Inflation Determinants in Low and High Frequencies: An Implication of Spectral Analysis to Iran

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Abstract

There is no evidence that previous studies, available to Iran's inflation literature, have used spectral methodology to analyze a possible relationship between inflation and its main determinants within a specific period. Accordingly, the present study investigates the effects of money growth, real output growth, output gap and interest rate changes on inflation at low and high frequencies by using seasonal data, Engle' s spectral estimator and Newey-West corrected standard errors over 1974-2006. The results indicate that money growth, output growth and output gap are significant determinants affecting inflation at low frequencies. In addition, at high frequencies, except for money growth, output growth, output gap and interest rate changes have significant and expected effects on inflation in Iran.

Keywords: *Inflation, Spectral analysis, Low and High Frequencies*

JEL Classification: *C20, E31*

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1. Introduction

Inflation in the economy of Iran is one of the chronic phenomena that research to explore its main reasons is still required through using specific methods. Due to the fact that determinants of inflation in the low and high frequencies are different, an analysis of spectral method seems to be useful, since such analyses are powerful tools to study cyclical developments and lagged relationship between variables, especially inflation and the relevant determinants.

Hanan (1963) in the mid-1960s used an application of the spectral analysis for macroeconomic time series data. The initial work focused on the problem of seasonal adjustment methods and economic data structure. Methods introduced by Hanan are appropriate for estimating coefficients in a multivariate linear system of equations, which have two main advantages: First, they express the behavior of the nonparametric regression errors, and second it is not necessary to assume stationarity for errors.

Furthermore, these methods make an opportunity to consider the regression on the frequency and the spectral analysis is recognized as a consistent regression. Engle (1974) and Robinson (1973) extended the spectral analysis and even used them in the non-linear models.

The aim of this study is to conduct a spectral analysis on the relationship between money growth and inflation, productivity growth and output gap in low and high frequencies in Iran. Additionally, we analyze the relationship between inflation and output gap in the high frequencies. Then, the spectral analysis assists us to test the following hypotheses:

a) At low frequencies, there is a direct relationship between inflation and money growth and an indirect relationship between inflation and output growth.

b) At high frequencies, there is a direct relationship between inflation, output gap and interest rate.

This study is set in six sections. Section 2 will review such studies which have dealt with the spectral analysis on inflation rate. The third section introduces the empirical model of inflation in Iran. The fourth section analyzes variable trends in inflation model and considers their stationary frequency domain. The empirical results of the inflation model are analyzed in Section 5, and the last section concludes the remarks.

2. Literature Review

Gerlach (2003) studied the effects of monetary growth, output growth and production gap on inflation for the European region at low and high frequencies by using spectral analysis during 1998- 2001. He introduced initially two-pillar Phillips curve and concluded that:

- Standard Phillips curve is not allowed to consider any difference between high frequencies while production gap changes in low frequencies.
- Output gap has been linked strongly with high frequency inflation movements.
- The low-frequency component of inflation has a close association with the low-frequency component of monetary growth and real income growth.
- The intercept of the Phillips curve depends on components of low inflation or money growth and output growth. These findings support two-pillar Phillips curve of inflation.

Huge and Dewald (2004) studied the interaction between money supply, M_2, real and nominal income and inflation in various frequencies. They used the Christiano and Fitzgerald filtering method to extract the cycles that were stable from two to eight years (business cycle) and from eight to forty years (long-term cycles), and then they used annual data for eleven major industrial countries (Canada, Denmark, France, Italy, Japan, Netherlands, Norway, Sweden, Switzerland, England and the US) during 122 years (1880-2001). They entered two countries, Belgium and Germany, in their analysis after World War Π (1946-2001).

The purpose of their study has been to verify how changes in money growth can be related to nominal changes in real output and inflation in those countries. Huge and Dewald (2004) found that a business cycle frequency, the nominal and real GDP growth and inflation did not show a clear pattern for money growth in those countries. At low frequency, long-term effects were quite different on the frequency bands for eight years to forty years. There was also no clear pattern for supporting a relationship between money growth and real GDP growth. They concluded that money played an important role in inflation of these countries. Bruggeman, et al. (2005) also investigated the role of money growth and output gap in inflation. They used seasonal data in selected European countries during 1986-2003, indicating that at low frequencies, the current inflation had a direct and significant relationship with inflation, output gap money growth with a three-year interruption, money growth with three years and seven year lags but had a negative relationship with an output gap with six year lag. Kristen (2005) estimated the bipolar Phillips curve in the frequency domain for Switzerland, while his results indicated that inflation expectations were important factor in the country, and smoothing parameter was highly significant in the M_1 model but not significant in the M_2 model.

Benati (2005) analyzed the relationship between inflation and growth rates of broad and narrow money in England for different frequencies. During 1871-2003, England had several monetary systems as the gold standard in two different periods, Bretton-Woods regime and the Pound. He examined the relationship between inflation rates and monetary base M_3 and M_4 in each of these systems, separately. Benati (2005) used spectral analysis and concluded that components of inflation are related systematically and positively to money growth during a period of thirty years (low frequency) in the entire systems.

Assenmacher and Gerlach (2005) have analyzed spectrally inflation in Europe, considering long-term fluctuations during a period of more than four years as well as short-term fluctuations during a period of less than four years. They imposed assumptions on the money growth to estimate the regression by applying a Pillips's spectral estimator. The results showed that, at low frequencies, money growth led to the same changes in inflation, but at high frequencies, there was no effect on inflation. In addition, the effect of real production growth on inflation was not significant, while a gap in output affected directly inflation rate within a high frequency. Assenmacher and Gerlach (2005) analyzed the determinants of inflation in which money growth and inflation affect inflation in different frequencies. They concluded that interest rate was not significant at low frequencies, but production gap had a direct and significant impact on inflation. In high frequencies, changes in interest rates and money growth were not significant and output gap was statistically significant only when the frequencies were defined as periods of less than four years.

In another study, Assenmacher and Gerlach (2006) clarified the determinants of inflation in Japan during the period (1970-2005) by using spectral analysis through estimating their model by the Engle's spectral estimator. The results showed that money growth, output growth and output gap had different effects on inflation at low frequencies. More specifically, money growth and output growth had no significant effect on inflation at high frequencies. However, output gap affected inflation significantly and positively within such frequencies, while, at low frequencies, money growth influenced inflation indirectly.

3. The Model Specification

According to Jordan (2001), determinants of inflation should change within different frequencies. In this way, a monetary analysis raises movements in low frequencies or changes in inflation in local steady-state and real indices. Such analysis also provides prediction on temporary frequencies in steady-state. To formulate the approach, inflation is classified into low frequencies (*LF*) and high frequency (*HF*) (Assenmacher and Gerlach, 2006):

$$\pi_t = \pi_t^{LF} + \pi_t^{HF} \qquad (1)$$

where π_t, π_t^{LF} and π_t^{HF} denotes current inflation, low frequency inflation and high frequency inflation, respectively. Gerlach (2003) assumes that high frequency movements in inflation depend on the output gap (g_t), while movements in output gap depend on cost pressures arising from labor costs, exchange rate changes and value added tax. Such variables are considered as a lag of their values:

$$\pi_t^{HF} = \alpha_g g_{t-1} + \varepsilon_t^{HF} \qquad (2)$$

where g_{t-1} denotes the lagged output gap at one period. ε_t^{HF} stands for the error term in high frequency. Low frequency inflation changes can be expressed under the quantity theory of money, as follows:

$$\pi_t^{LF} = \alpha_\mu \mu_{t+}^{LF} + \alpha_\gamma \gamma_t^{LF} + \alpha_\nu \nu_t^{LF} \qquad (3)$$

where μ shows money growth rate, γ_t is real production rate and ν_t^{LF} stands for the growth rate of money velocity. It is obvious that Equation (3) is an identity that can be used to define the money velocity. Assume that a change in money velocity depends on a change in short-term interest rate (p_t):

$$\nu_t^{LF} = \alpha_\rho^{'} \rho_t^{LF} + \varepsilon_t^{\nu.LF} \qquad (4)$$

Where ν_t^{LF} , ρ_t^{LF} and $\varepsilon_t^{\nu.LF}$ indicate money velocity, interest rate and error term in low frequencies. Replacing Equation (4) into Equation (3) and using $\alpha_\rho = \alpha_\upsilon \alpha_\rho$, the following equation is obtained:

$$\pi_t^{LF} = \alpha_\mu \mu_t^{LF} + \alpha_\lambda \gamma_t^{LF} + \alpha_\rho \rho_t^{LF} + \alpha_\nu \varepsilon_t^{\nu.LF} \qquad (5)$$

According to Equations (1), (2) and (5) and using $\varepsilon_t = \alpha_r \varepsilon_t^{\nu.L.F}$ Equation (6) is obtained as follows:

$$\pi_t = \alpha_\mu \mu_t^{LF} + \alpha_\gamma \gamma_t^{LF} + \alpha_\rho \rho_t^{LF} + \alpha_g g_{t-1} + \varepsilon_t \qquad (6)$$

To estimate Equation (6), we should convert variables to the frequency domain by using Fourier transformation. Finally, the following model would be estimated by Engle and (Newey-West) approaches for Inflation in Iran:

$$\pi_t^i = \alpha_0^i + \alpha_\mu^i \mu_t^i + \alpha_\gamma^i \gamma_t^i + \alpha_t^i \rho_t^i + \alpha_g^i g_{t-1}^i + \varepsilon_t^i \qquad (7)$$

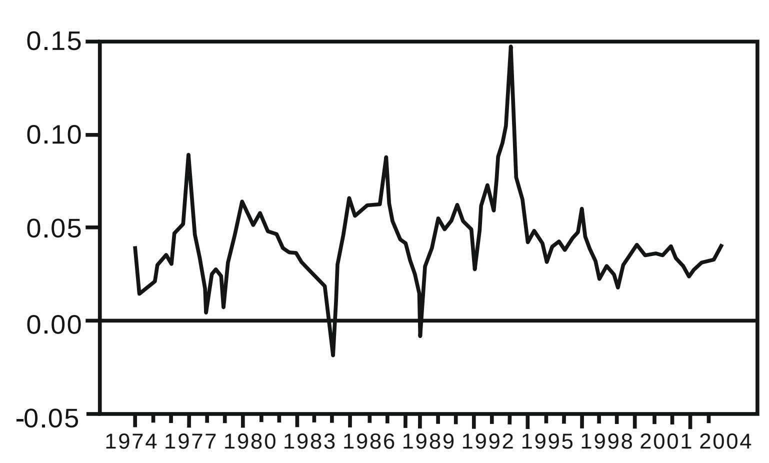
In this equation, the uppercase i counts for low and high frequencies. $\mu_t^i, \gamma_t^i, g_{t-1}^i$ and p_t^i denotes real money growth, real GDP growth and interest rate changes and the one period lagged value of output gap, respectively. ε_t^i shows the error term in frequency i at time t. It is expected that real money growth, real *GDP* growth and output gap affect inflation at low frequencies while it is affected by output gap and interest rate changes at high frequencies.

4. Analyzing Trends of Inflation Determinants

In this study, quarterly data have been used for the period 1974-2006. Except for interest rate, all variables are applied in log values. In addition, the weighted average rate of short-term bank deposits is as the annual short-term interest rate that has been used by this research. Figure (1) shows the trends of the variables used in the inflation model.

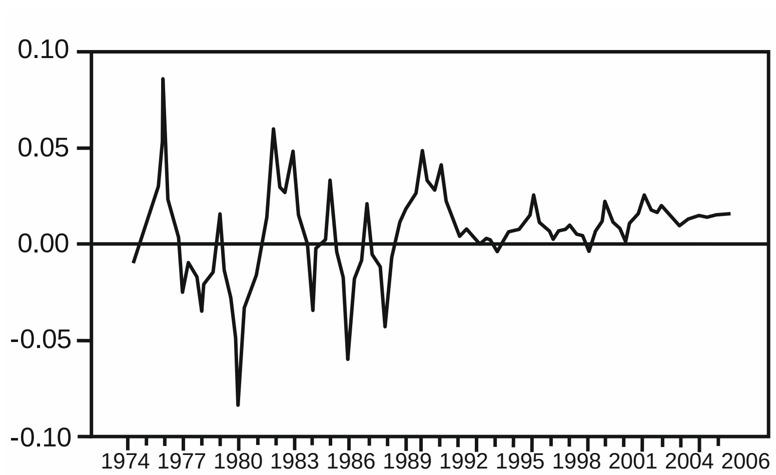
Figure 1: Trends of the model variables

Inflation



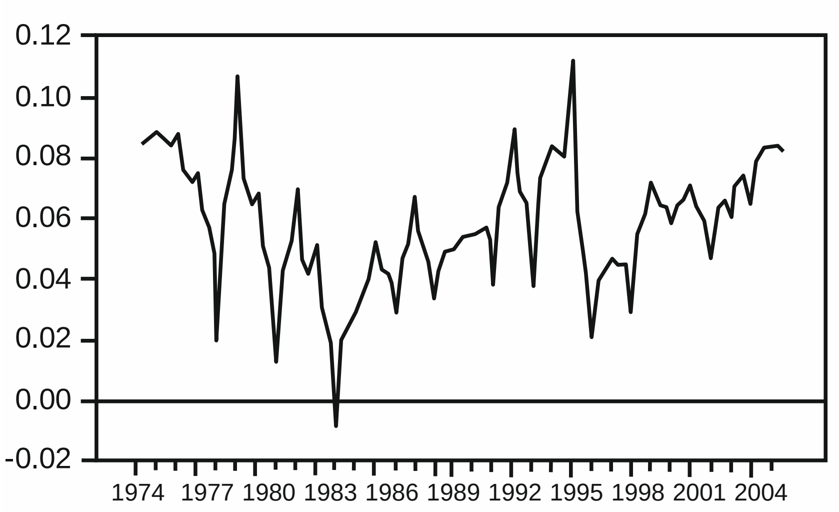
Panel (a)

Real Production Growth



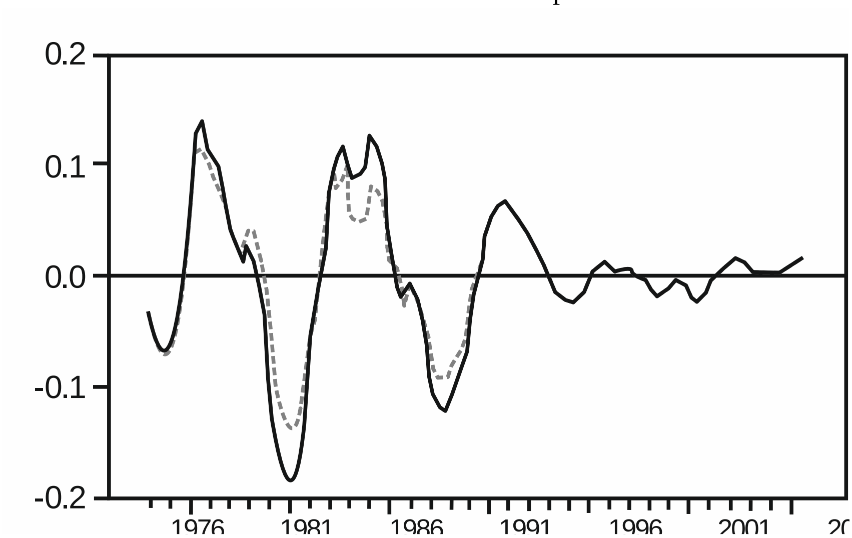
Panel (b)

Money Growth



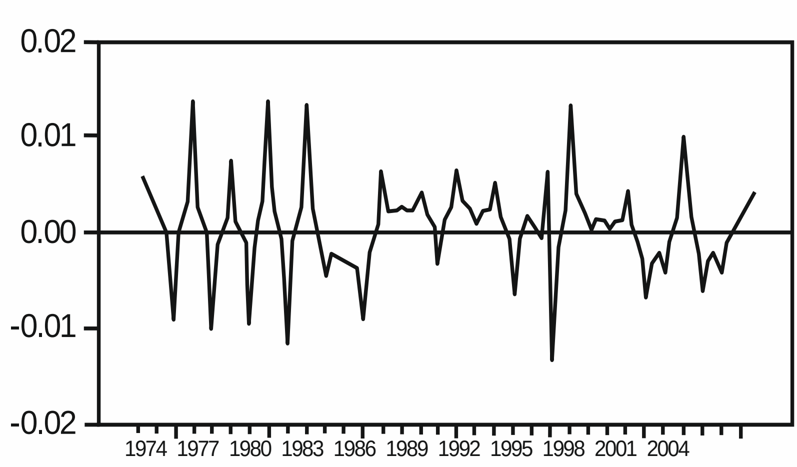
Panel (c)

Production Gap



Panel (d)
_ Production gap (spectral filter)
…. Production gap (HP filter)

Interest Rate Changes



Panel (e)

Panels (a), (b) and (c) depict changes in inflation, real production growth and money growth during the period 1974-2006. Inflation and money growth show a co-movement relation during the period, indicating a direct relationship between continued changes in prices and money balances. However, the real GDP growth has shown a different movement during the period.

Following Assenmacher and Gerlach (2006), the trend for output gap has been measured by two methods of HP and spectral filtering, while data obtained from such filtering have close trends during the period. Fluctuations in both trends of output gap have been modified smoothly within the second half of the period. Totally, output trends have been seen at the low frequencies. However, panel indicates changes in interest rate at the high frequencies. This reveals the fact that both inflation and interest rates have a synchronized relationship.

5. Empirical Result

In the frequency domain, using the estimated coefficient depends on the stationarity of variables (Phillips 1991 and Assenmacher and Gerlach 2005 and 2006). To test unit root of the model variables, we use three relevant methods: Augmented Dickey Fuller (ADF), Phillip- Peron (PP) and KPSS [presented by Kwiatkowski et al. (1992)]. For the first two tests (ADF and PP), the null hypothesis stands for the non-stationary variables, but it is otherwise to the KPSS test. Table (1) summarizes the unit root results for the variables, which are mostly stationary based on the number of lags found by the AIC. According to the results, the variables are significantly stationary at the ordinary level[1].

Table 1: Unit root tests for the model variables

Variable	ADF	PP	KPSS	AIC lag
Inflation	-6.58	-6.89	0.28	5
Money Growth	-8.97	-8.97	0.34	3
Production Growth	-3.66	-3.66	0.54	4
Production Gap	-6.44	-6.44	0.05	6
Interest Rate Changes	-5.87	-5.87	0.08	4

Source: Authors'

Note: Last column shows numbers of lags in the test that is compiled by the AIC.

Engel (1974) showed that if $y = \beta x + \varepsilon$ is a non-spurious regression in a time domain, instead it can be transformed into the frequency domain used for the dependent and independent variables. If $\tilde{x}$ and $\tilde{y}$ show converted variables in the frequency domain, regression equation would be $\tilde{y} = \tilde{x}\beta + \tilde{\varepsilon}$. Estimator $\hat{\beta}$ is thus calculated as bellow:

$$\hat{\beta} = \left[\sum_{k=0}^{T-1} \hat{f}_{xx}(\omega_k) \right]^{-1} \left[\sum_{k=0}^{T-1} \hat{f}_{xy}(\omega_k) \right] \qquad (8)$$

where the estimator $\hat{\beta}$ is called Engle estimator, T is the size of the sample and $\omega \in [-\pi, \pi]$ indicates the frequency. $\hat{f}(\omega)$ is a periodgram of x in (ω) frequency and $\hat{f}_{**}(\omega)$ is a vector of cross periodograms. Crucial benefit of converting regression to the frequency domain is to test a hypothesis that not only allows all the frequencies but some frequencies can also be tested.

If the idempotent matrix $A_{T \times T}$ is pre-multiplied by regression equation ($\tilde{y} = \tilde{x}\beta + \tilde{\varepsilon}$), we will obtain the following

$$A\tilde{y} = A\tilde{x}\beta + A\tilde{\varepsilon} \qquad (9)$$

1- The results have been obtained by RATS 7.1

where the relevant variance is also defined as

$$^{*}E(A\tilde{\varepsilon})(A\tilde{\varepsilon}) = \sigma^{2} A \qquad (10)$$

Sign * can be expressed as additional matrix. In other words, Equation (8) is estimated for a subset of frequencies, consequently, $\tilde{\beta}$ is a consistent estimator but it is not efficient because it does not use all of the available information. In contrast, the model is only used in certain frequency because using all frequencies might obscure the relationship between the variables. Engel showes that *F* test can be used for equality of parameters in the desired frequency (Assenmacher and Gerlach, 2006 and 2010).

To estimate the Iran's inflation model, two-year threshold is considered for low and high frequencies. The selection of this threshold is arbitrary and logic, otherwise it affects the results. Seriously the rotation movements of more than two years are considered as a low frequency band and frequency of cycles in less than two years is considered as a high frequency band. The variables used to estimate the limited Fourier approach and Engle estimator (1974) are transferred to the frequency domain, and then they are classified into low and high frequencies.

Based on theoretical principles and methods of estimating the proposed model, however, relevant hypotheses are tested, raising the fact that why there is a direct relationship between inflation and money growth in low frequencies and why there is a reverse relationship between inflation and output growth in Iran. In addition, if there is a direct relationship between inflation, production gap and interest rate change within high frequency. The first hypothesis is that at low frequencies, inflation has a direct relationship with money growth and has a reverse relationship with production growth in Iran. To test this hypothesis, we estimate the inflation model specified in Equation (7) at low frequencies (frequencies less than two years) by using a spectral estimator and by applying WinRATS. As shown in Table (2), except for interest rates, all coefficients of variables are statistically significant.

Table 2: Estimation results for Equation (7) during 1974 to 2006: A frequency band regression in low frequencies

Independent variables	Coefficient of variables	Coefficient	Statistic *t*	Probability
Constant	$\hat{\alpha}_o$	-0.00046	-0.140	0.889
μ_t^{LF}	$\hat{\alpha}_\mu$	0.33	8.96	0.000
γ_t^{LF}	$\hat{\alpha}_\gamma$	-0.31	-2.624	0.014
ρ_t^{LF}	$\hat{\alpha}_\rho$	0.033	0.524	0.604
g_{t-1}^{LF}	α_g	0.019	2.228	0.034
R^2=0.75		DW=2.05		df = 27

Source: Authors

Coefficient of Money growth (0.33) is statistically significant. Because the model is estimated in logarithm, at low frequencies results indicate that the one percentage change in money growth causes 0.33 percent increase in inflation.

The lagged output gap coefficient with ($\hat{\alpha}_g$) is statistically significant and equals 0.19, which implies at the low frequencies, one percentage change in output gap causes a positive change in inflation rate. The output growth coefficient ($\hat{\alpha}_\mu$) is significant with the value of 0.33 in low frequencies that can be expressed as an indirect percentage change in output growth. Hence, not only at low frequencies money growth and output growth but also output gap affects inflation.

The second hypothesis is that at the high frequency, inflation has direct relationship with output gap and interest rates in Iran. To examine this hypothesis, the inflation model shown in (7) is estimated by using spectral regression which has been reported in Table 3.

Table 3: Estimation results for Equation (7) during 1974 to 2006: A frequency band regression in high frequencies

Independent variables	Coefficient of variables	Coefficient	statistic	Probability
Constant	$\hat{\alpha}_o$	0.001	2.102	0.038
μ_t^{LF}	$\hat{\alpha}_\mu$	0.053	0.943	0.348
γ_t^{LF}	$\hat{\alpha}_\gamma$	-.355	-16.139	0.000
ρ_t^{LF}	$\hat{\alpha}_\rho$	0.3690	13.699	0.000
g_{t-1}^{LF}	α_g	0.142	2.285	0.024
R^2 =0.75	DW =1.9			df =93

Source: Authors'

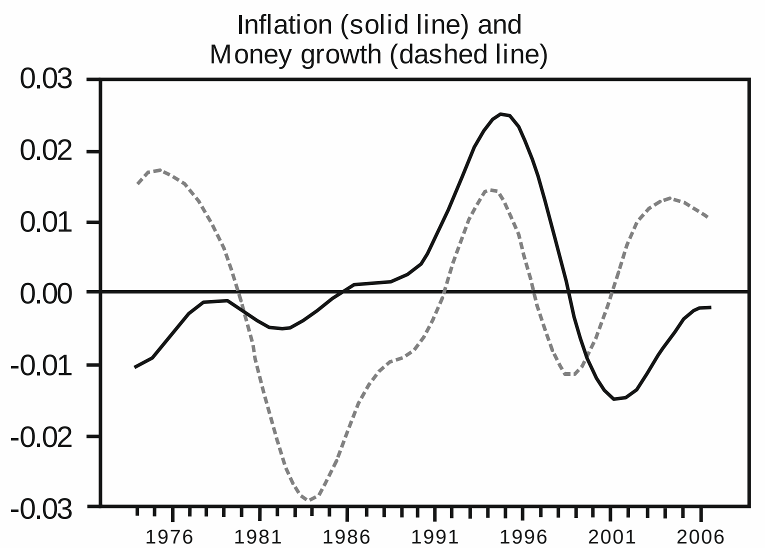
As shown by this table, all coefficients, except for money growth, have theoretically expected signs. The coefficient of money growth is not significant, which shows money growth has no effect on inflation rate at high frequency in Iran. However, this result contradicts Assenmacher and Gerlach (2005, 2010), who have indicated that money growth has negative and significant effect on inflation at high-frequency. Output growth coefficient is negative and significant indicating that output has negative effect on inflation rate in high frequencies, as expected.

Empirical results show that the coefficient of interest rate is strongly significant and positive which is consistent with the literature. Assenmacher and Gerlach (2010), for instance, show that interest rate has significant and positive relationship with inflation at high frequencies in Swiss. This conclusion is based on Friedman's demand approach in which an increase in interest rate in the short-term leads cash flow to increase and hence inflation increases. On other hand, output gap coefficient is positive and strongly significant, indicating that the effect of this variable on inflation is positive at high frequencies. Since the log form of the model has been estimated, one percent change in interest rates and one percent change in output gap cause positive change in inflation of 0.39 and 0.14, respectively, at high frequencies. One percent change in output growth cause -0.35 percent change in inflation. Overall, it can be concluded that increases in output gap and interest rate and a fall in real output growth cause inflation in Iran. Clearly, fluctuations in such factors show that inflation is a chronic phenomenon in Iran.

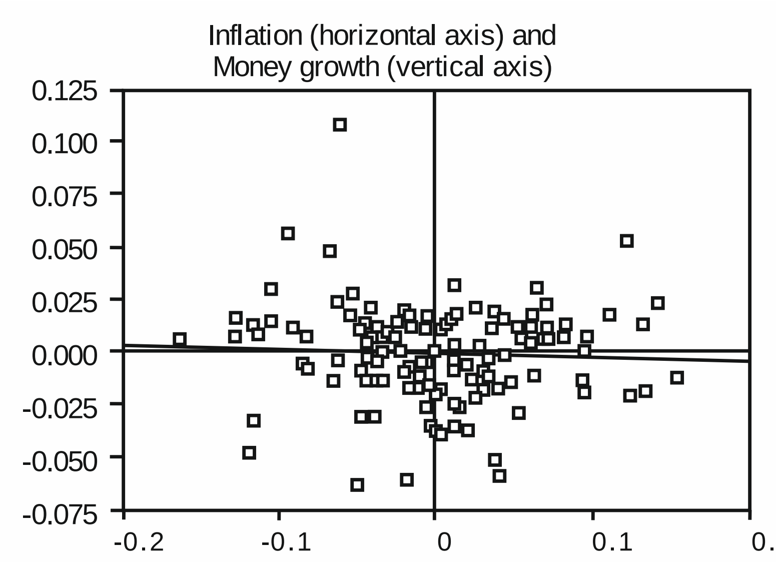
Due to the results obtained, the determinants of inflation are different at low and high frequencies. Figures (2) and (3) show how money growth and output growth affect inflation in the low and high frequencies. Diagram (a) in Figure (2) sketches the relationship between inflation and money growth at low frequencies, while Diagram (b) show their Scatter plots at high frequency.

Clearly, at low frequencies money growth has a positive correlation with inflation, but it has no effect on inflation at high frequency because distributed values of inflation and money growth are almost identical in all four regions. Based on Diagram (c) in Figure (3), production growth has a reverse correlation with inflation rate in low frequencies. Additionally, in high frequencies, it has negative effect on inflation, because it is more scattered in the second and fourth regions.

Figure 2: Relationship between money growth and inflation rate in low and high frequencies



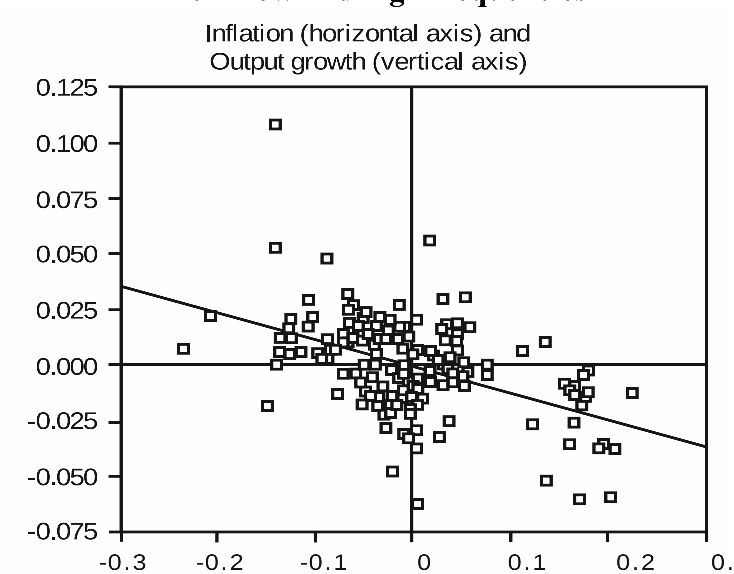
(a)



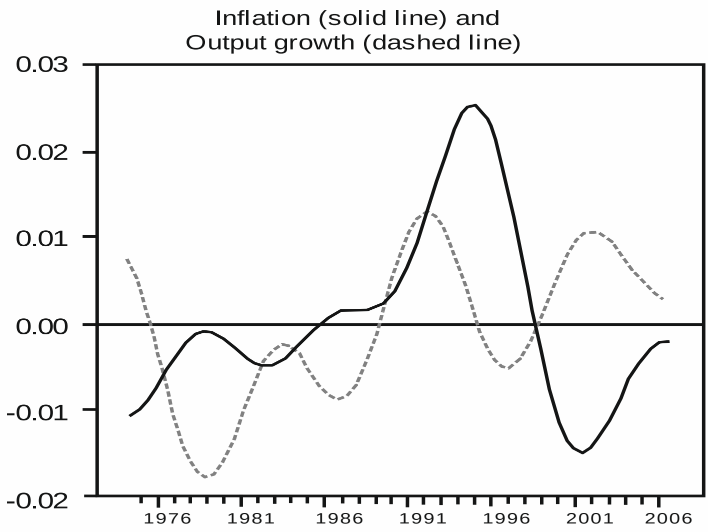
(b)

Source: Authours

Figure 3: Relationship between real production growth and inflation rate in low and high frequencies



(c)



(d)

Source: Authors'

6. Conclusion

Empirical findings of this study show that money growth (M_1) in low frequencies has a significant and positive effect on inflation. It should be noted that due to the impact of other factors on inflation, money growth is not the only factor which affects inflation. Money growth in the low frequencies justifies price changes in the economy of Iran. As a result, inflation in Iran is not only a monetary phenomenon. The results show that output growth has a negative and significant effect on inflation in low-frequency. In practice, this result revealed that there was a significant inverse relationship between output growth and inflation. This means that a rise in real GDP growth is considered as a major factor in controlling inflation. Iran's economy has been fluctuated in the last three decades and economic growth has relatively led to increase of the inflation rate. There is also a significant direct relationship between the lagged output gap and inflation in which the economy may be inflationary.

Based on the results obtained, GDP growth has a significant negative effect on inflation rate in high frequencies. In such situation, an increase in imports, especially raw materials, causes inflation to decrease and production to increase. Thus, the conclusion is that there is a significant inverse relationship between output growth and inflation rate. Increasing production growth causes a reduction in inflation rate and vice versa. Thus, in the high frequencies, an increase in GDP growth plays a major role in decreasing Iran's inflation. Furthermore, the output gap coefficient has significant positive coefficient in high frequencies. Thus there is a significant and direct relationship between the output gap and inflation rate, as an indication of expansionary inflation. The lagged output gap that implies the structural feature of Iran's economy depends on several factors such as cost pressures from labor costs, exchange rate changes, value added tax, etc. It seems that output gap to be one of the major determinants of inflation in the economy of Iran.

The results have confirmed that an increase in money growth in low frequencies is synchronized by inflation. In general, fluctuations in inflation in low and high frequencies require effective supervision of the central banks on the economy without intervention of governmental administration in different markets. In addition, uncontrolled inflation in the country requires structural modification of production by removing the production gap.

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