]

$$EC_t = E_t - P_t + P_t^f - 6.27 + 0.50D7379_t - 0.72D79_t. \tag{6.7}$$

The seven dummy variables as mentioned in section two were also included, one by one. Similarly, dummy variables for outliers were used when necessary after looking at the residuals.

After excluding insignificant terms, the models reported in Table 6.6 were obtained. The three models appear to be statistically well specified, with only weak evidence of ARCH in the exchange rate equation. The coefficients of the error correction term are statistically significant and have the correct signs in the models for ΔE_t and ΔP_t. The magnitude of the coefficient of EC_{t-1} in the equation for ΔE_t shows that the adjustment towards long–run PPP occurs mainly through the nominal exchange rate. In the model for ΔP_t^f, the coefficient of the error correction term is not significant. This implies that domestic prices have no effect on the foreign price. This is as expected given that Iran is a small open economy.

According to the results, the external source of inflation in the long–run is exchange rate and foreign price changes, although inflation adjusts rather slowly to PPP deviations. The slow rate of adjustment towards equilibrium is mainly due to higher uncertainty following higher inflation in the economy (see chapter four), imposing barriers on trade, and costly information gathering [see, for example, Johansen and Juselius, (1992)]. In addition, foreign inflation also has a short–run effect on domestic inflation, with a coefficient that is not significantly different from

[4] It should be noted that if the error correction term is calculated using the ML estimates in Table 6.5,

unity. Two dummy variables are significant in the ΔP_t equation. The first shows an increase in domestic inflation following the increase in oil prices in 1973. The second dummy reflects the positive effects on inflation of the adjustment programme that started in 1989 and included the removal of price controls, reductions in government subsidies, and a big exchange rate devaluation.

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 ΔP_t was insignificant, no such evidence is obtained here. On the other hand, the coefficient of the lagged dependent variable is significant in the equation for ΔP_t^f, which supports the inflation inertia hypothesis for the US.

6.6 Conclusion

This chapter analysed the international transmission effects on domestic prices in Iran during 1959 – 1996. It was found that purchasing power parity (PPP) holds in the long–run after accounting for structural breaks in 1973 and 1980. The OLS, P–H and ML estimators all provided very similar estimates, which can be considered as a sign of the robustness of the results. The error correction models show that deviations from PPP are eliminated mainly through changes in the nominal exchange rate. Domestic inflation also adjusts to PPP deviations, but more slowly. However, as would be expected, foreign inflation is not caused by changes in either the exchange rate or domestic inflation.

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the results are very similar.

Table 6.1 Univariate Augmented Dickey–Fuller Tests: 1959 –1996

Regression: $\Delta Y_t = \hat{\mu} + \hat{\alpha} T + \hat{\delta} Y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta Y_{t-i} + \hat{\varepsilon}_t$

	n	k	$\hat{\mu}$	$t_{\hat{\mu}}$	$\hat{\alpha}$	$t_{\hat{\alpha}}$	$\hat{\delta}$	$t_{\hat{\delta}}$
P_t	36	1	-0.30	-1.85	0.013	2.64	-0.06	-1.78
ΔP_t	36	0	-.016	-0.50	0.005	2.64	-0.64	-3.91**
P_t^f	36	1	-0.12	-1.89	0.004	1.99	-0.08	-2.17
ΔP_t^f	35	1	0.02	1.69	-0.003	-0.52	-0.38	-3.19*
P_t^{EX}	36	1	-0.59	-1.74	0.020	2.27	-0.09	-1.76
ΔP_t^{EX}	35	1	-0.02	-0.22	0.010	2.16	-0.94	-4.65***
P_t^{IM}	37	0	0.19	1.98	0.002	0.68	0.07	2.68
ΔP_t^{IM}	36	0	-0.05	-1.63	0.007	3.57	-0.73	-4.39***
E_t	37	0	0.13	0.79	0.015	2.37	-0.06	-1.20
ΔE_t	36	0	-0.10	-0.65	0.007	2.02	-0.84	-4.82***
TOT_t	36	1	-0.47	-1.98	0.013	1.90	-0.21	-2.24
ΔTOT_t	36	0	0.04	0.54	-0.010	-0.20	-0.71	-4.21***
O_t	36	1	0.05	0.43	0.010	0.85	-0.09	-1.35
ΔO_t	36	0	0.12	1.12	-0.003	-0.61	-0.71	-4.25***
Z_t	36	1	0.95	1.85	0.005	1.27	-0.16	-1.84

Notes:

- Δ is the difference operator; P_t is the log of the GDP deflator; P^f_t is the log of wholesale prices of the US; P_t^{EX} is the log of the price of exports; P_t^{IM} is the log of the price of imports; E_t is the log of the parallel market exchange rate; TOT_t is the log of the terms of trade; O_t is the log of the domestic oil price; and Z_t is the real exchange rate.
- n is the number of observations; and k is the number of lags.
- ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively, according to the critical values of the ADF test.

Table 6.2 Univariate Perron Tests for Unit Roots (Model A and C): 1959 – 1996

Regressions: Model (C)

$$Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\beta}D_t + \hat{d}TB_t + \hat{\delta}DT_t + \hat{\gamma}Y_{t-1} + \sum_{i=1}^{k}\hat{c}_i\Delta Y_{t-i} + \hat{\varepsilon}_t$$

Model (A) $$Y_t = \hat{\mu} + \hat{\alpha}T + \hat{\beta}D_t + \hat{d}TB_t + \hat{\gamma}Y_{t-1} + \sum_{i=1}^{k}\hat{c}_i\Delta Y_{t-i} + \hat{\varepsilon}_t$$

	Model (A)	Model (C)	Model (A)	Model (C)	Model (A)
	Z_t	P_t	ΔP_t	E_t	ΔE_t
n	37	36	36	36	35
k	0	1	0	1	1
λ	0.54	0.35	0.35	0.54	0.54
$\hat{\mu}$	1.83	-0.60	-0.02	1.69	-0.001
$t_{\hat{\mu}}$	(3.98)	(-1.49)	(-0.69)	(2.89)	(-0.01)
$\hat{\alpha}$	-0.004	0.004	0.003	-0.002	-0.02
$t_{\hat{\alpha}}$	(-1.36)	(0.60)	(1.27)	(-0.71)	(-0.06)
$\hat{\beta}$	0.33	-0.32	0.08	-0.93	1.01
$t_{\hat{\beta}}$	(3.63)	(-0.98)	(1.51)	(-2.36)	(3.66)
$\hat{d}$	0.48	0.11	0.13	0.47	-0.02
$t_{\hat{d}}$	(3.56)	(1.22)	(1.58)	(2.63)	(-2.07)
$d7\hat{3}79$	-0.19	-	-	-	-
$t_{d7\hat{3}79}$	(-3.02)	-	-	-	-
$\hat{\delta}$	-	0.03	-	0.07	-
$t_{\hat{\delta}}$	-	(1.21)	-	(2.87)	-
$\hat{\gamma}$	0.71	0.82	0.25	0.61	-0.44
$t_{\hat{\gamma}-1}$	(-3.82)**	(-1.38)	(-4.41)***	(-2.90)	(-6.26)***

Notes:

- Z_t is the real exchange rate; P_t is the log of the GDP deflator; and E_t is the log of the nominal 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 $t^* = 1973$ for P_t and $t^* = 1980$ for E_t and Z_t.

- $D7379_t$ is additional dummy variable in the real exchange rate model to take into account the effect of the second break in 1973, which takes the value of 1 if t = 1973 – 1979 and 0 otherwise.
- n is the number of observations; k is the number of lags; and λ denotes the ratio of pre–break sample size to total sample size.
- *** and ** indicate statistical significance at the 1% and 5% levels, according to the critical value of the Perron test (1989, Tables IV.A and VI.C).

Table 6.3 Selecting the Order of the VAR Model: 1961– 1996

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 6.4 Cointegration Results Based on Johansen's Maximum Likelihood Procedure

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

Notes:

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

Table 6.5 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).

Table 6.6 Error Correction Models of Exchange Rate, Domestic and Foreign Prices

Model for	ΔE_t		ΔP_t		ΔP_t^f	
Explanatory Variables:						
Intercept	-		-		0.01	(1.33)
DO_t	-		0.12	(5.43)	-	
$D7379_t$	-		-		-	
$D79_t$	0.20	(10.98)	-		-	
$D91_t$	-		0.15	(4.43)	-	
$TB73_t$	-		-		0.08	(3.01)
$TB75_t$	-		-0.26	(-3.55)	-	
$TB80_t$	0.78	(10.35)	-		-	
ΔE_{t-1}	-		-		-	
ΔP_{t-1}	-		-		-	
ΔP_{t-1}^f	-		1.09	(3.46)	0.74	(7.02)
EC_{t-1}	-0.28	(-3.96)	0.14	(2.30)	0.02	(0.90)
n	37		36		36	
$\overline{R}^2$	0.878		0.753		0.618	
s	0.0711		0.0594		0.0270	
DW	1.87		1.78		-	
$\chi^2_{SC}(1)$	0.05	[0.82]	0.29	[0.59]	0.57	[0.45]
$\chi^2_{FF}(1)$	2.53	[0.11]	2.10	[0.15]	0.08	[0.77]
$\chi^2_{N}(2)$	2.49	[0.29]	1.29	[0.52]	0.92	[0.63]
$\chi^2_{ARCH}(1)$	5.16	[0.03]	0.17	[0.68]	2.57	[0.11]
F_1	0.67	[0.58]	1.24	[0.31]	0.86	[0.43]
F_2	0.07	[0.93]	0.02	[0.98]	1.18	[0.84]

Notes:

- Δ is the difference operator; 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.
- DO_t is dummy variable for the first oil boom, which takes 1 if t > 1972 and 0 otherwise; D7379 is dummy variable for the real exchange rate, which takes 1 if t = 1973 – 1979 and 0 otherwise; D79 is dummy variable for the second oil boom and the eight–year war, which takes 1 if t > 1979 and 0 otherwise; D91 is dummy variable for the economic reform programme, which takes 1 if t > 1991 and 0 otherwise; $TB73_t$ = 1 if t = 1973 and 0 otherwise; $TB75_t$ = 1 if t = 1975 and 0 otherwise; $TB80_t$ = 1 if t = 1980 and 0 otherwise.
- The error correction term is $EC_t = E_t - P_t + P_t^f - 6.27 + 0.50D7379_t - 0.72D79_t$.

- The numbers in brackets next to regression coefficients are t–statistics; and the numbers in square brackets next to diagnostic test statistics are P–values.

- n is the number of observations; $\overline{R}^2$ is the adjusted squared multiple correlation coefficient; s is the standard error of regression; DW is the Durbin–Watson statistic; χ^2_{SC} is Lagrange Multiplier (LM) test statistic for residual autocorrelation; χ^2_{FF} is RESET statistic for misspecification; χ^2_N is Jarque–Bera test statistic for normality; χ^2_{ARCH} is test statistic for autoregressive conditional heteroscedasticity; F_1 and F_2 are F–test statistics for the significance of all the omitted variables, and P_{t-1} and P^f_{t-1} variables, respectively.

Figure 6.1 The Real Exchange Rate: 1959 – 1996

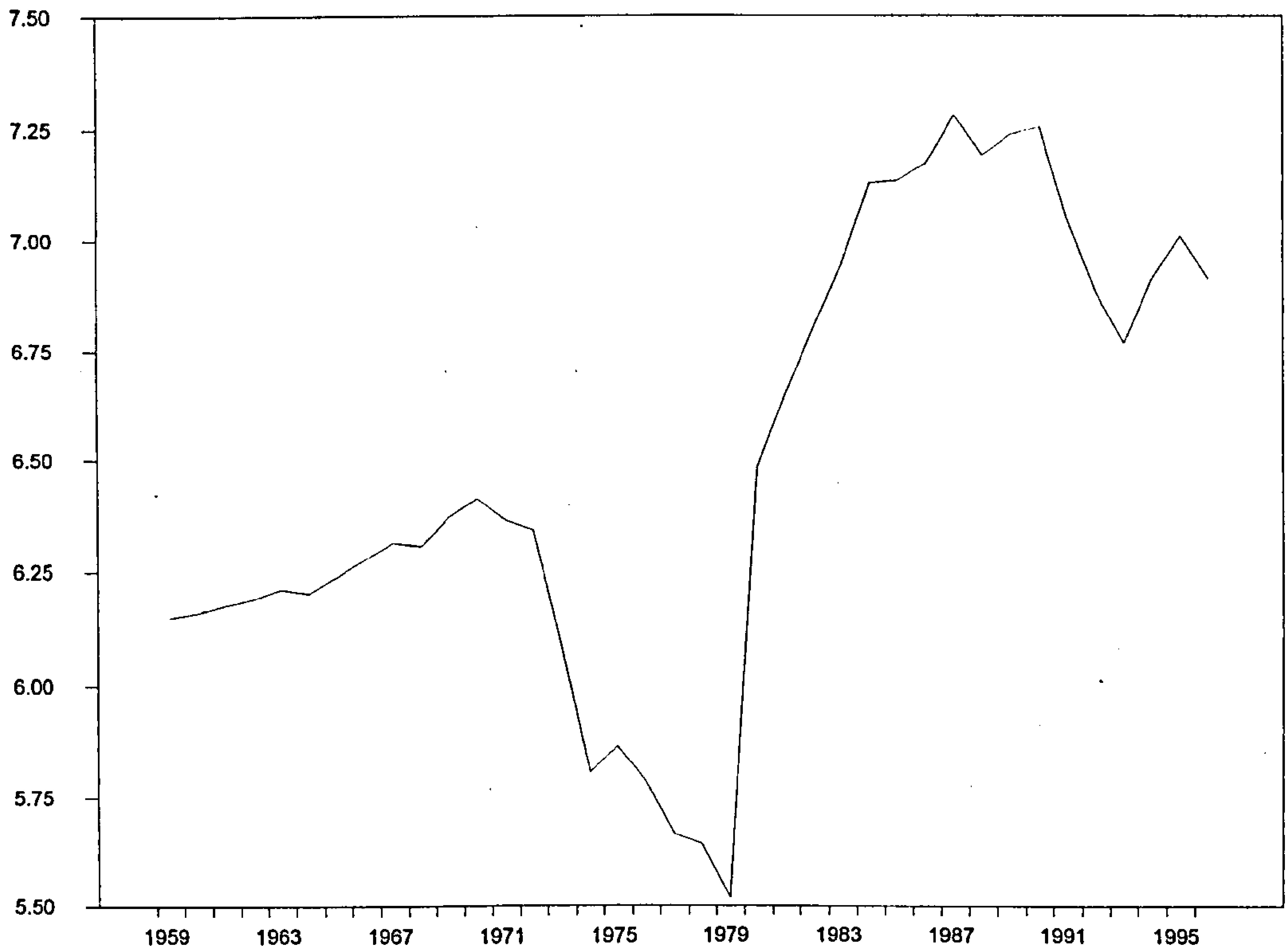
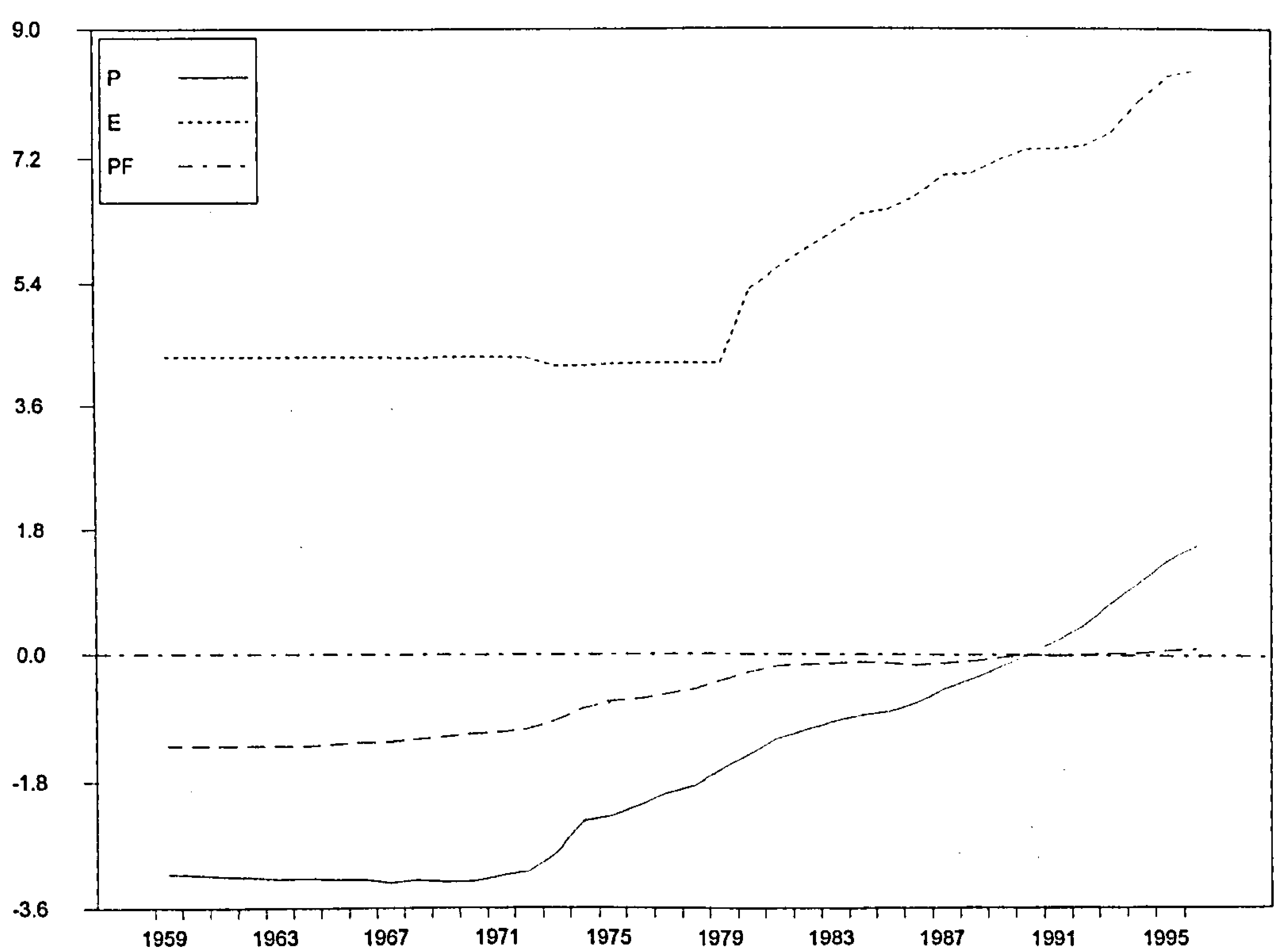


Figure 6.2 The Logs of the GDP Deflator (P), Nominal Exchange Rate (E), and Foreign Prices (PF): 1959 – 1996



7 DEVELOPING A DYNAMIC MODEL OF INFLATION

7.1 Introduction

The aim of this chapter is to develop a dynamic model to investigate the main determinants of inflation in Iran using the cointegration results of chapters five and seven. The model combines the monetarist approach to inflation that considers excess money supply as the source of inflation together with the external transmission channel of inflation through PPP. These two sources of inflation, through the money demand function and the PPP relationship, are analysed through an error correction model.

The model can be extended to analyse the effect on inflation of other factors such as oil prices, terms of trade, and real per capita government spending. The key empirical findings show that in the long–run domestic inflation appears to be determined by excess money supply, the exchange rate and foreign prices, while in the short–run changes in the oil price also have an effect.

The chapter is organised into four sections. The next section reviews previous studies of inflation in Iran. Section three develops a dynamic model of inflation. Finally, section four presents the empirical analysis and draws tentative conclusions.

7.2 Previous Studies of Inflation in Iran

There are a number of studies concerning the analysis of inflation in Iran. These studies are categorised into two groups to analyse their merits and shortcomings. The first group of studies such as Dadkhah (1985), Nili (1985), Looney (1985), Eikani (1987), Darrat (1987), Makkian (1990), Tabatabi–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. The second group of studies such as Bahmani–Oskooee (1995), Tavakkoli (1996), 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 uses an error correction model.

Bahmani–Oskooee (1995) specifies an augmented monetarist model of inflation in the following form:

$$P_t = \alpha + \beta M2_t + \theta Y_t + \gamma IP_t + \lambda E_t + \varepsilon_t \tag{7.1}$$

where all variables are in logarithms; P_t is the CPI; $M2_t$ is nominal money supply; Y_t is real GDP; IP is world import prices proxied by the index of unit value of industrial countries' exports; and E_t is the parallel market exchange rate. He uses annual data over the period 1959 – 1990 and finds that Y_t, E_t, and IP_t are I (1), while P_t and $M2_t$ are I (2) using the Perron procedures. However, he concludes that P_t and $M2_t$ can also be regarded as I (1) variables for three reasons. Firstly, Perron's statistic is not strongly significant; secondly, the ADF test (without including any dummy variable) shows that both variables are I (1); thirdly, the autocorrelation function suggest that the first differences of the series are stationary.

Using the Engle–Granger procedure, he finds that equation (7.1) is cointegrated when a dummy variable for the revolution (*D*78) together with a linear trend are included. The estimated regression is reported below:

$$P_t = 5.17 + 0.01T - 0.30D78_t + 0.52M2_t - 0.71Y_t + 0.04IP_t + 0.26E_t \qquad (7.2)$$

$R^2 = 0.99$ DW = 1.05

As can be seen, money supply, import prices and the exchange rate have positive effects while real GDP has a negative effect on the price level.

Tabibian and Souri (1997) also start with equation (7.1) but use import prices as a proxy for the exchange rate. They use annual data over 1959 – 1995 and find two long–run relationships based on the Johansen procedure, after allowing for the revolution in 1978 and the third oil shock in 1986 through dummy variables. The estimated equations are (numbers in brackets are t–statistics):

$$P_t = M2_t - \underset{(-9.41)}{1.60}Y_t \qquad (7.3)$$

which describes the quantity theory of money, and

$$IP_t = M2_t - \underset{(-6.68)}{2.07}Y_t \qquad (7.4)$$

which shows the positive effects of nominal money supply and negative effects of real GDP on import prices.

Tavakkoli (1996) is the only study of inflation in Iran to use a dynamic model constructed using cointegration analysis. He uses a model originally proposed by Aghevli and Khan (1978) and models a price equation, which includes nominal balances, nominal government spending, the expected rate of inflation, and excess money supply. He employs quarterly data over the period 1972.1 – 1990.1 and obtains the following error correction model:

$$\Delta P_t = 0.23\Delta M_t + 0.04\Delta g_{t-2} - 0.40\Delta \pi_{t-2} + 0.09EC_{t-1} \qquad (7.5)$$

(2.79) (2.24) (-2.30) (4.10)

where $EC_t = MP_t - 0.10Y_t + 5.70\pi_t - 0.05T - 2.06D_t + 0.06DT_t$, ΔP_t is the inflation rate; M is the log of nominal M1; g_t is the log of nominal government expenditure; and π_t is the expected rate of inflation. Expectations are formed adaptively, and D_t and DT_t are dummy variables: D_t takes the value 1 if t > 1980.2 and 0 otherwise, while DT_t = t if t > 1980.2 and 0 otherwise. This model is more appropriate for a closed economy rather than an open economy such as Iran. Moreover, the value of 0.10 for the income elasticity of money demand seems too low.

7.3 A Dynamic Model of Inflation

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
- external theories of inflation
- inertia theories of inflation

The monetary theories emphasise the unique role of excess money as an independent cause of inflation in a closed economy. The external theories of inflation describe the foreign transmission channels of inflation in a small open economy.

Among the inertia theories of inflation, backward–looking indexation is considered by using lagged inflation to explain price inertia.[1]

Theoretically, other markets such as labour and capital markets also affect inflation. However, in the case of Iran, there is no strong labour union and the wage rate is 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 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 (1991) and Durevall and Ndung'u (1999)]. The relevant cointegration relationships were estimated separately in chapters five and seven. Here a general error correction model is specified which includes the error correction terms from both the money demand function and the PPP relationship. The model also contains other relevant variables, which are stationary and may have short–run effects on inflation.

The general form of the error correction model is as follows:

[1] For details of the inertia theories of inflation such as backward and forward looking indexations see, for example, Heyman and Leijonhufvud (1995).

$$\Delta P_t = \beta_0 + \beta_1 T + \beta_2 \Delta PMP2_{t-1} + \beta_3 \Delta PY_{t-1} + \beta_4 \Delta P_{t-1} + \beta_5 \Delta E_{t-1} + \beta_6 \Delta P^f_{t-1} + \delta_1 \Delta O_{t-1} + \delta_2 \Delta TOT_{t-1} + \delta_3 \Delta G_{t-1} + \lambda_1 EC1_{t-1} + \lambda_2 EC2_{t-1} + \Phi D_t + \varepsilon_t \quad (7.6)$$

where $PMP2_t$ is the log of per capita real balances; PY_t is the log of real per capita 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 imoprt prices; G_t is the log of real per capita government spending; D_t is a set of dummy variables; and $EC1_t$ and $EC2_t$ are the error correction terms derived from the money demand function in chapter five and the PPP relationship in chapter seven and are defined as follows:

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

$$EC2_t = E_t - P_t + P_t^f - 6.27 + 0.50D7379_t - 0.72D79_t$$

7.4 Empirical Results and Conclusion

Given annual observations and the limited sample size, only one lagged value of the differenced series[2] is included in the general model (7.6). After simplification the following model is obtained:[3]

$$\Delta P_t = 0.17DO_t + 0.10D91_t - 0.36TB75_t - 0.11TB88_t + 0.14\Delta O_{t-1} \quad (7.7)$$

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

[2] The order of integration of all series considered in this chapter was determined in previous chapters except for nominal and real per capita government spending. The ADF results for these series show that there is a unit root in the level but not in the first difference of these series.

[3] A general error correction model similar to (7.6) was also estimated for real balances and the exchange rate, but there was no improvement compared to the models reported in chapters five and seven.

$$+0.10EC1_{t-1} + 0.11EC2_{t-1}$$

(2.23) (2.05)

$n = 36$ $\overline{R}^2 = 0.802$ $s = 0.0532$ $\chi^2_{SC}(1) = 0.05$ [0.83]

$\chi^2_{FF}(1) = 2.03$ [0.15] $\chi^2_{N}(2) = 0.9$ [0.95] $\chi^2_{ARCH}(1) = 0.58$ [0.45]

$F_1(7, 22) = 0.78$ [0.61] $F_2(4, 25) = 1.96$ [0.13]

where n is the number of observations; $\overline{R}^2$ is the adjusted squared multiple correlation coefficient; s is the standard error of regression; χ^2_{SC} is Lagrange Multiplier (LM) test statistic for residual autocorrelation; χ^2_{FF} is RESET statistic for misspecification; χ^2_{N} is Jarque–Bera test statistic for normality; χ^2_{ARCH} is test statistic for autoregressive conditional heteroscedasticity; F_1 is F–statistic for the joint significance of the omitted variables: $\Delta PMP2_{t-1}$, ΔPY_{t-1}, ΔP_{t-1}, ΔE_{t-1}, ΔP^f_{t-1}, ΔTOT_{t-1}, and ΔG_{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 both error correction terms are significant and have the correct signs. 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.

Apart from the effects of adjustment to deviations from PPP and equilibrium money demand, there are 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 ΔP_{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 subsides 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 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. However, the fact that both adjustment coefficients are very low means that such policies may not be effective.

8 SEIGNIORAGE AND INFLATION

8.1 Introduction

This chapter examines the relationship between seigniorage and inflation in Iran. Seigniorage is the raising of revenue by money creation, and can be used by the government to finance expenditure when taxes cannot be raised from other sources. A number of issues are examined in this chapter: whether a Laffer curve relationship exists between seigniorage revenue and the rate of inflation; the rate of monetary expansion that maximises seigniorage revenue; model stability under adaptive and rational expectations; and the speed of agents' response to shocks, such as an unanticipated increase in the inflation rate, in adjusting their holding of real balances.

The per capita money demand function is used as a basis for answering the above questions. The evidence shows that the actual rates of monetary growth and inflation generally exceeded the corresponding rates that would maximise seigniorage revenue over the sample period. This means that the government could have obtained extra seigniorage with a lower rate of inflation. The estimated model can be used to determine the rate of monetary expansion that would maximise seigniorage in future periods under different assumptions about output and population growth.

The structure of the chapter is as follows: Section two analyses a basic model of seigniorage and inflation. Section three introduces a model corresponding to the characteristics of the Iranian economy. Section four discusses the empirical results, and section five concludes.

8.2 Seigniorage and Inflation: A Basic Analysis

In developed economies governments tend to resort little to seigniorage and rely, instead, on taxation and bond sales, or borrowing, to finance their expenditures [see Fischer, (1982)]. But it may be more important for countries which do not rely on bonds, such as Iran, or which have less well-developed tax systems. Since money creation is associated with inflation, it is important to examine the relationship between inflation and seigniorage. The famous analysis of Cagan (1956) is first considered and then the analysis is modified to better fit the Iranian case.[1]

8.2.1 Some Terminology

Before examining Cagan's model it will be useful to define some terminology such as seigniorage, inflation tax, Laffer curve, the use of seigniorage to finance, and adaptive and rational expectations.

[1] This analysis is based upon the exposition of Blanchard and Fischer (1994).

Seigniorage[2] is defined as the real revenues of a government acquired by printing new money. In this study, the following conventional definition of seigniorage is used:[3]

$$S = \frac{\Delta M}{P} = (\frac{\Delta M}{M})(\frac{M}{P}) = \mu \frac{M}{P} = \mu m \tag{8.1}$$

where S is seigniorage; M is aggregate nominal money balances; P is the price level; m is aggregate real money balances; and $\mu = \frac{\Delta M}{M}$ is the growth rate of aggregate nominal money.

The inflation tax refers to the total loss in the value of real balances in the face of inflation, in other words, this is equal to the real depreciation of the public's cash holdings. The inflation tax can be expressed formally as

$$IT = \pi \frac{M}{P} = \pi m \tag{8.2}$$

where IT represents inflation tax; and π is the rate of inflation. It is common to interpret π as the inflation tax rate and m as the tax base. In equilibrium, the inflation tax and seigniorage are equal, since $\pi = \mu$.[4]

The concept of the Laffer curve was originally introduced to analyse the relationship between taxes paid and the rate of tax. This concept can be applied to monetary policy. In this case, the Laffer curve shows the relationship between seigniorage revenue and the rate of inflation. Figure 8.1 represents the Laffer curve

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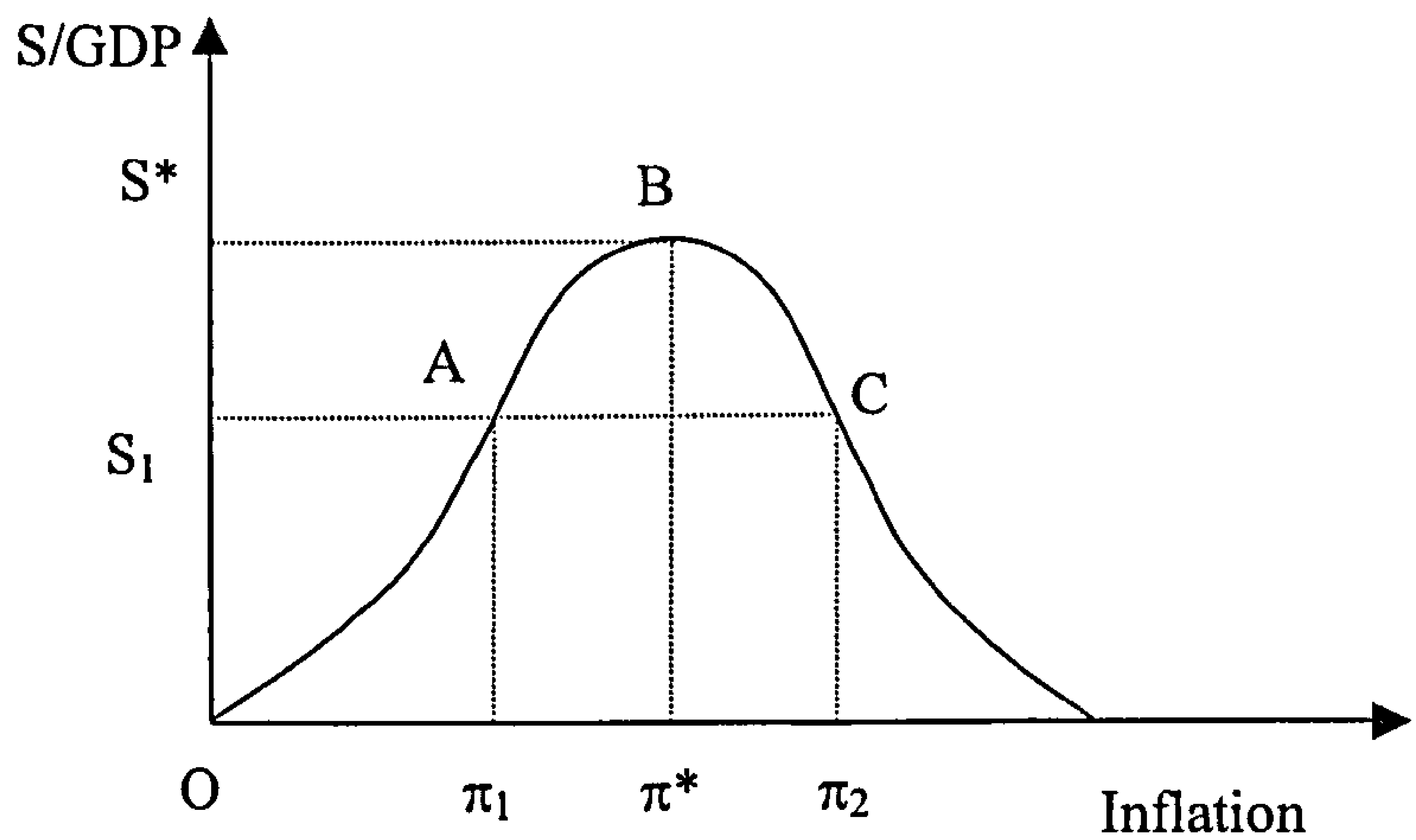
[2] The term of seigniorage comes from *seigneur*. This French word was used for feudal lord in the Middle ages. The feudal lord had monopoly right on his land to coin money, while this right belongs to the government today [see, for example, Mankiw (1997)].

[3] See, for example, Friedman (1971), Bruno and Fischer (1990), Blanchard and Fischer (1994), and Obstfeld and Rogoff (1996).

[4] This statement assumes that inflation is solely due to demand side pressures caused by money creation. In what follows we do not consider any supply side causes, or consequences, of inflation.

in the context of monetary policy. The horizontal axis measures the rate of inflation and the vertical axis measures seigniorage revenue as a percentage of GDP.

Figure 8.1: The Laffer Curve



Initially as the rate of creation of money and the rate of inflation rises, seigniorage also increases. At point B seigniorage revenue is at a maximum, S*, corresponding to an inflation rate of π^*. At any higher rate of money creation, the total seigniorage revenue will decline while the rate of inflation increases. This happens because, with the higher rate of inflation people like to hold less money than before, since they choose to avoid the inflation tax and hence their real balances are lower. At C, for example, with $\pi_2 > \pi_1$, revenue is the same as at A; although the tax rate is higher with a higher inflation rate, the tax base, m, is lower at C than at A.

Developing countries such as Iran have little access to financial markets or to foreign resources to finance budget deficits. Seigniorage is the main source of government financing and the fiscal deficit may be assumed to be financed entirely by money growth. Hence, the government budget constraint can be written as follows:

$$D_t = M_t - M_{t-1} \quad (8.3)$$

where D is the primary deficit i. e. G – T; where G and T are government expenditure and tax revenue at current prices, respectively. Equation (8.3) can be rewritten as

$$d_t = m_t - m_{t-1} + m_{t-1}\frac{\pi}{1+\pi} \quad (8.4)$$

where d and m are in real terms and $\pi_t = \frac{\Delta P_t}{P_{t-1}}$. The continuous time version of (8.4) is:

$$d_t = \dot{m}_t + m_t \pi_t \quad (8.5)$$

where $\dot{m}_t$ is the time derivative of real money balances. In equilibrium, with $\dot{m} = 0$ and $\pi = \mu$, equation (8.5) reduces to $d_t = \mu m_t = S_t$.

Two forms of inflation expectations are considered, adaptive expectations (or error learning) and rational expectations. Under adaptive expectations, economic agents revise their expectations based on the most recent error. In particular, agents'expectations change according to:

$$\frac{d\pi^e}{dt} = \beta(\pi - \pi^e) \qquad 0 < \beta \leq 1 \quad (8.6)$$

where β reflects the speed of revision of expectations. This expression says that agents revise their expectations each period by a fraction, β, of the forecast error. So if π exceeds π^e, the expected rate of inflation increases. Under rational expectations, economic agents generally do not waste information and so, expectations are based on the structure of the entire system. This can be written formally as:

$$\pi^e = E(\pi \mid \Phi_{t-1}) \quad (8.7)$$

where E is the mathematical expectations operator; and Φ_{t-1} is all the information available at time t-1.

8.2.2 Cagan's Model and Seigniorage–Maximisation

Cagan examined the hyperinflation experience in several European economies in the first half of this century. Under short periods of hyperinflation,[5] he was able to assume that changes in real variables, such as population, output and the real interest rate, were negligible relative to the monetary changes. This simplification helps to focus on monetary matters but will be relaxed later since for the period we examine it is necessary to recognise that real variables changed.

Given this simplification, Cagan used an aggregate demand for money function of the following form:

$$m^d = (\frac{M}{P})^d = c\exp(-\alpha\pi^e) \qquad c, \alpha > 0 \tag{8.8}$$

The higher the expected inflation, the lower the real demand for money balances since agents want to avoid the inflation tax. Cagan assumed that in a hyperinflation environment the change in the price level ensures that desired and actual cash balances are continuously equated. He also assumed that π^e is formed according to the adaptive expectations hypothesis.

The money demand function affects the calculation of the seigniorage–maximising inflation rate. Using the equilibrium condition, $M^d = M^s = M$, equation (8.8) yields:

[5] He arbitrarily defined hyperinflation to be inflation of more than 50 percent per month.

$$M = Pc\exp(-\alpha\pi^e) \tag{8.9}$$

Differentiating this with respect to time after taking logarithms yields:

$$\frac{\dot{M}}{M} - \frac{\dot{P}}{P} = \mu - \pi = -\alpha\dot{\pi}^e \tag{8.10}$$

In steady state, with $\dot{m} = \dot{\pi} = 0$, (8.10) yields:

$$\pi^e = \pi = \mu \tag{8.11}$$

Substituting the real money demand function into the seigniorage equation (8.1) yields:

$$S = \mu c\exp(-\alpha\pi^e) \tag{8.12}$$

Using the steady state condition (8.11), the maximum steady state seigniorage revenue, S^*, can be obtained by:

$$S^* = \max_{\{\pi\}} \pi c\exp(-\alpha\pi) \tag{8.13}$$

Accordingly, the rate of monetary growth that maximises seigniorage is:

$$\mu^* = \pi^* = \frac{1}{\alpha} \tag{8.14}$$

This shows that the revenue–maximising net rate of money growth is simply the inverse of the semi–elasticity with respect to inflation, α, in the demand for real money function.

The corresponding maximum level of seigniorage is:

$$S^* = \frac{c}{e}\frac{1}{\alpha} \tag{8.15}$$

8.2.3 Dual Equilibrium and Inflation Expectations

Since the rate of inflation that generates enough seigniorage revenue to finance the deficit depends on money demand, and this varies with inflationary expectations, the price level path depends on how expectations are formed. The stability properties of the system also depend upon inflation expectations and upon whether one assumes expectations to be formed adaptively or rationally. This section examines such issues to compare the behaviour of the economy under adaptive and rational expectations.

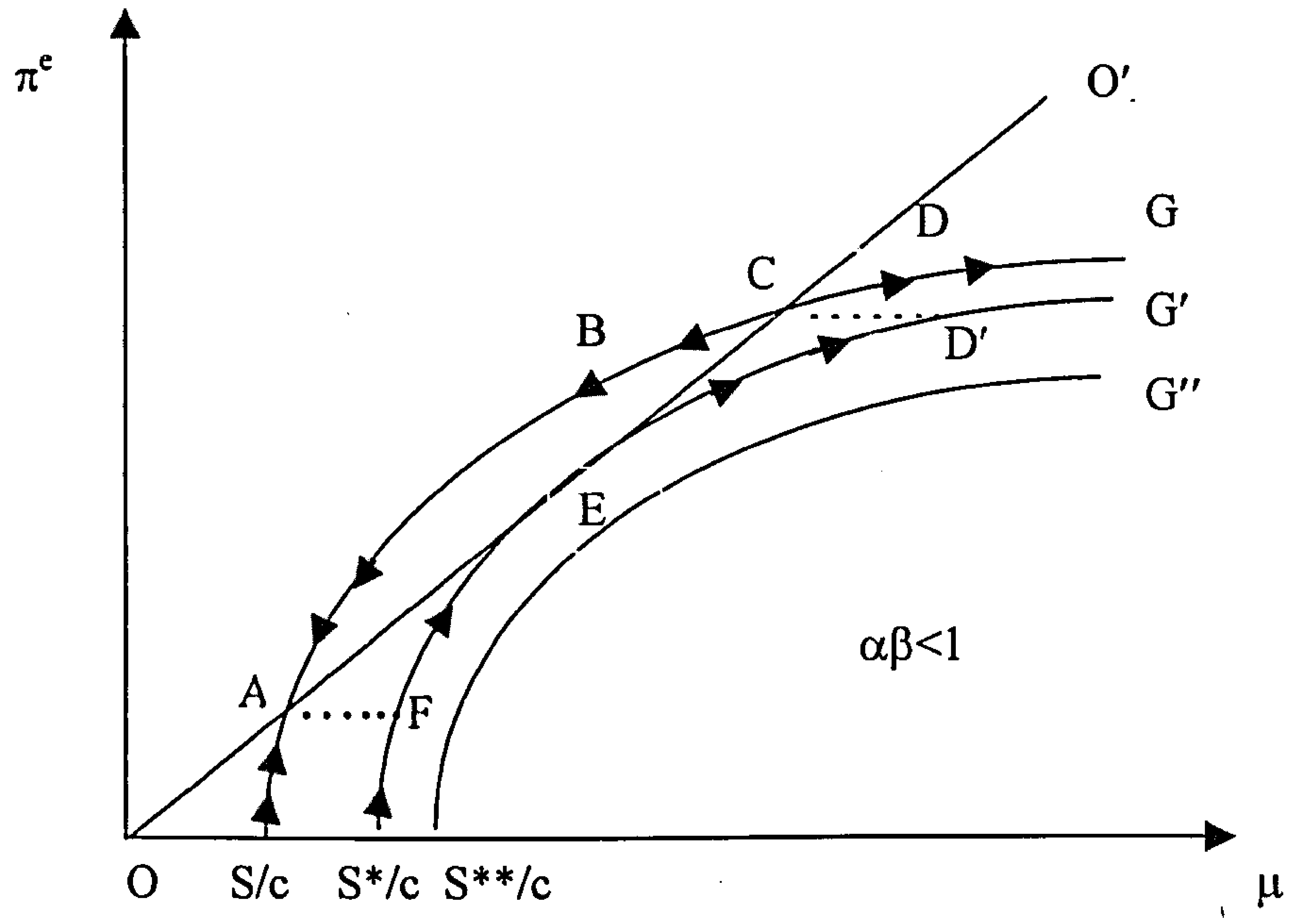
Adaptive Expectations

Consider that a government wishes to finance a fixed amount of real expenditure using seigniorage. For a given level of seigniorage, equation (8.12) may be written as follows:

$$\pi^e = \frac{1}{\alpha}\ln(\mu c) - \frac{1}{\alpha}\ln S \qquad (8.16)$$

For a given value of *S*, equation (8.16) shows the relationship between expected inflation, π^e, and the rate of monetary growth, μ. This relationship yields the iso–seigniorage or G–curves plotted in Figure 8.2, each curve showing a positive relationship between the expected rate of inflation and the growth rate of money. The vertical axis of Figure 8.2 measures the expected rate of inflation and the horizontal axis measures the growth rate of money. A change in seigniorage shifts the G–curve to the right or left. A rise in seigniorage revenue leads to a movement to the right, while a fall leads to a leftward movement.

Figure 8.2: Dynamics of Inflation with Fixed Seigniorage: under adaptive expectations



The figure shows three G–curves, G, G′ and G″ and the steady–state line, OO′. In steady state, the growth rate of money, μ, is equal to the expected rate of inflation, π^e, which is shown by the 45–degree line. Consider the curve G. The intersections of this curve and the 45–degree line give two steady state values of the growth rate of money. Similarly, note that the curve G′ yields a unique steady state, whilst the curve G″ yields no steady state. Thus, it is possible to have two, one or no steady state inflation rates depending on the level of seigniorage. The maximum level of seigniorage consistent with steady state inflation, S^*, underlies the curve G′. For a lower level of seigniorage, such as that underlying the curve G, there are two steady states (as shown at points A and C on the figure), and for a higher level of seigniorage there is no steady state.

To understand the stability of the system, substitute π from equation (8.10) into (8.6) to yield:

$$\dot{\pi}^e = \frac{\beta}{(1-\alpha\beta)}(\mu - \pi^e) \tag{8.17}$$

First, consider the case when $\alpha\beta < 1$. In this case examination of (8.17) shows that if the economy starts from any point above the 45–degree line, for example point B on the curve G, where $\mu \prec \pi^e$, the expected rate of inflation is falling. If the economy starts from any point below the 45–degree line, for example point D on the curve G, where $\mu \succ \pi^e$, expected inflation is rising. The arrows shown on the curve G, therefore, show the direction of inflation and indicate that the steady state at A is locally stable and that at C is unstable.

At both steady state points on curve G, the government earns the same level of seigniorage revenue. But point A corresponds to large real balances with a lower rate of inflation, while point C corresponds to small real money balances with a higher rate of inflation. We assume that point A is preferable since it yields the same revenue at a lower inflation rate.[6]

If the coefficient of adaptive expectations or the elasticity of the demand function with respect to inflation is sufficiently large, so that $\alpha\beta > 1$, the results are reversed. In this case, if the economy starts from any point above the 45–degree line where $\mu \prec \pi^e$, the expected rate of inflation is rising. If the economy starts from any point below the 45–degree line where $\mu \succ \pi^e$, the expected rate of inflation is falling. In this case, point A is unstable and point C is locally stable.

Similar analysis may be carried out with respect to curves G′ and G″. The unique steady state at point E on G′ is stable from below if $\alpha\beta < 1$ and stable from

[6] This assumption is reasonable, since inflation affects welfare inversely. For further details concerning the welfare cost of inflation see, for example, Cooley and Hansen (1991), Eckstein and Leiderman (1992), Gillman (1993), and Braun (1994).

above if $\alpha\beta > 1$. The curve G″ leads either to accelerating inflation or deflation depending on whether $\alpha\beta$ is less than or greater than 1.

As mentioned earlier, any exogenous change in seigniorage causes the G–curve to move to the left or right. If the government increases the budget deficit permanently, for example from S to S^*, in Figure 8.2, then the curve G shifts to G′. Consider the case, for example, where $\alpha\beta < 1$ and assume that the economy starts at the stable steady state point A. The change in seigniorage causes the economy to move to point F, with a jump in the growth rate of money. Since $\mu \succ \pi^e$ and $\alpha\beta < 1$, there is a gradual further upward movement of the expected rate of inflation and the growth rate of money as the economy moves from F to the new unique steady state at E.

The effects of an exogenous change in seigniorage can also be considered when $\alpha\beta > 1$. For example, consider that the economy starts in the stable steady state at point C for this case. Notice that point C is 'on the wrong side of the Laffer curve', that is point A, the unstable steady state, is preferable to point C since, point A shows lower inflation. A rise in seigniorage to S^* now causes the economy to move from point C to point D′, where $\mu \succ \pi^e$ and so $\dot{\pi}^e \prec 0$ from expression (8.17). The reduction of the expected rate of inflation causes the economy to move from point D′ to point E.

Thus, if $\alpha\beta < 1$ then, as long as seigniorage remains less than or equal to S^*, a rise in seigniorage will cause the stable steady state of inflation to rise. The reverse result is found when $\alpha\beta > 1$. If seigniorage exceeds S^* there is no steady state in either case.

The case of rational expectations is now examined, or, rather more accurately, of perfect foresight since the analysis has no random shocks. Following the perfect foresight assumption,[7] where $\pi_t^e = \pi_t$, any change in the anticipated sequence of deficits is immediately incorporated into inflationary expectations. Using this assumption, equation (8.16) becomes:

$$\pi = \frac{1}{\alpha}\ln(\mu c) - \frac{1}{\alpha}\ln S \qquad (8.18)$$

and equation (8.10) yields:

$$\dot{\pi} = -\frac{1}{\alpha}(\mu - \pi) \qquad (8.19)$$

Since $\alpha > 0$, the analysis under perfect foresight is similar to the case when $\alpha\beta > 1$ under adaptive expectations. However, in the case of rational expectations, inflation expectations can adjust instantaneously and the economy is assumed to jump immediately to the stable equilibrium because of the availability of information [(see, for example, Bruno et al., (1990)].

8.3 Seigniorage and Inflation in Iran

The above analysis must be amended to deal with the Iranian case. Specifically it is necessary to allow for income growth and population change. Write the per capita demand function for real money, which is derived in [Moradi (1999)], and specified as:

$$m^d = ce^{-\alpha\pi^e} y^\gamma \tag{8.20}$$

where m^d is now the demand for per capita real monetary base; y is per capita real income; and γ is the elasticity of real monetary base per capita with respect to real per capita income. The aggregate demand for nominal money is now:

$$M^d = NPce^{-\alpha\pi^e} y^\gamma \tag{8.21}$$

where N is population. Using the equilibrium condition, where money demand is equal to money supply and the steady state conditions $\pi^e = \pi$ and $\frac{d\pi}{dt} = 0$, and taking the logarithm of equation (8.21) and differentiating with respect to time yields:

$$\mu = n + \pi + \gamma g \tag{8.22}$$

where n is the growth rate of population and g is the growth rate of real income per capita.

Substituting the growth rate of money in equation (8.1) yields:

$$S = \frac{M}{P}\mu = \frac{M}{P}(n + \pi + \gamma g) = N.ce^{-\alpha\pi} \; y^\gamma (n + \pi + \gamma g) \tag{8.23}$$

To find the value of inflation that maximises the revenue from money creation, equation (8.23) is differentiated with respect to the inflation rate. The first order condition may be written as follows:

$$\frac{dS}{d\pi} = Nce^{-\alpha\pi} y^\gamma - Nc\alpha e^{-\alpha\pi} y^\gamma (n + \pi + \gamma g) = \frac{M}{P}[1 - \alpha(n + \pi + \gamma g)] = 0 \tag{8.24}$$

---

[7] Rational expectations or perfect foresight can be considered as the limiting case when $\beta \to \infty$. Dividing both sides of equation (8.6) by β and letting $\beta \to \infty$ yields $\pi = \pi^e$.

The rate of inflation that gives the maximum revenue satisfies the following equation:

$$\alpha(n+\pi+\gamma g)=1 \tag{8.25}$$

The solution of this equation for the rate of inflation is

$$\pi^{*}=\frac{1}{\alpha}-n-\gamma g \tag{8.26}$$

As can be seen, the value of inflation that maximises the revenue, π^{*}, for developed countries is higher than developing countries, since in developing countries n and g are higher than developed countries. Using (8.22), the growth rate of money which maximises seigniorage revenue is:

$$\mu^{*}=\frac{1}{\alpha} \tag{8.27}$$

Substituting equations (8.26) and (8.27) into equation (8.23) yields the maximum steady state seigniorage revenue as:

$$S^{*}=\frac{Nc}{\alpha}e^{[\alpha(n+\gamma g)-1]}y^{\gamma} \tag{8.28}$$

Comparing equation (8.27) with (8.14), it can be seen that the inclusion of income and population does not affect the rate of monetary growth that maximises seigniorage. In contrast, the rate of inflation that yields the maximum revenue is influenced when income and population are also included in the model [compare equations (8.26) and (8.14)]; the faster the rate of population or income growth the lower is the seigniorage maximising rate of inflation. The logic for this result is that government seigniorage revenue may be seen as being derived from two sources. One is the tax on existing real cash balances and the other is the tax on the additional balances that are demanded as population and income grow. Since the demand for cash balances declines as the rate of inflation increases, the revenue from the second source decreases as inflation rises. Thus, population or income growth causes the revenue maximising inflation rate to fall [(see, for example, Friedman, (1971)].

8.4 The Empirical Evidence

Seigniorage is an attractive source for government finance in Iran. There is an inefficient tax system and collection costs are high, there is no advanced financial market, and the proportion of oil revenue in the government revenue is very high and volatile (see chapter two, part 2.3.1). Moreover, it should be pointed out that the oil price and the amount of oil exports of Iran are exogenously determined in the world market and OPEC, respectively. Consequently, the government uses seigniorage to smooth its spending, which demonstrates the link between fiscal and monetary policy.

Macroeconomic Stylised Facts

This section considers some stylised facts of the Iranian economy concerning seigniorage and its relationship with macro variables. Figure 8.3 shows seigniorage obtaining from monetary base as a percentage of GDP over the period. Seigniorage has been on average 4.3 percent of GDP. There were spikes in seigniorage revenue following the first, second and third oil shocks in 1973, 1979 and 1986, respectively, the revolution in 1978 and exchange rate unification in 1993. The maximum seigniorage rate was 11.3 % of GDP in 1978 following the revolution.

Figure 8.4 provides useful insight concerning the analysis of seigniorage and inflation. As can be seen from the figure, the government has not always used this instrument efficiently. In some periods, the economy has remained on the wrong side of the Laffer curve where an increase in inflation is associated with a decrease in seigniorage revenue.

Figure 8.5 presents the relationship between the rate of inflation and the growth rate of nominal monetary base. As can be seen, these series move quite closely together over the period. Moreover, seigniorage shows a positive relationship with the growth of nominal monetary base (see Figure 8.6).

Figure 8.7 shows that a low level of expenditure is accompanied by a low level of revenue collection through seigniorage, and Figure 8.8 shows a positive relationship between the rate of inflation and real government expenditure as a percentage of GDP.

Seigniorage–Maximising Rate of Inflation

This section uses the empirical estimates of the demand function for the per capita real monetary base estimated in chapter five to calculate seigniorage–maximising inflation. The results for the whole and four sub–sample periods[8] are reported in Table 8.1. It can be seen that the actual inflation rate exceeded the revenue–maximising inflation rate in the following periods:

- 1973 – 1978
- 1989 – 1996

The first of these periods followed the first oil boom, and the second period followed the end of the eight–year war. The latter period includes the implementation of the economic reform programme followed by debt crisis and inflationary pressures. The

[8] The characteristics of the sub–sample periods are discussed in detail in chapter two.

large value of π^* during the period of the war was due to the negative growth rate of per capita real GDP. The results imply that the government could have increased revenue through seigniorage by accepting a higher rate of inflation over the war period and by reducing inflation in the periods before and after the war.

Table 8.1 Actual and Seigniorage–Maximising Inflation Rates (Percent)

Period	g	n	π*	π	π* − π
1961 – 1996	2.18	2.85	15.19	13.09	2.10
1961 – 1972	7.30	2.88	3.00	0.42	2.59
1973 – 1978	1.77	2.86	16.15	19.75	-3.60
1979 – 1988	-4.70	3.63	30.37	15.49	15.24
1989 – 1996	3.40	1.82	13.31	24.09	-10.77

Notes:

- g is the growth rate of per capita real GDP; n is the growth rate of population; π^* is the seigniorage–maximising inflation rate, calculated from equation (8.26) using the estimates $\hat{\alpha} = 4.31$ and $\hat{\gamma} = 2.37$ from Table 8.7.
- π ($=\Delta P$) is the actual inflation rate is calculated here and throughout the thesis by using $\Delta P = \ln P_t - \ln P_{t-1}$ measure except chapter two where the following measure is used:

$$\Delta P = (\frac{P_t - P_{t-1}}{P_{t-1}}) \times 100$$

The revenue–maximising inflation rate is also calculated period–by–period. Figure 8.9 plots the difference between seigniorage–maximising inflation and actual inflation rates. These results are consistent with those derived from the four sub–periods.

The rate of monetary growth that maximises seigniorage is 23.21 percent, while the actual average annual growth rate of the nominal monetary base was 20.96 percent for the whole sample period. Figure 8.10 shows that the actual growth rate of nominal monetary base exceeded the seigniorage maximising rate during 1973 – 1978 and after 1994.

If we allow for the fact that the growth rate of the economy was negative during the war years, then the results suggest that $\pi > \pi^*$ following the first oil boom. This implies that the economy was on the wrong side of the Laffer curve, that is, point C in Figure 8.2. In order for this point to be locally stable, we need to assume that expectations are formed rationally or, if expectations are formed adaptively, that $\alpha\beta > 1$. To check for the last restriction, an ARIMA (0,1,1) model for inflation is estimated to obtain the value of β. The implied estimate is $\hat{\beta} = 0.48$ so that $\hat{\alpha}\hat{\beta} = 4.31 \times 0.48 = 2.07$, which is consistent with $\alpha\beta > 1$. Hence, the economy has operated at point C which is locally stable, irrespective of whether expectations are formed rationally or adaptively.

The Dynamics of the Model and Seigniorage Revenue

The error correction model (ECM), estimated in chapter five, is also relevant here. Agents respond to changes in their equilibrium holding of real balances only gradually. Seigniorage revenue obtaining from monetary base can be decomposed into two parts. The first part of the revenue is generated from real balances in the new equilibrium and the second part is the flow of the revenue generated through the period, while agents are out of equilibrium [see, for example, Adam and et al., (1996)].

The crucial parameter of the ECM is the speed of adjustment coefficient. The low value of this coefficient, -0.12, implies that any deviation from equilibrium persists for a relatively long period of time. This has important implications for seigniorage revenue. Following a shock (e. g. an increase in inflation), agents adjust their real balances slowly toward new equilibrium and so agents hold excess money for some time. Hence, in this case, the government can generate considerable seigniorage revenue through the adjustment period.

8.5 Conclusion

This chapter examined the relationship between seigniorage and inflation in Iran. There exists evidence of a Laffer curve relationship between seigniorage revenue and the rate of inflation. The evidence shows that the actual rate of inflation generally exceeded the corresponding rate that would maximise seigniorage revenue. This means that the government could have obtained extra seigniorage with a lower rate of inflation. However, during the war period the government could have accepted a higher inflation rate due to the negative growth in GDP. These results do not depend on whether the expectations of agents form adaptively or rationally. Given the slow speed of adjustment of real money balances, the government can also generate considerable seigniorage revenue over the adjustment period.

Figure 8.3 Seigniorage Obtaining from Monetary Base as a Percentage of GDP

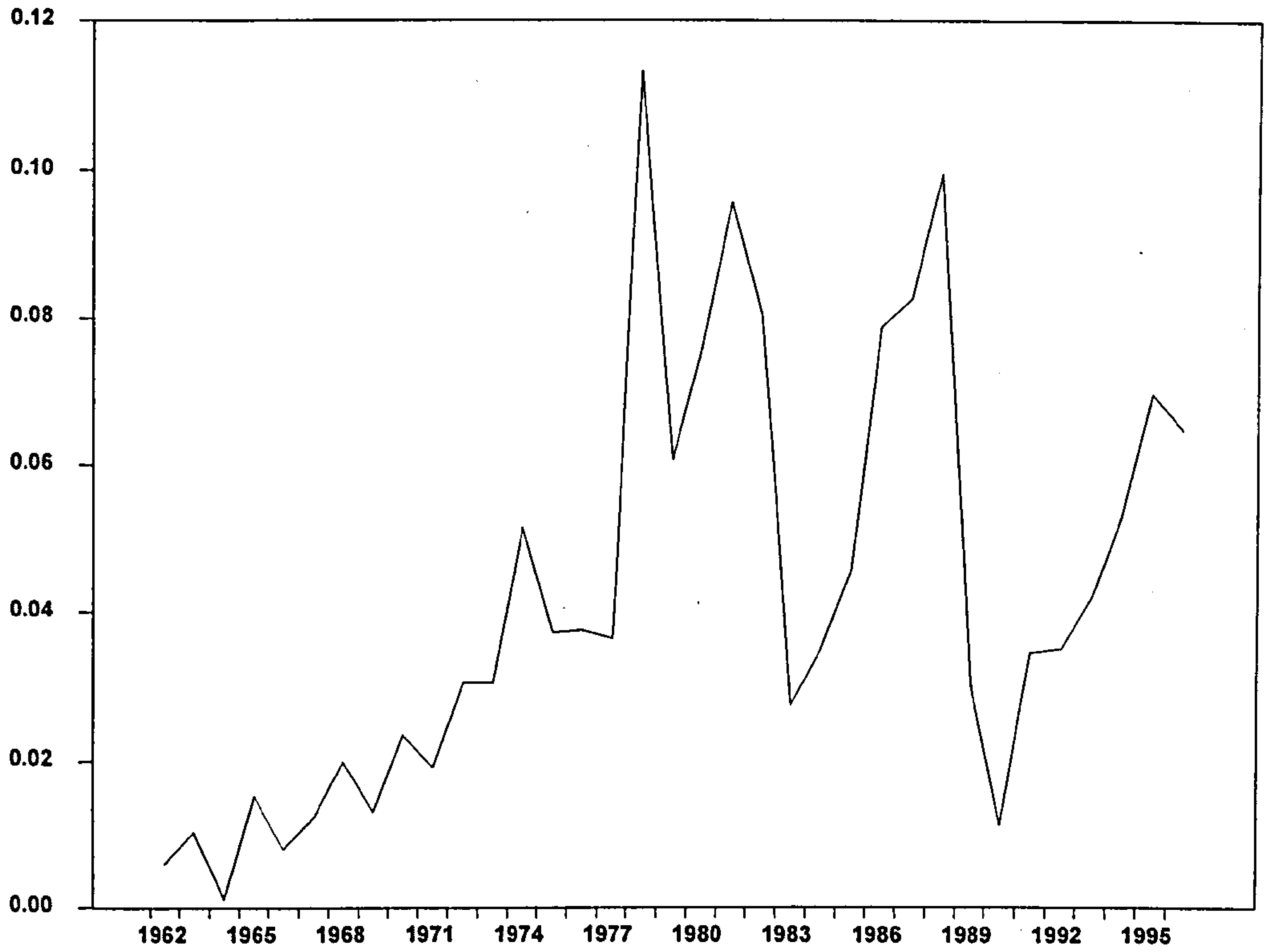


Figure 8.4 Seigniorage (as a percentage of GDP) against Inflation

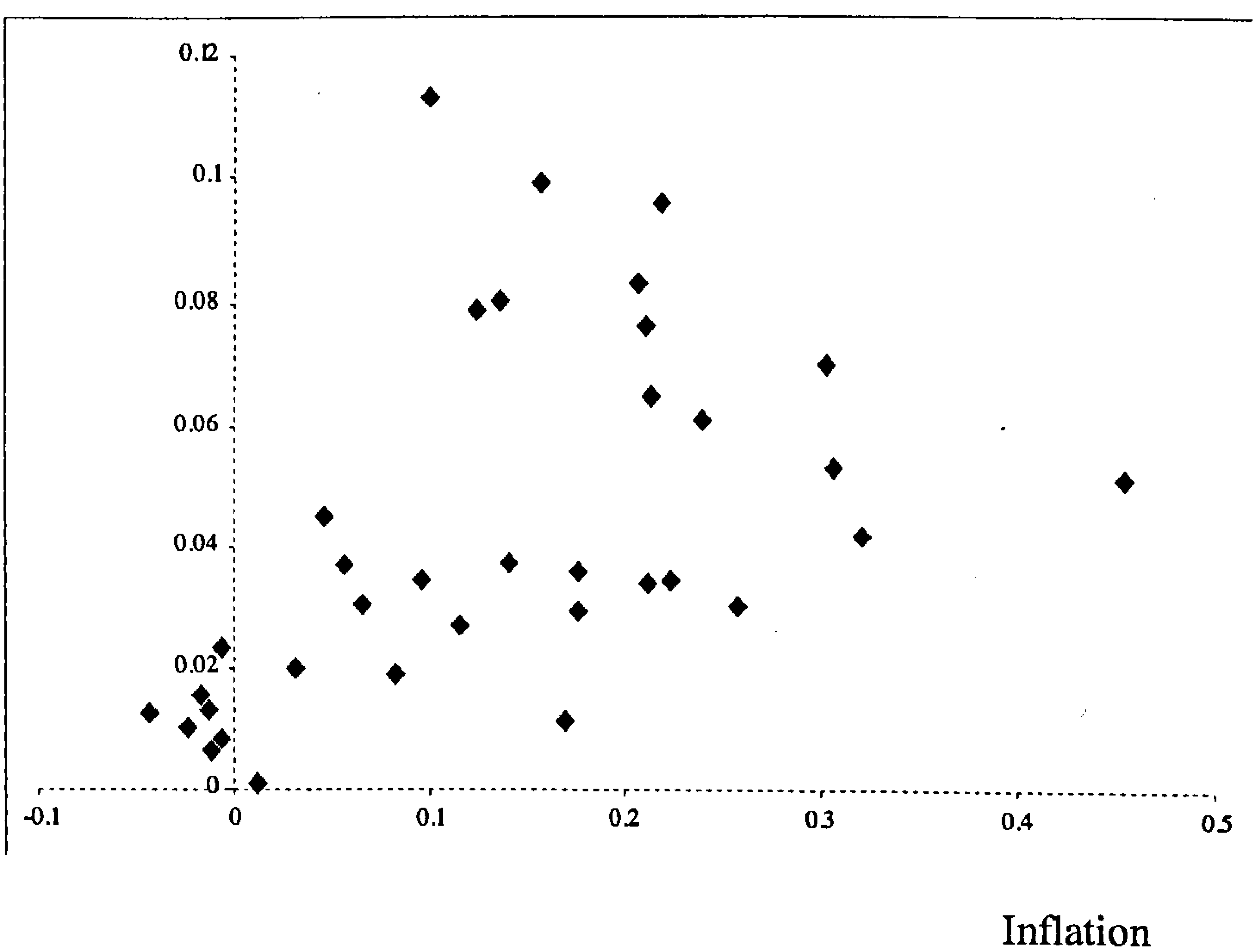


Figure 8.5 Inflation (DP) and the Growth Rate of Nominal Monetary Base (DMB)

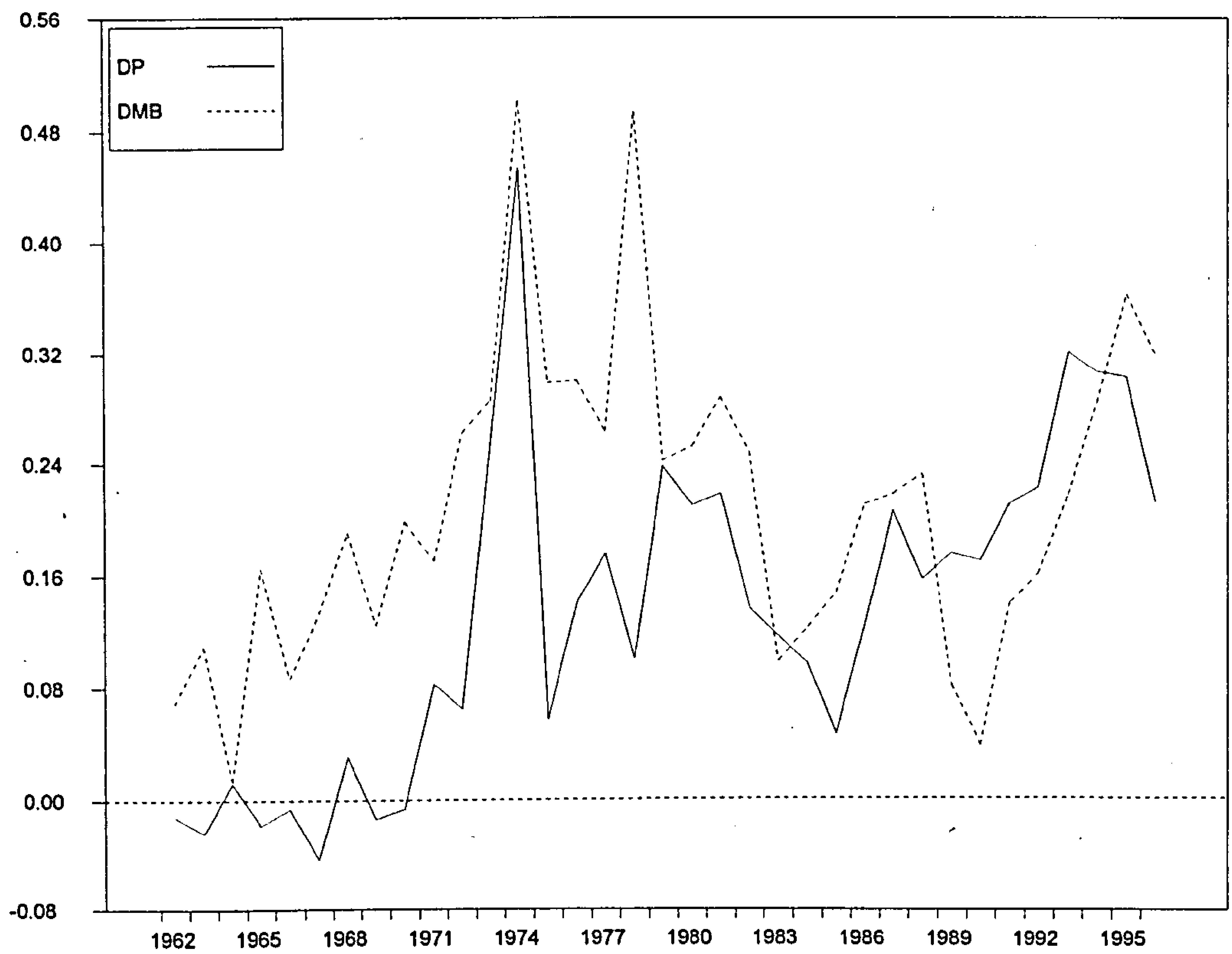


Figure 8.6 Seigniorage (% GDP) and the Growth Rate of Nominal Money (DMB)

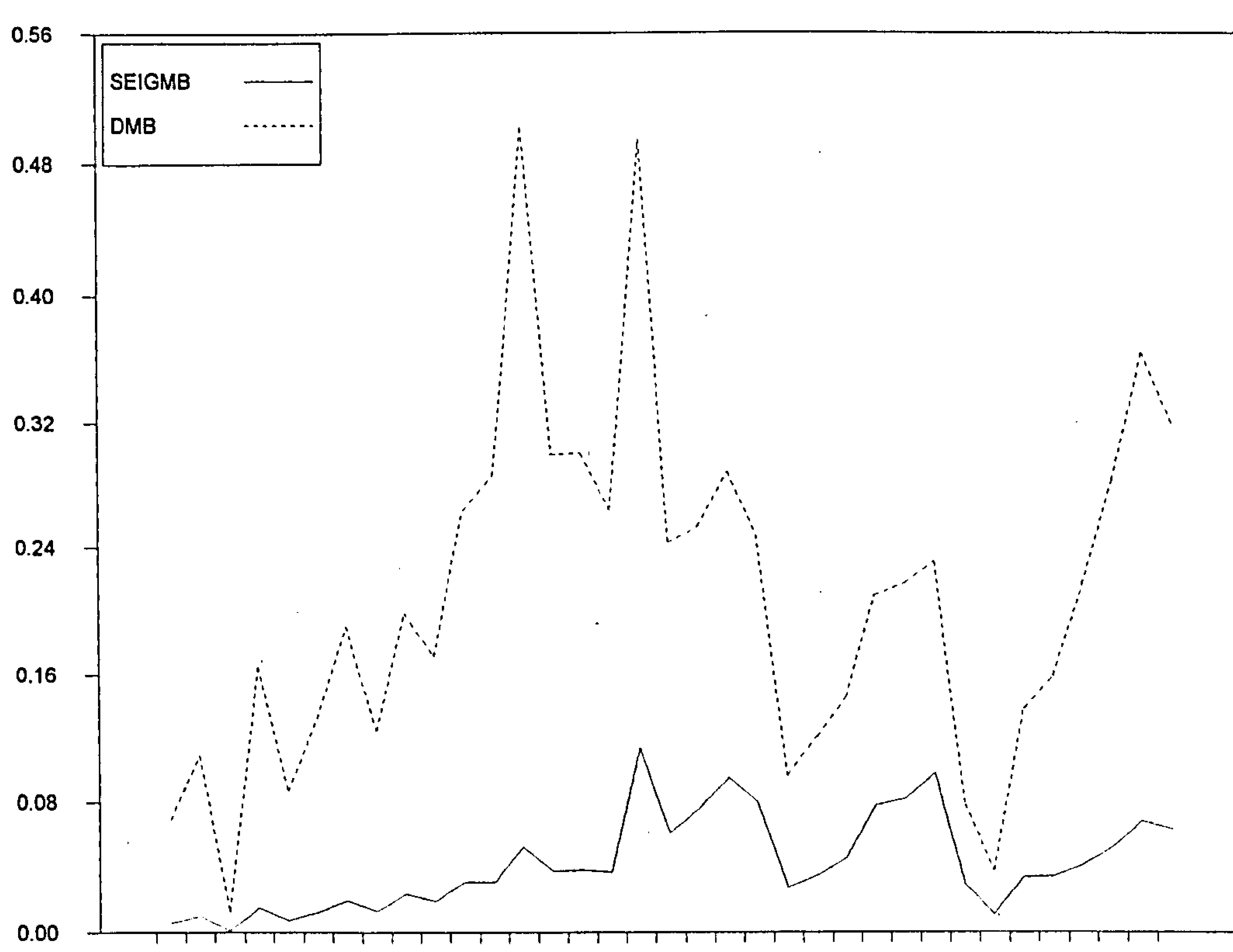


Figure 8.7 Seigniorage (SEIGMB) and Real Government Expenditure (RGE) as a Percentage of GDP

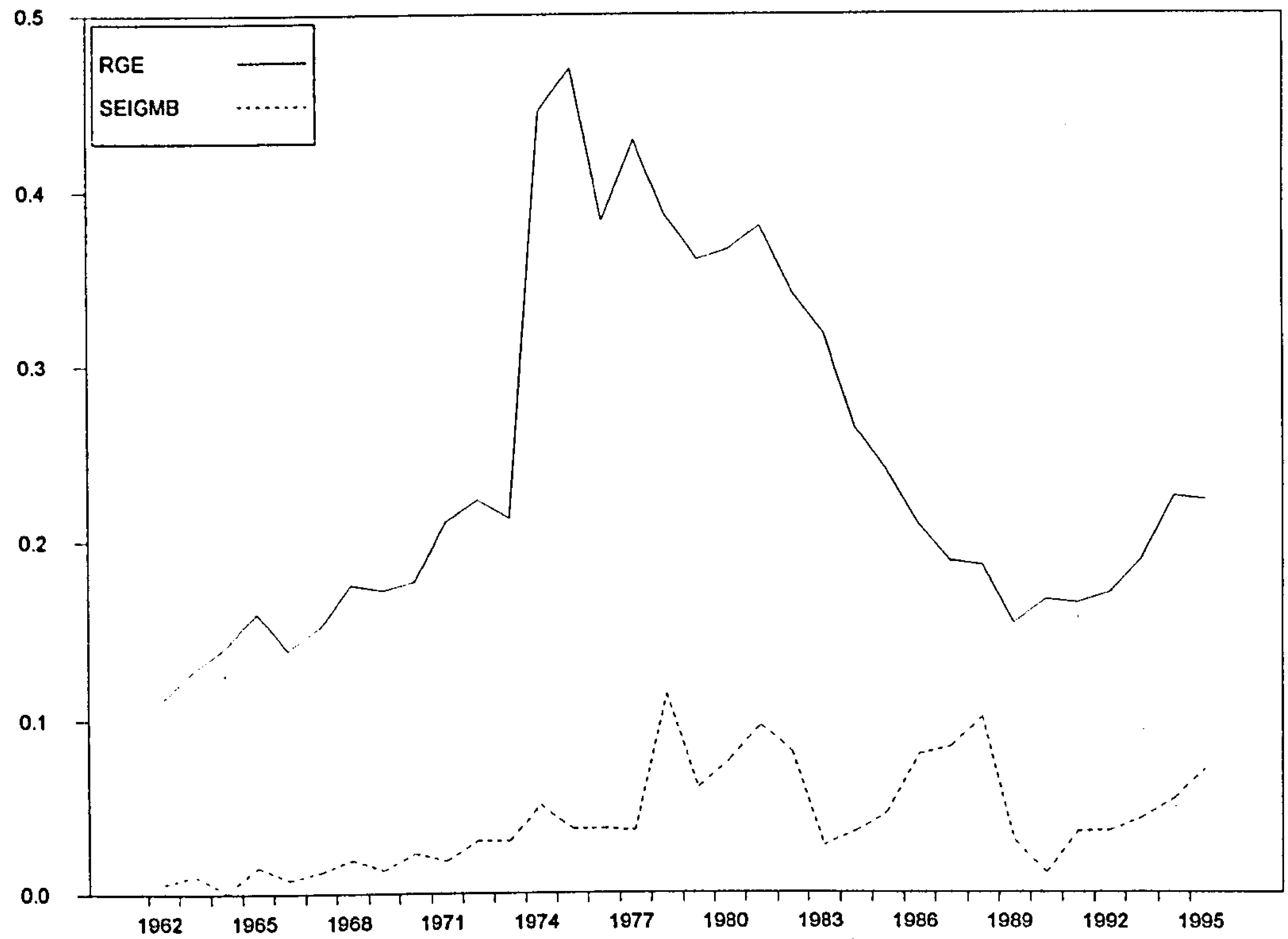


Figure 8.8 Inflation (DP) and Real Government Expenditure (RGE) as a Percentage of GDP

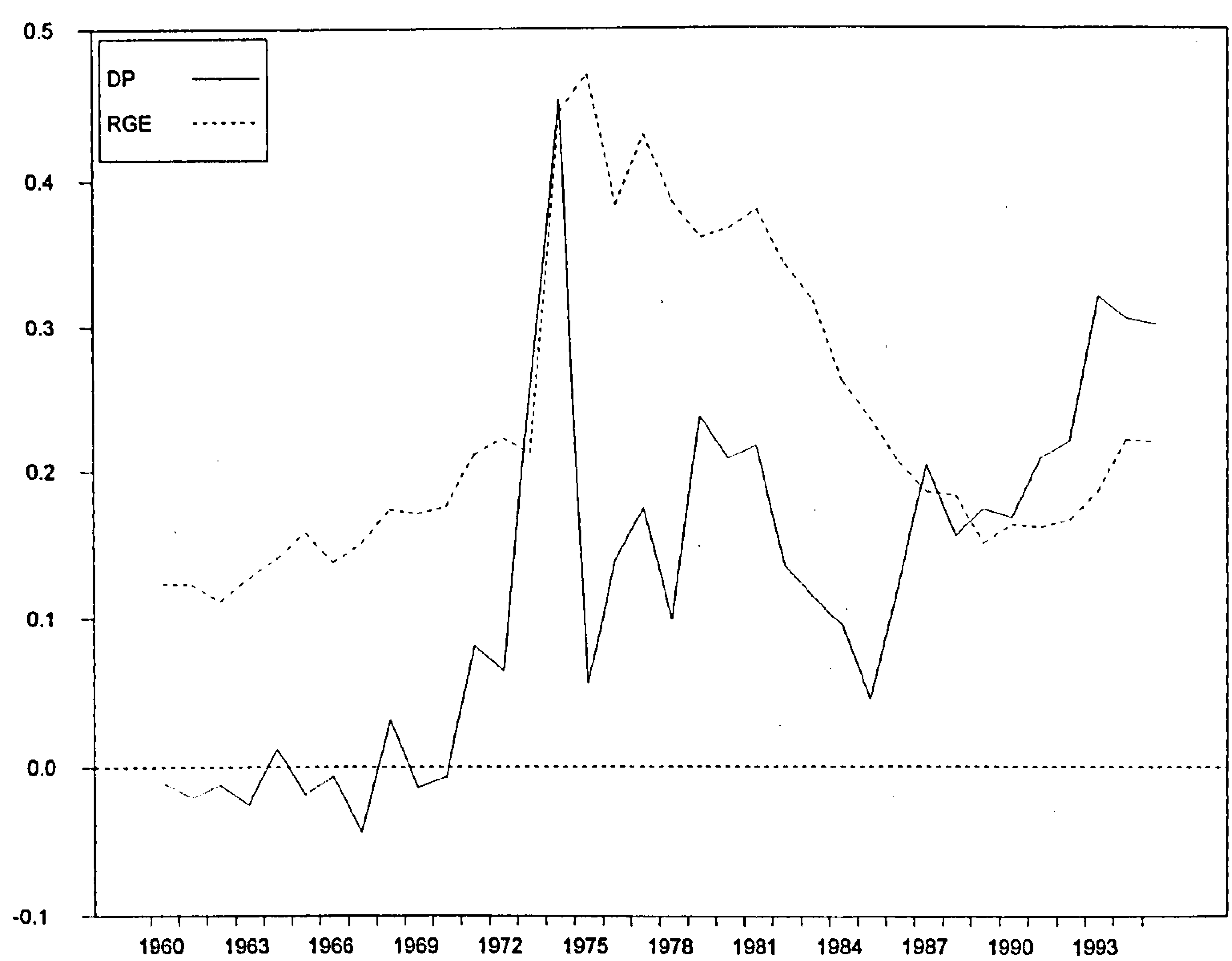


Figure 8.9 The Difference Between Seigniorage–Maximising Inflation and Actual Inflation Rates ($\pi - \pi^*$)

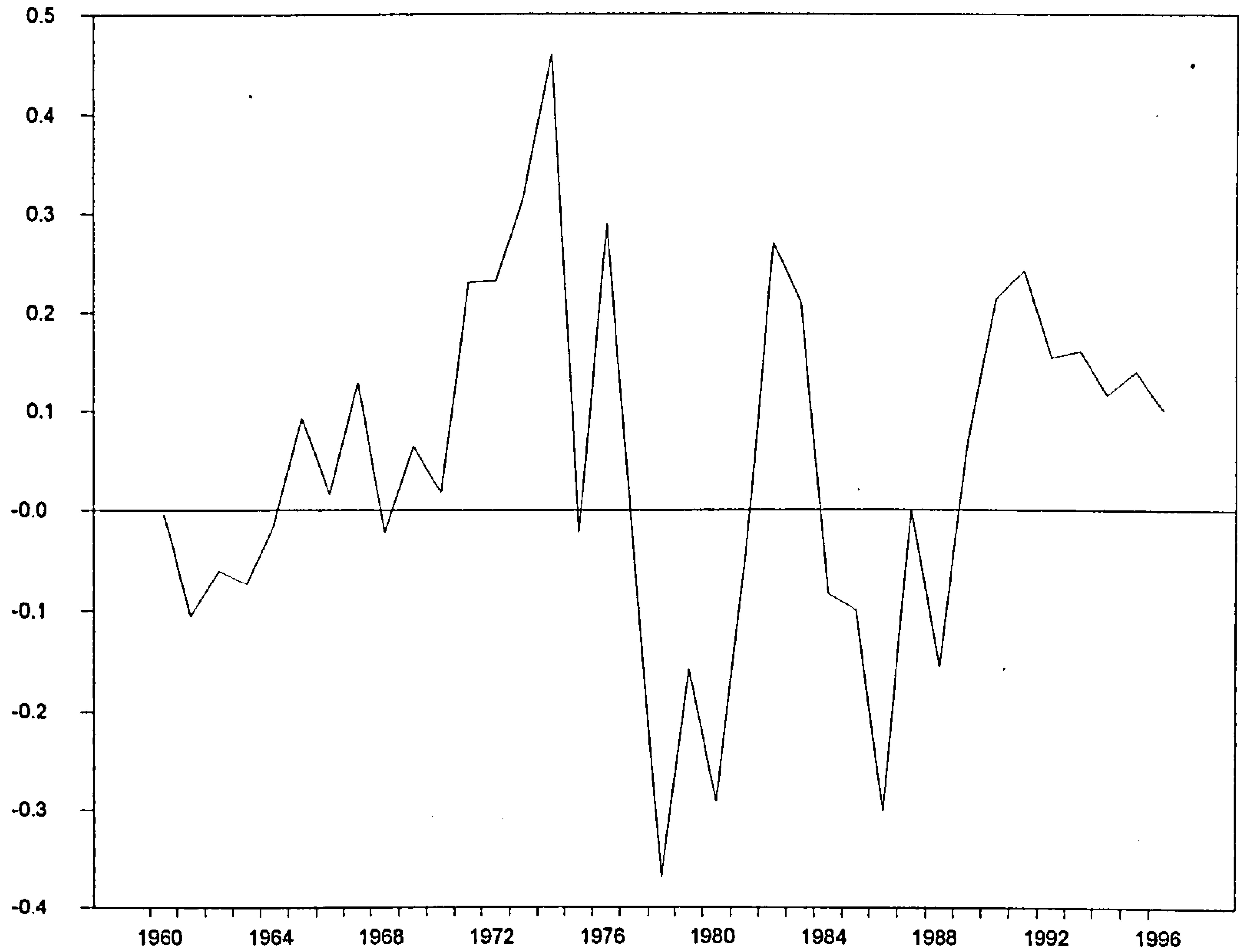
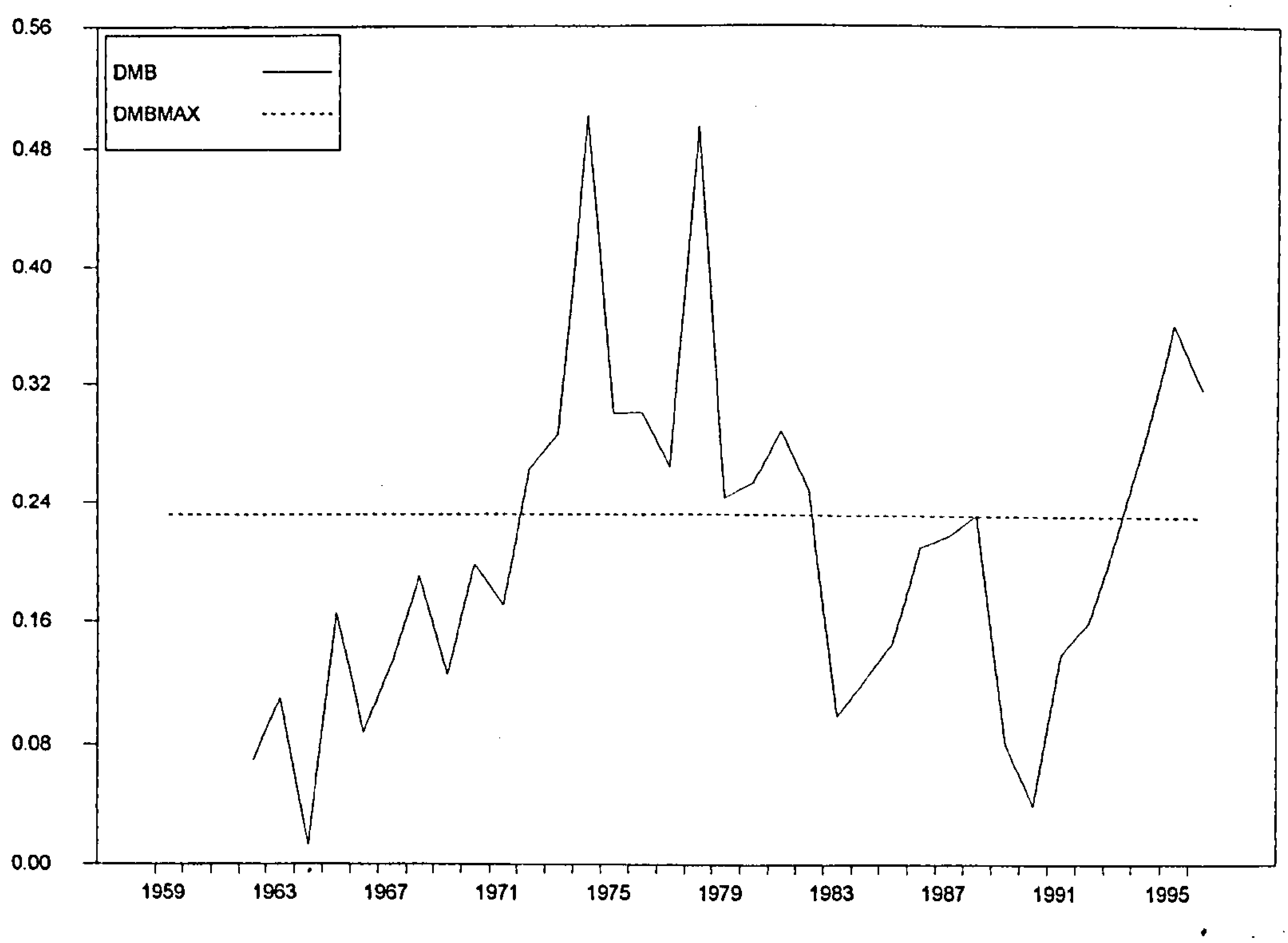


Figure 8.10 Actual (DMB) and Optimal (DMBMAX) Rate of Monetary Base Growth



9 POLICY IMPLICATIONS

This thesis provides some major policy implications for the Iranian economy. This chapter 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 the fight 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. It means that a reduction in money supply has a negative effect on per capita real income. So, money does matter to aggregate demand 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$\uparrow \Rightarrow$ Bank Deposits $\uparrow \Rightarrow$ Bank Loans $\uparrow \Rightarrow$ 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 $\uparrow \Rightarrow$ Inflation $\uparrow \Rightarrow$ 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, 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 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.

It was shown that inflation in Iran increased substantially and became more variable after the first oil shock. It was also shown that 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. Although the government was able to earn revenue through seigniorage by accepting a higher rate of inflation, higher inflation resulted in higher uncertainty in the economy and affected the effectiveness of government policies (more specifically monetary and exchange rate policies as shown in chapter seven). 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. This will also reduce uncertainty.

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. Although measuring the impacts of uncertainty on the effectiveness of policy is difficult and it is beyond the scope of this study, our results suggest a link between the low values of the adjustment coefficient and uncertainty. 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)].

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 programme, captured by the dummy *D*91 in equation (7.6), 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. The investigation of a nonlinear dynamic model of inflation to compare with the linear specification in equation (7.6) is the extension of the present study to which I will turn in the immediate future.

10 CONCLUSION

The introduction has outlined the special features of the Iranian economy. Their implications for the analysis of the problem of inflation have been taken into account throughout the thesis. The results have been summarised at the end of each chapter. This concluding chapter brings together the main findings of the thesis, along with their policy implications.

(i) Inflation follows a stationary process with a break in 1973, following the first oil shock.

(ii) However, the null hypothesis of linearity is rejected against the alternative of a smooth transition autoregressive (STAR) model. A plausible logistic STAR model is identified and estimated, which is equivalent to a threshold AR model describing different AR processes for low and high inflation regimes, and implies that very high inflation rates cannot persist.

(iii) There is evidence of conditional autoregressive heteroscedasticity, Friedman hypothesis that the conditional variance is positively associated with the level of inflation is supported. This is important for policy since a reduction in inflation will mean lower inflation variability and, therefore, a lower level of uncertainty in the economy.

(iv) Despite two different political regimes (pre– and post–revolution), the eight–year war, a large economic reform programme after the war, and three big oil shocks, a long–run demand for money exists after accounting for a break in 1979. The empirical estimates support the theoretical model of the demand function for money that is constructed for the Iranian economy using the cash–in–advance models. The estimates of the income elasticity and inflation semi–elasticity are plausible, although the speed of adjustment of real money balances (and of real income) towards equilibrium is rather slow. The exchange rate plays no role in the demand for money.

(v) Seigniorage–maximising inflation rate was below the actual inflation rate for the period after 1972 and the government could have obtained extra revenue with a lower rate of inflation. The exception is the war period when, due to negative output growth, the optimal rate exceeded the actual rate, meaning that the government could have accepted higher rate of inflation in order to raise extra seigniorage. Furthermore, the slow adjustment of real money balances implies that the government can generate considerable seigniorage over the adjustment period.

(vi) The Standard long–run PPP relationship is strongly supported after allowing for breaks in 1973 and 1980. Deviations from PPP are eliminated mainly through changes in the nominal exchange rate. The domestic price level also adjusts to PPP deviations but more slowly. The terms of trade and the oil price play no role in the PPP relationship.

(vii) The dynamic model for inflation shows that the error correction terms from the long–run relationships for money demand and PPP are both significant and have the correct signs. This suggests that inflation in Iran was affected both by domestic factors, through excess money supply, and by external factors, through deviations from PPP. However, the adjustment coefficients are very small, implying that monetary or exchange rate policies to control inflation are unlikely to be effective.

(viii) The coefficient of ΔP_{t-1} in the final model for ΔP_t is insignificant, implying that the inertia hypothesis is not supported.

(ix) Among other factors considered, changes in government spending and the terms of trade have no effect while changes in the oil prices have a positive effect on inflation. Dummy variables are required to account for the increase in inflation after the first oil boom and also after the reform programme which culminated in a big devaluation in 1993.

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APPENDIX A:

A MICROFOUNDATION MODEL OF MONEY DEMAND IN IRAN: A CASH–IN–ADVANCE FRAMEWORK[1]

1 Introduction

This paper deals with the designing of a microfoundation model of the demand for money for the Iranian economy using a cash–in–advance framework. Three frameworks have been used to design a money demand function. They comprise transactions technologies, money in the utility function[2] and cash–in–advance models. Clower (1967) proposes a cash–in–advance model where the use of money for transactions is not explicit. Lucas and Stocky (1983), Singleton (1985), Eckstein and Leiderman (1988), Hodrick, Kocherlakota, and Lucas (1991), and Braun (1994) use this approach to derive a money demand function. This paper uses the cash–in–advance framework proposed by Lucas and Stocky and developed by Braun to derive a money demand function in Iran.

The paper is organised as follows: Section two reviews the literature on the cash–in–advance models. Section three constructs a demand function for money

[1] Moradi, M. A., (1999), A Microfoundation Model of Money Demand in Iran: A Cash–in–Advance Framework, *Liverpool Research Papers in Economics, Finance and Accounting*, No. 9908, University of Liverpool.

[2] Feenstra (1986) shows the equivalence between the models with money in the utility function and transactions technologies. Mulligan and Sala–I–Martin (1997) argue that Feenstra's equivalence result cannot hold when there are consumption taxes unless taxes enter the utility function.

based on the cash–in–advance framework corresponding to the characteristics of the Iranian economy.

2 Cash–in–Advance Models

Clower (1967) proposes a cash–in–advance framework that can be used in modelling the money demand. In this model, money does not enter the utility function and agents must acquire currency to cover their consumption. A cash–in–advance framework is considered in an empirical setting by Lucas and Stocky (1983), and the model is extended by Singleton (1985), Eckstein and Leiderman (1988), Chari, Christiano, and Kehoe (1991), Hodrick, Kocherlakota, and Lucas (1991), and Braun (1994).

Lucas and Stocky (1983) introduce the structure of a cash–in–advance model for an economy without capital[3], and apply this framework in barter and monetary economies. They consider two consumption goods that comprise cash goods and credit goods. In this model the preferences[4] are given by

$$E\{\sum_{t=0}^{\infty}\beta^t U(c_{1t},c_{2t},x_t)\} \qquad (1)$$

where x_t is leisure; c_{1t} is cash goods; c_{2t} is credit goods. Cash goods can be purchased only with fiat money previously accumulated, while credit goods can be paid for with

[3] Chari, Christiano, and Kehoe (1991) extend this model to an economy with capital.

[4] As expressed in a barter economy model, the preferences of representative consumer are based on the von Neumann–Morgenstern utility function as follows:

$$E\{\sum_{t=0}^{\infty}\beta^t U(c_t,x_t)\} = \sum_{t=0}^{\infty}\beta^t \int U(c_t(g^t),x_t(g^t))dF^t(g^t)$$

where c is the consumer good; x is the leisure; g is the government consumption that is taken to follow a given stochastic process. c and x depend on g^t, the history of government shocks between 0 and t.

labour income contemporaneously accrued. The household faces two constraints. The period budget constraint is of the form

$$\int q_1 dg_1[p_0c_{10} - M_0 + p_0c_{20} - p_0(1-\tau_0)(1-x_0) - p_{00}b_{20}]$$
$$+ \sum_{t=1}^{\infty} \iint q_{t+1} dg_{t+1}[p_t c_{1t} - M_t + p_t c_{2t} - p_t(1-\tau_t)(1-x_t) - p_{t0}b_{2t}]dg_1^t$$
$$+[M_0 - B_0] + \sum_{t=1}^{\infty} \int q_t[M_t - {}_0B_t]dg_1^t \le 0 \tag{2}$$

where g is the government consumption good[5]; $\tau = \{\tau_t\}_{t=0}^{\infty}$ is contingent tax rates; $p = \{p_t\}_{t=0}^{\infty}$ is the price sequence; q_t (g^t) is the dollar price at time t, contingent on the history g_t; p_t (g^t) is the current dollar price at time t of a unit of either type of goods at time t, contingent on the history g_t[6]; $M_t \ge 0$ is wealth held in the form of currency; B and b are two kinds of securities which are held by the household, contingent claim $\{{}_0B_t\}$ to dollars at times t = 0. 1, 2, ..., priced at $\{q_t\}$, and contingent claim $\{{}_0B_{2t}\}$ to credit goods at time t = 0,1 2, ..., priced at $\{q_{t+1}p_t\}$ to coincide with the timing of payments for such goods; ${}_tb = \{{}_tb_s\}_{s=0}^{\infty}$, t = 0, 1, 2, ..., is government debt in the form of sequence.

The first terms of (2) collect receipts and payments due at the beginning of period t +1, for t = 0, 1, 2, ..., including unspent currency carried over from t, priced accordingly at q_{t+2}. The second terms collect returns on dollar–denominated securities in t less the amount held in currency. Since (2) contains term of the form $[q_t(g^t) - \int q_{t+1}(g^{t+1})dg_{t+1}]M_t(g^t)$, the budget constraint will be binding if and only if

$$q_t(g^{t+1}) - \int q_{t+1}(g^{t+1})d(g_{t+1}) \ge 0 \quad t = 0, 1, 2, ..., \text{ all } g^t \tag{3}$$

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[5] It is a stochastic process the realisations $g \equiv (g_0, g_1, g_2, ...)$ of which have a joint distribution F^t. It is assumed that F^t is the marginal distribution of the history $g^t \equiv (g_0, g_1, ..., g_t)$ of these shocks from 0 through t, for t = 0, 1, 2, ... It is assumed that F has a density f, and f^t is the density of F^t. It is also defined that $g_s^t \equiv (g_s, g_{s+1}, ..., g_t)$, for 0≤ s ≤ t, and F_s^t (.| g^{s-1}), with density f_s^t (. |g^{s-1}), it denotes the conditional distribution of g_s^t given g^{s-1}.

[6] It means consumer expects that in each period t = 0, 1, 2, ..., given g^t, the market price of a claim to a unit of current goods or labour will be $p_t(g^t)$.

The second one is the following cash–in–advance constraint[7]

$$p_t c_{1t} - M_t \leq 0 \qquad t = 0, 1, 2, ..., \quad \text{all } g^t \tag{4}$$

which indicates that household must have enough money to cover spending on cash goods. Moreover, they consider those two kinds of consumption goods – credit and cash goods–, leisure, and government consumption related by the following technology

$$c_{1t} + c_{2t} + x_t + g_t \leq 1 \tag{5}$$

The household maximises her/his objective function, (1), subject to budget constraints (2) and (4) given initial securities holdings $\{_0B_t, {_0b_{2t}}\}$, prices $\{(p_t, q_t)\}$ and tax rates $\{\tau_t\}$. γ and $\rho_t\,(g^t)$ are the multipliers associated with (2) and (4), respectively. It yields the following first order conditions:

$$\beta^t U_1(c_{1t}, c_{2t}, x_t) f^t(g^t | g_0) - \gamma p_t \int q_{t+1} dg_{t+1} - \rho_t p_t = 0 \tag{6}$$

$$\beta^t U_2(c_{1t}, c_{2t}, x_t) f^t(g^t | g_0) - \gamma p_t \int q_{t+1} dg_{t+1} = 0 \tag{7}$$

$$\beta^t U_x(c_{1t}, c_{2t}, x_t) f^t(g^t | g_0) - \gamma p_t \int q_{t+1} dg_{t+1}(1 - \tau_t) = 0 \tag{8}$$

$$\gamma[\int q_{t+1} dg_{t+1} - q_t] + \rho_t = 0 \quad t = 0, 1, 2, \ldots, \text{all } g^t \tag{9}$$

where c_{1t}, c_{2t}, x_t, and M_t are positive. If $\rho_t > 0$, it means that (4) holds with equality, and if $\rho_t = 0$, it implies that the consumer is indifferent between holding securities and excess cash.

Since any equilibrium obtained under this hypothesis must satisfy (2), (3), and (4), they may be combined to yield

[7] Cooly and Hansen (1992) consider the following cash–in–advance constraint

$$(1 + \tau_t) p_t c_{1t} \leq m_t + (1 + R_t) b_t - b_{t+1}$$

where p_t is the price level; τ_t is the consumption tax rate; c_{1t} is the cash goods; $(1 + R_t) b_t - b_{t+1}$ is the principle plus interest from government bond holding, b_t; household acquires bonds that they carry into the next period, b_{t+1}. It provides the household with $m_t + (1 + R_t) b_t - b_{t+1}$ units of currency for purchasing goods.

$$0 = \int q_1 dg_{t+1} p_0[(c_{20} -_0 b_{20}) - (1-\tau_0)(1-x_0)] + p_0[c_{10} - \frac{_0B_0}{p_0}] \tag{10}$$

$$+\sum_{t=1}^{\infty} \int(\int q_{t+1} dg_{t+1} p_t[(c_{2t} -_0 b_{2t}) - (1-\tau_t)(1-x_t)]$$

$$+ q_t p_t [c_{1t} - \frac{_0B_t}{p_t}]) dg_1^t$$

Letting $_0b_{1t} = \frac{_0B_t}{p_t}$, multiplying equation (10) through by γ and using (4) and (6) through (8) yields

$$\sum_{t=0}^{\infty} \beta^t \int [c_{1t} -_0 b_{1t}, c_{2t} -_0 b_{2t}, x_t - 1] \begin{bmatrix} U_1 \\ U_2 \\ U_x \end{bmatrix} dF^t(g^t | g_0) = 0 \tag{11}$$

In the absence of both outstanding debt and government expenditures, efficiency would be attained from the first order conditions (6) through (8). If both the labour income tax rate and multiplier ρ_t were set equal to zero, it means that in (9) $\int q_{t+1} dg_{t+1} = q_t$, or a nominal interest rate is equal to zero.

An allocation $\{(c_{1t}, c_{2t}, x_t)\}$ which satisfies (11) with $_0b_{1t} \equiv 0$ can be used by optimal choices of tax rates and money supplies $\{(\tau_t, M_t)\}$. From the first order equations (7) and (8), the required taxes are

$$\frac{U_x(c_{1t}, c_{2t}, x_t)}{U_2(c_{1t}, c_{2t}, x_t)} = 1 - \tau_t \quad t = 0, 1, 2, \dots, \text{all } g^t \tag{12}$$

and from the first order conditions (6), (7) and (9), the required nominal interest factors satisfy

$$\int q_{t+1} dg_{t+1} = q_t \frac{U_2(c_{1t}, c_{2t}, x_t)}{U_1(c_{1t}, c_{2t}, x_t)} \quad t = 0, 1, 2, \dots, \text{all } g^t \tag{13}$$

Since the constraint (3) must hold in equilibrium, equation (13) implies that in addition to satisfying the condition (11), feasible allocations must satisfy

$$U_2(c_{1t}, c_{2t}, x_t) - U_1(c_{1t}, c_{2t}, x_t) \le 0 \tag{14}$$

An optimal open–loop policy corresponds to an allocation $\{(c_{1t}, c_{2t}, x_t)\}$ that maximises (1) subject to (5), (11) and (14). The first order conditions for these problems are

$$(1+\lambda_0)U' + \lambda_0 U'' \begin{bmatrix} c_t & -_0 b_t \\ x_t & -1 \end{bmatrix} - \mu_{0t} 1 - \nu_t \begin{bmatrix} U_{21} & -U_{11} \\ U_{22} & -U_{12} \\ U_{2x} & -U_{1x} \end{bmatrix} = 0 \tag{15}$$

$$\nu_t(U_2 - U_1) = 0 \quad t = 0, 1, 2, \ldots, \text{all } g^t \tag{16}$$

where λ_0 is the multiplier associated with (11); ν_t is the multiplier associated with (14) and U″ is the matrix

$$U'' \equiv \frac{\delta^2 U}{\delta(c_{1t}, c_{2t}, x_t)^2} = \begin{bmatrix} U_{11} & U_{12} & \cdots & U_{1n} & U_{1x} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ U_{n1} & U_{n2} & \cdots & U_{nn} & U_{nx} \\ U_{x1} & U_{x2} & \cdots & U_{xn} & U_{xx} \end{bmatrix}$$

Within each period, in each state, the optimal allocation satisfies the Ramsey tax rule. Ramsey argues that if government needs to raise revenues with distorting taxes, it is optimal to tax all goods including the liquidity services derived from holding money.

To find out an optimal tax policy, it requires *that equations (15) and* (5) be solved for the allocations $\{(c_{1t}, c_{2t}, x_t)\}$. Substituting the results into (11), it obtains λ_0, and optimal allocation. The excise tax structure that implements this allocation can be obtained by using (12).

Chari, Christiano, and Kehoe (1991) use a version of the Lucas and Stocky (1983) model. They argue that money earns a gross nominal return of 1. Consequently they propose the following:

For the utility function of the form $U(c_1, c_2, \ell) = h(c_1, c_2)v(\ell)$ the Ramsey equilibrium has $R(s^t) = 1$ for all s_t.

where s_t denotes many events that are defined by $s^t = (s_0, s_1, \ldots, s_t)$, the history of events; and R_t is the nominal interest rate. Therefore, the first order condition concerning the above proposition is

$$\frac{U_1}{U_2} = R(s^t) = 1 \tag{17}$$

This means that, in this economy, the tax on labour income implicitly taxes consumption of both goods at the same rate. Consequently, if preferences are homogeneous in the two consumption goods and weakly separable in leisure, then the optimal monetary policy is to tax all consumption goods at the same rate.

If R (s^t) > 1, it means that the cash goods are taxed at a higher rate than the credit goods, since cash goods must be paid for immediately but credit goods are paid for with a one period lag. Hence, efficiency requires that R (s^t) = 1.

Braun (1994) considers the Lucas and Stocky (1983) model and derives a demand function for money by using the following form of the representative agent preferences:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_{1t}, c_{2t}, n_t) \tag{18}$$

where U is utility; c_{1t} and c_{2t} denote the consumption of cash and credit goods, respectively; and n_t is labour. Household supplies labour that is used to produce an output that satisfies the following aggregate resource constraint:

$$c_{1t} + c_{2t} + g_t \leq z_t n_t \tag{19}$$

where g_t is government purchases; and z_t is a shock to labour's productivity, or a technology shock. The cash goods are restricted by the cash–in–advance constraint considered by Lucas and Stokey, equation (4).

The security market satisfies

$$M_t + B_t + p_{t-1}c_{1t-1} + p_{t-1}c_{2t-1} \leq p_{t-1}(1-\tau_{t-1})z_{t-1}n_{t-1} + M_{t-1} + R_{t-1}B_{t-1} \tag{20}$$

where τ_t is the tax rate on labour income; B_t is a nominal state–noncontinget bond; and R_t is the gross return on bonds.

The first order conditions are

$$\frac{U_{1t}}{U_{2t}} = R_t \tag{21}$$

$$-\frac{U_{3t}}{U_{2t}} = (1-\tau_t)z_t \tag{22}$$

$$E_t\left[\frac{U_{2t+1}p_t}{U_{2t}p_{t+1}} R_{t+1}\right] = \frac{1}{\beta} \tag{23}$$

The government budget constraint is of the form

$$M_t + B_t = M_{t-1} + R_{t-1}B_{t-1} + p_{t-1}g_{t-1} - p_{t-1}\tau_{t-1}z_{t-1}n_{t-1} \tag{24}$$

The implementability constraint that can be used in solving for the optimal Ramsey policies is proposed as follows:[8]

[8] Ramsey (1927) considers an economy where government finances its expenditures through the levy of tax on the consumption goods. Consequently the government chooses a tax policy that maximises

$$E_0 \sum_{t=0}^{\infty} \beta^t [c_{1t} U_{1t} + c_{2t} U_{2t} + n_t U_{3t}] = 0 \tag{25}$$

The Ramsey allocations can be found by maximising

$$E_0 \sum_{t=0}^{\infty} \beta^t \{U(c_{1t}, c_{2t}, n_t) + \lambda [c_{1t} U_{1t} + c_{2t} U_{2t} + n_t U_{3t}]\} \tag{26}$$

subject to equation (19) and the following constraint

$$U(c_{10}, c_{20}, n_0) + \lambda [c_{10} U_{10} + c_{20} U_{20} + n_0 U_{30}] = 0 \tag{27}$$

This is considered as a primal Ramsey tax at time 0.[9]

He parameterises the objective function as follows:

$$U(c_{1t}, c_{2t}, n_t) = h[g(\frac{\theta_1 (c_{1t})^{1-\gamma_1}}{1-\gamma_1} + \frac{\theta_2 (c_{2t})^{1-\gamma_2}}{1-\gamma_2}) v(n_t)] \tag{28}$$

where h (·), g(·), and v(·) are monotonic and twice differentiable. There are three useful properties for this form of preferences:

- this form nests the different specifications that have been considered by others, for instance, Chari, Christiano, and Kehoe (1991), and Cooley and Hansen (1992).
- this allows the optimality of both the Friedman rule[10] and the case where a positive nominal interest rate is optimal.
- the ratio of γ_2/γ_1 can be estimated without knowing the functional form of h, g, and v.

Using equation (28), the first order condition in (21) is given by

$$\gamma_0 + \gamma_1 \ln(c_{1t}) - \gamma_2 \ln(c_{2t}) + \ln(R_t) = 0 \tag{29}$$

Substituting the cash–in–advance constraint,(4), the following empirical money demand is obtained[11].

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the utility of consumer or minimises the excess burden of welfare cost of taxation. The tax rates on the consumption goods depend on their relative demand elasticities.

[9] The first order conditions are used in conjunction with the household's first order conditions and the government budget constraint to derive the properties of optimal monetary and fiscal policy.

[10] The central focus of the Friedman rule is based on the social production cost of money. Government should provide money at zero cost, since it is costless. In other words, the optimal Friedman rule requires a deflation at a rate equal the internal rate of discount or a zero nominal interest rate. It implies a zero inflation tax. [See, for example, Friedman, (1969)].

[11] Braun takes a log Taylor expansion of the last term of the equation:

$$\ln(\frac{M_t}{p_t}) = \vartheta_0 - \vartheta_1 \ln(R_t) + \vartheta_2 \ln(Y_t) + \varepsilon_t \quad (30)$$

3 Money Demand Function for Iran

A demand function for money is constructed based on a cash–in–advance model concerning the Iranian economy. The model is based on the following assumptions:

- the representative household holds two types of assets. They comprise money and trees. More specifically trees indicate the investment deposits of the consumer in the bank as well as other kinds of assets that can be held by the household except bonds, for instance, durable goods and gold. The household holds the assets to share the profits of investment or to avoid money balances losing value as a result of inflation.
- there is no bond financing, consequently the issue of bonds is zero.[12]
- there are two consumption goods, cash and credit goods.
- government consumption is exogenous..
- government imposes a tax rate on labour income.
- a constant returns to scale technology is considered to transform labour into output.

$$\ln(R_t) = -\gamma_0 - \gamma_1 \ln(\frac{M_t}{p_t}) + \gamma_2 \ln(Y_t - \frac{M_t}{p_t})$$

and then finds the following relationship between ϑ_2 and $\alpha_2 = \frac{\gamma_2}{\gamma_1}$,

$$\vartheta_2 = \frac{\alpha_2}{1+(1-\alpha_2)v^{-1}}$$

where v^{-1} is the value of the velocity at the point where the Taylor approximation is evaluated.

[12] It should be noted that since 1979 the issue of bonds has been illegal in this economy. Although before 1979 there was bond financing, the proportion of income from bond financing was negligible.

The utility of the representative agent is a function over stochastic processes of two consumption goods, cash and credit goods, and labour. Consequently, the preferences can be written in the following form:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_{1t}, c_{2t}, \ell_t) \tag{31}$$

where ℓ_t is labour; and U (·) satisfies the usual concavity properties. We use timing conventions as in Lucas and Stokey (1983). The budget constraint corresponding to the characteristics of Iranian economy can be written as

$$M_t + s_t(a_t p_t) = M_{t-1} - p_{t-1}c_{1t-1} - p_{t-1}c_{2t-1} + s_{t-1}(a_{t-1} + d_{t-1})p_{t-1} \tag{32}$$
$$+ p_{t-1}(1 - \tau_{t-1})w_{t-1}\ell_{t-1}$$

where s_t represents the trees[13] that the representative household holds; a_t is the price of trees and d_t is the return on trees that is called fruit; and w_t is the wage rate. Moreover, the cash goods are restricted by the following standard cash–in–advance constraint:

$$p_t c_{1t} \leq M_t \tag{33}$$

The aggregate resource constraint is

$$c_{1t} + c_{2t} + g_t \leq w_t \ell_t \tag{34}$$

where g_t is the government purchases.

The consumer maximises expected utility in a stochastic environment, (31), subject to (32) and (33). Using the Lagrangean method, the maximand may be written as follows:

$$\begin{aligned} L = {} & u(c_{10}, c_{20}, \ell_0) + E_0 \beta u(c_{11}, c_{21}, \ell_1) + \cdots + \mu_{10}[p_0 c_{10} - M_0] + \mu_{20}[M_0 + s_0(a_0 p_0) \\ & - M_{-1} + p_{-1}c_{10-1} + p_{-1}c_{20-1} - s_{-1}(a_{-1} + d_{-1})p_{-1} - p_{-1}(1 - \tau_{-1})w_{-1}\ell_{-1}] \\ & + \mu_{11}[p_1 c_{11} - M_1] + \mu_{21}[M_1 + s_1(a_1 p_1) - M_0 + p_0 c_{10} + p_0 c_{20} - s_0(a_0 + d_0)p_0 \\ & - p_0(1 - \tau_0)w_0 \ell_0] + \mu_{12}[p_2 c_{12} - M_2] + \mu_{22}[M_2 + s_2(a_2 p_2) - M_1 + p_1 c_{11} \\ & + p_1 c_{21} - s_1(a_1 + d_1)p_1 - p_1(1 - \tau_1)w_1 \ell_1] + \cdots \end{aligned} \tag{35}$$

Maximising this with respect to the consumer choice variables c_{10}, c_{11}, ..., c_{20}, c_{21}, ..., ℓ_0, ℓ_1, ..., M_0, M_1, ..., s_0, s_1, ..., gives:

[13] See, for example, Lucas (1978).

$$0 = \frac{\delta L}{\delta c_{10}} = u'(c_{10}) + \mu_{10} p_0 + \mu_{21} p_0 \tag{36}$$

$$0 = \frac{\delta L}{\delta c_{11}} = E_0 \beta u'(c_{11}) + \mu_{11} p_1 + \mu_{22} p_1 \tag{37}$$

$$0 = \frac{\delta L}{\delta c_{20}} = u'(c_{20}) + \mu_{21} p_0 \tag{38}$$

$$0 = \frac{\delta L}{\delta c_{21}} = E_0 \beta u'(c_{21}) + \mu_{22} p_1 \tag{39}$$

$$0 = \frac{\delta L}{\delta \ell_0} = u'(\ell_0) - \mu_{21} p_0 (1 - \tau_0) w_0 \tag{40}$$

$$0 = \frac{\delta L}{\delta \ell_1} = E_0 \beta u'(\ell_1) - \mu_{22} p_1 (1 - \tau_1) w_1 \tag{41}$$

$$0 = \frac{\delta L}{\delta M_0} = -\mu_{10} + \mu_{20} - \mu_{21} \tag{42}$$

$$0 = \frac{\delta L}{\delta M_1} = -\mu_{11} + \mu_{21} - \mu_{22} \tag{43}$$

$$0 = \frac{\delta L}{\delta s_0} = \mu_{20}(a_0 p_0) - \mu_{21}(a_0 + d_0) p_0 \tag{44}$$

$$0 = \frac{\delta L}{\delta s_1} = \mu_{21}(a_1 p_1) - \mu_{22}(a_1 + d_1) p_1 \tag{45}$$

The following relationships can be derived from the household's first order conditions:

$$\frac{u'(c_{1t})}{u'(c_{2t-1})} = \frac{p_t}{p_{t-1}} \tag{46}$$

$$-\frac{u'(\ell_t)}{u'(c_{2t})} = (1 - \tau_t) w_t \tag{47}$$

$$E_t[\frac{u'(c_{2t+1})(a_{t+1} + d_{t+1})}{a_{t+1}}(\frac{p_t}{p_{t+1}})] = \frac{1}{\beta} \tag{48}$$

The government budget constraint is of the form

$$p_{t-1} g_{t-1} = p_{t-1} \tau_{t-1} + M_t + s_t (a_t p_t) - M_{t-1} - s_{t-1}(a_{t-1} + d_{t-1}) p_{t-1} \tag{49}$$

This constraint is used in solving for the optimal Ramsey policy. The government optimal policy maximises the utility of the representative household subject to the government budget constraint and household decision rules implied by the first order conditions.

The representative preferences are specified as follows:

$$U(c_{1t},c_{2t},\ell_t)=\frac{\theta_1 c_{1t}^{1-\gamma_1}}{1-\gamma_1}+\frac{\theta_2 c_{2t}^{1-\gamma_2}}{1-\gamma_2}+\upsilon(\ell_t) \tag{50}$$

To derive the money demand function, the first order condition in equation (46) is used together with the derivatives of the representative preferences equation, (50), with respect to cash and credit goods. This yields:

$$\gamma_0+\gamma_1\ln(c_{1t})-\gamma_2\ln(c_{2t-1})+\ln(\frac{p_t}{p_{t-1}})=0 \tag{51}$$

Using the cash–in–advance constraint the following money demand function is specified:

$$\ln(\frac{M_t}{p_t})=\psi_0-\psi_1\ln(\frac{p_t}{p_{t-1}})+\psi_2\ln(Y_{t-1})+\varepsilon_t \tag{52}$$

This model differs from the model derived by Braun (1994), as in equation (30), in that the rate of inflation $\pi_t=\ln P_t-\ln P_{t-1}$ rather than the interest rate R_t represents the opportunity cost of money. Model (52) is identical to the hyperinflation model of Cagan (1956) except that Cagan assumes that output can be treated as constant over the short period of a hyperinflation.

Concerning the optimal policy, the parameter that is of interest in this model is the elasticity of real balances with respect to income. Since the elasticity was found to be greater than one (see chapter five) the Friedman rule is optimal.

Acknowledgements

I am deeply indebted to my supervisors, Brain Hillier and Panos Michael, for their help and valuable comments. Any remaining errors are my own responsibility.

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APPENDIX B:

DATA SOURCES

1. IMF, International Financial Statistics Yearbook, Various Issues.

   - Exports
   - Imports
   - Official Exchange rate
   - Population
   - Wholesale Price of the US

2. Plan and Budget Organisation of Iran, (1996), The PDS Economic Time Series, Second Version.

   - Government Expenditure and its Components
   - Government Revenue and its Components

3. Central Bank of Iran

   - Consumer Price Index (CPI)
   - Consumption
   - Domestic Oil Price
   - Exports Price Index
   - GDP Deflator
   - Gross Domestic Product (GDP) and Its Components
   - Imports Price Index
   - Investment
   - Monetary Base, M1, and M2
   - Parallel Market Exchange Rate of the Iranian Rial per US Dollar exchanged in Iran
   - Wholesale Price Index (WPI)

4. Pick's World Currency Yearbook (World Currency Yearbook), Various Issues

   - Parallel Market Exchange Rate of the Iranian Rial per US Dollar exchanged in the New York Market

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