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MONEY DEMAND AND INFLATION: A LINEAR OR THRESHOLD RELATION?

Abstract: *This study is an attempt to empirically investigate the role of inflation on the money demand function in Iran. The main purpose of this study is to focus specifically on the relationship between inflation and money demand, that is whether the relationship is non-linear and as well as to estimate the threshold level; at which the sign of the relationship between two variables would switch. In order to achieve the objective, there were used time-series data over the period 1980 through 2013 in this study. Empirical results provide the evidence that the nonlinear model presents a better fit than the linear model for Iran's money demand. This non-linearity is explicitly modelled using threshold regression procedure. Also, exchange rate and real income explain some variations of money demand. The results obtained in this study suggest that the Central Bank should carefully monitor the exchange rate and inflation as two most important indicators of monetary policy, because these two determinants are the main drivers of demand for money in Iran.*

Keywords*: money demand function, inflation, threshold regression, optimum threshold level, Iran*

JEL *:* C 32, E 31, E 41

1 Introduction

Demand for money plays a major role in macroeconomic analysis, especially in selecting appropriate monetary policy actions [9]. As Goldfeld [36] states the relation between the demand for money and its main determinants is an important building block in macroeconomic theories and is a crucial component in the conduct of monetary policy. Therefore, the demand for money is one of the topical issues that have attracted the most attention in the literature both in developed and developing countries [47]. Since, countries with underdeveloped financial markets generally rely on the existence of a stable money demand function for the formulation and conduct of efficient monetary policy [50]. A stable money demand permits for higher predictions of the result of monetary policy on interest rates, output, and inflation, and so reduces the likelihood of inflation bias [23]. So, erroneously in money demand estimation will make the monetary authorities take a wrong action when policy is designed. Implementation of such policy as a following will bring a disaster to the country. Therefore, numerous theoretical literature and empirical studies on the demand for money were conducted to provide more understanding about conditions of demand for money. Most of the theoretical grounds and accumulated evidence indicate a strong link between money and price. The significance of the expected rate of inflation as a factor influencing the demand for money is well established.

Several theoretical and empirical literature show a negative relationship between inflation and demand for money. Nevertheless, some economists and researchers have accounted for the opposite. Recently, linear co-integration analysis has been the mainstream approach in examining the money demand function. The study of Cagan [16] postulated a linear relationship between expected rate of inflation and demand for money. However, there are some empirical evidence that suggest that Cagan money demand function does not fit well for low and high inflation period at the same time and present of a varying coefficient (e.g. example, [7, 45, 12]). Theoretically, there is no reason to believe that economic systems must be intrinsically linear. Empirically, there was a great number of studies showing that inflation rate causes a non-linear in the relation with demand for money. Empirical results of Basco *et al.,* [8] using time-series approach are consistent with cross-country evidence of study by De Grauwe and Polan [27]. Findings of both studies show that money velocity is positively correlated with money growth and inflation under high inflation. On the contrary, velocity is negatively correlated to inflation and money growth under low inflation. If such a nonlinear relationship exists then it should be possible, in principle, to estimate the threshold level, at which the sign of relationship between the inflation and money demand would switch.

A considerable body of literature have investigated the demand for money in developing countries like Kalra [43], Sacerdoti and Xiao [58], Omotor [52] and Vuong and Tran [67], and such as developed countries; Hamburger [38], Beyer [13], Brand and Cassola [15] and Calza *et al.,* [17]. However, there is far less literature on money demand-inflation nexus in a threshold regression, and what is clear in these papers is that no consensus has been obtained about the effect of inflation on money demand. The main purpose of this study is to focus mainly on the relationship between inflation and money demand, and we applied threshold regression and linear technique in order to get more valid results. How do we proceed? After discussing some empirical studies in Section 2, Section 3 develops theories of money demand. Section 4 introduces model specification. Section 5 presents threshold regression and results. Section 6 concludes.

2 Literature Review

The importance of the money demand function has encouraged a wide range of economists to empirically study its determinants and stability from along ago. The basic valuable effort on money demand function can be attributed to Friedman's

[14] pioneering study, who shaped the foundation for large body of research and that search continues even today. The reason for this continuous search of an estimated demand for money function is that if a stable demand function containing a limited number of explanatory variables exists, policy actions that alter the money stock can be expected eventually to have predictable effects on ultimate target variables. Therefore, the knowledge of a stable demand function decreases the outcome uncertainty of monetary and fiscal policy. In this part, we aim at introducing some relevant literature.

Arango and Nadiri [4] stated the demand for real cash balances deduces from an underlying portfolio model of the financial market depends upon domestic variables and foreign monetary developments. The model was estimated using quarterly postwar data for Canada, Germany, the U.K, and the US. There was clear evidence that demand for money is affected not only by changes in domestic variables such as permanent income, domestic interest rate and price expectations, but also by fluctuations in exchange rate expectations and foreign interest rates.

Arango and Gonzalez [3] used a nonlinear smooth transition regression model of the demand for narrow money in Colombia by using monthly data for cash, prices, industrial GDP, the interest rate and the rate of depreciation. In comparison with the linear error correction model, the nonlinear specification is highly superior according to the statistics.

Escribano [31] employed single-equation nonlinear error correction models with linear and nonlinear co-integrated variables to explore money demand specification. These models used to show how they can identify unknown threshold points in asymmetric models and to check the stability properties of the long-run equilibrium. The results showed two threshold points are around 0 and 0.2. Also, the stability of money demand more than a century, 1878 to 2000 was remarkable for author.

Valadkhani [66] examined the long- and short-run determinants of the demand for money in six countries in the Asian-Pacific region using panel data (1975-2002). Various country-specific coefficients were allowed to capture inter-country heterogeneities. The estimation brought three main results, (a) the demand for money in the long-run positively responds to real income and inversely to the interest rate spread, inflation, the real effective exchange rate, and the US real interest rate; (b) the long-run income elasticity is greater than unity; and (c) both the currency substitution and capital mobility hypotheses hold only in the long run.

Bitrus [14] employed a comparative analysis on the effectiveness of the determinants of money demand in both developing and developed countries. It was found that income related factors or the scale variables are more effective in the developing countries while factors that work through the financial system are more effective in the developed economies, i.e. the level of the development of a country's financial system determines which factors will be relevant targets in moping excess liquidity within an economy.

Gümüşoğlu [37] employed both linear (autoregression VAR model) and nonlinear estimation methods (MTAR threshold cointegration) to investigate the relationship between money demand, GDP, inflation and interest rates for the Euro Area over the period 1980-2010. Linear model found evidence of stability; however, it had some conflicting results which was explained by the nonlinearity of the model. Empirical results of threshold co-integration verified the nonlinearity in European money demand, and it presented better fit to economic literature than linear model for European money demand.

3 Theories of Demand for Money[1]

The purpose of the theory of demand for money is to look at the variables that motivate people to hold part of their wealth in money as opposed to other assets. Following Jhingan [41], there are three approaches to the demand for money: The classical approach, the Keynesian approach and the post Keynesian approach.

3.1 Classical demand for money theory

The quantity theory of money, dating back to contributions made in the mid-16th century is one of the oldest theories in economics. Fisher [32] gave quantity theory of money as inherited from his classical and pre-classical predecessors; its modern formulation. Fisher's version, typically termed equation of exchange or transaction approach can be stated as:

$$M.VT = T.PT \tag{1}$$

where M = stock of money, VT = velocity of the stock of money to finance the transaction volume, T, and PT = price level.

According to the neo-classical assumptions – namely that the economy is running at full potential and V is constant – P would move in strict proportion to changes in M: A rise (decline) in the economy's stock of money would increase (reduce) the price level. In this theoretical framework, money is neutral as far as its effects on output are concerned. Changes in M affect P, but do not have any impact on Y or V.

3.1.1 The Cambridge approach

The Cambridge approach or cash balance approach is associated with Pigou [57] and Marshall [49]. It differs from Fisher's approach in three aspects. First, the Cambridge approach is a microeconomic approach, describing individual choice rather than market equilibrium. It asks: What determines the amount of money an individual would wish to hold, given that the desire to conduct transactions makes money holding attractive. The Cambridge approach moved the analytical focus from a model where the velocity of money was determined by making payments

1 This part has been extracted heavily from chapter 2 of book entitled "Monetary economics in globalized financial markets", [11].

to one where market agents have a demand for money [22]. Second, money is held not only as a medium of exchange for making transactions as in Fisher's case, but also as a store of value, providing satisfaction to its holder by, for instance, adding convenience and security. Third, the concept of money demand comes across more explicitly as will be discussed in more detail below; Cambridge economists pointed out the role of wealth and the interest rate in determining the demand for money.

Formalizing the Cambridge approach, Pigou assumed that for an individual the level of wealth, the volume of transactions and the level of income – at least over short periods – would move in stable portions to one another. Other things being equal, the nominal demand for money, M_d, is then proportional to the nominal level of the transaction volume, PT:

$$M_d = kPT \tag{2}$$

where k represents the cash holding coefficient. The latter is simply the reciprocal of the velocity of money, that is: $V = 1/k$. If money supply, M_s, equals money demand M_d, we can write:

$$\begin{aligned} M_S &= M_D = kPT \\ M &= \frac{1}{V}(PT) \\ MV &= PT \end{aligned} \tag{3}$$

with the latter expression representing the familiar equation of exchange. The Cambridge formulation of the quantity theory provides a description of monetary equilibrium within the neo-classical model by focusing on peoples' demand for money, especially the demand for real money balances, as the important factor determining the equilibrium price level consistent with a given quantity of money. The emphasis which the Cambridge formulation placed on the demand for money and implicitly also on its determinants like, for instance, interest rates, strongly influenced both the Keynesian and the Monetarist theories.

3.2 Keynesian money demand theory

The Keynesian theory of money demand (or liquidity preference theory) focuses on the motives that lead people to hold money. More specifically, Keynes [44] distinguished between the demand for transaction balances (including the demand for precaution balances), L_T, and the demand for speculative balances, L_S:

$$L_T = L_t(Y) = kY, \text{ with } \partial L_T / \partial Y > 0 \tag{4}$$

$$L_S = L_S(r) = R - dr, \text{ with } \partial L_S / \partial r < 0 \text{ and } \partial^2 L_S / \partial r^2 < 0 \tag{5}$$

where k = income balance coefficient, Y = nominal output, R = autonomous speculative balance, d = interest rate elasticity and r = representative interest rate. Combining the demand for transaction balances (4) and speculative balances (5) yields the Keynesian demand for money:

$$L = L_T + L_S = kY + L_S(r) \tag{6}$$

In equilibrium, money supply M, equals money demand, that is, in real terms, $M/P = L$. Similar to the quantity theory, the transaction demand for money emphasizes the role of money as a means of payment, suggesting that the transaction demand for money depends on the level of current income. The store-of-value function is reflected in the speculative motive of the demand for money.

In the Keynesian theory, market agents' portfolio decisions are driven by expectations regarding future bond prices, e.g. bond yields. Bonds are willingly held if the expected total return (defined as the sum of interest payable on the bond and expected capital gains) is greater than zero. The pricing formula for the bond market is:

$$BP = \left(\frac{n}{r}\right) . NV \tag{7}$$

where BP = bond market price, n = nominal coupon of the bond (in percent of its nominal value), r = effective yield in the bond market (market rate), and NV = nominal value of the bond. Now assume that each investor has an estimate of the normal market yield, r^{normal}, which might deviate from the current market yield. Depending on the subjectively perceived normal yield, an individual investor is expecting a capital gain or loss from bond holdings:

$$\textit{expected loss on bond holdings} = BP - BP^e \tag{8}$$

with BP^e as the expected bond price in the future. We can rewrite Eq. (8) as follows:

$$\textit{expected loss on bond holdings} = \left(\frac{n}{r}\right) . NV - \left(\frac{n}{r^{normal}}\right) . NV \tag{9}$$

The income from coupon payments on the bond is:

$$\textit{interset income} = n . NV \tag{10}$$

That said, an investor will hold interest bearing bonds if interest income is higher than expected capital losses from holding bonds:

$$n \,.\, NV >= \left(\frac{n}{r}\right) \,.\, NV - \left(\frac{n}{r^{normal}}\right) \,.\, NV \tag{11}$$

or, equivalently:

$$1 > \frac{1}{r} - \frac{1}{r^{normal}} \; or \tag{12.a}$$

$$r > \frac{r^{normal}}{1 + r^{normal}} \tag{12.b}$$

The level of *r*, which fulfils Eq. (12.b), is called the *critical market yield*. At the critical yield, the investor is indifferent as interest income from bond holdings equals expected capital losses of bond holdings. That said, one can draw the following conclusions:

- If the market rate is above the critical yield level, interest income is higher than the expected capital losses, so that the investor decides to keep his total wealth in bonds.
- If the market yield is below the critical market yield, the investor would decide to keep his total wealth *in money balances*, as he fears capital losses related to a forthcoming rise in market yields.

3.3 Post-Keynes theories of money demand

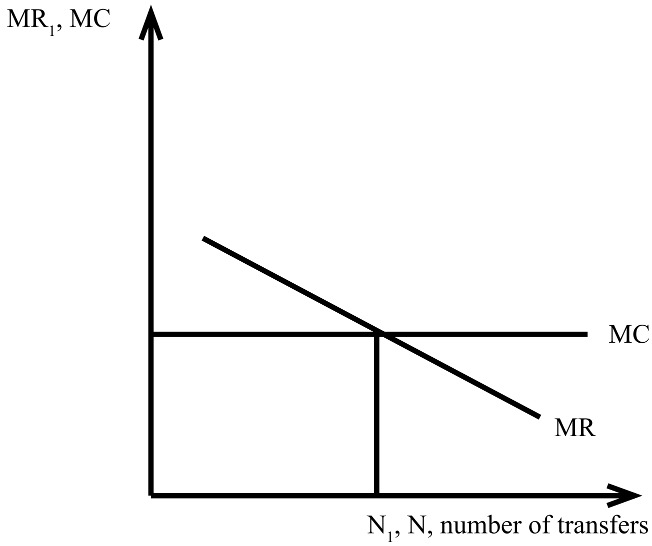
By using the store of value function of money, Keynes introduced the interest rate as one of the factors affecting money demand through the speculative motive. This however, suffered from a shortcoming; Keynes predicted that individuals would hold their wealth in bonds or money, that is, they would not diversify their portfolios. This was remedied by Harry Markowitz and James Tobin. In addition, William Baumol and James Tobin also provided the theory that explains why the transactions demand and even the precautionary demand depends on the interest rate.

3.3.1 James Tobin's explanation

Tobin noted that the Cambridge approach merely asserts that an individual must hold one-half of the periods receipts (and expenditure) as transactions balances. It does not specify the form in which these balances are held. According to Tobin, if an employee is paid salary (for example N3,000 in 30 days), he can deposit all in bonds and then visit the broker to liquidate N100 worth of bonds until the holding is completely liquidated. The demand for money diminished as the number of transfers between money and securities increases. The marginal revenue (MR) from each transaction with the broker is the extra interest earned by holding more securities and fewer money balances. As the number of transfers increases, the marginal revenue from each transfer diminished. The marginal cost (MC) consists of the brokerage fees, or transaction costs, of transferring securities to money and vice versa. The cost includes the "time and trouble" of switching between securities and money. The marginal cost (MC) curve is horizontal indicating a constant marginal cost (MC) of each transfer. The optimum number of transfers is determined at the point of equality between the MR and MC. The number of transfers determines the demand for money (Figure 1).

Figure 1

Marginal Revenue and cost of switching from money to securities and vice versa



3.3.2 William Baumols explanation

Baumol called his approach the inventory–theoretic approach. To find the optimal quantity of transactions balances that an individual should hold, Baumol applied optimizing techniques previously used to find the optimal inventory of goods that a firm should hold. In Baumols analysis, the demand for transactions balance depends on brokerage costs and the opportunity cost of deposits. Baumol assumed that every time an individual buys or sells bond, he or she incurs a brokerage fee, denoted by "*b*", with "*n*" transactions. The brokerage costs equals "*bn*". Brokerage costs are one of two components of the total cost of security transitions balances. The second component is interest forgone by holding wealth in money (deposits) rather than in securities. This opportunity cost of money equals $(i - r_D)\, M^d$. Thus total costs, *TC*, are

$$\text{Total cost} = \text{Brokerage costs} + \text{Opportunity cost or } TC = bn + (i - r_D)M^d \qquad (13)$$

Therefore the brokerage cost are b(Y/T) also, $M^d = T/2$, n= Y/T

$$TC = b\left(\frac{Y}{T}\right) + (i - r_D).(\frac{T}{2}) \quad (14)$$

The individual is now faced with the problem of deciding on the amount of funds to convert from bonds to cash at each withdrawal in order to minimize total costs. Determining the optimal size of *T* also gives us the size of money demand. The investors aim is to choose the level of *T* that minimizes total cost, that is the optimal values of *T*. Therefore, by differentiating *TC* with respect to *T*, setting the derivative equal to zero and solving for *T* we obtain:

$$T = \sqrt{\frac{by}{i} - r_D} \quad (15)$$

Since $M^d = T/2$ it follows that

$$M^d = \sqrt[\frac{1}{2}]{2b\ \frac{Y}{i} - r_D} \text{ (the famous square-root rule)} \quad (16)$$

where, *Y*= income; *b*= brokerage fee; *T*= number of transaction; *i*= interest rate; r_D= deposit rate

The transaction demand is directly proportional to the square root of the quantity of transactions and inversely proportional to square root of the opportunity cost. In other words, if the opportunity cost increases, it will be profitable to invest in bonds and the optimal cash balance ill reduce.

3.3.3 Milton Friedman's explanation

Friedman's contributions to the quantity theory of money are a restatement of money demand by the classical economist. According to Friedman, investors can hold their wealth in the form of money, bonds, equity shares and commodities. He concludes that the demand for money depends on rates of return of the four assets and upon income. Assuming bond and equity capital are perfect substitutes, with equal rates of return, Freedman's money demand function is:

$$M^d = M^d(i, r_D \frac{\Delta p}{P}, Y, W) \quad (17)$$

where M^d= money demand; *P*= price level (positive); *i*= interest rate (negative); *Y*= income (positive); *W*= wealth (positive); r_D = deposit rate (negative). According to him, all things being equal, an increase in the expected rate of inflation increases the demand for commodities and reduces the demand for money and vice versa.

4 Model Specification

The data sets utilized in this paper cover time series for Iran over the period of 1980-2013 and are mainly taken from World Development Indicator published by the World Bank and the Central Bank of Iran. Dominated of previous studies provide the empirical evidence and show that demand for money depends on the level of transactions or economic activities which is represented by variable expressing real wealth, real income or expenditure, and opportunity cost of holding money which is proxied by various kinds of market interest rates and rate of inflation. Generally, money demand function in this study can be specified as:

$$M = f\,(Y, Inf, Exc) \tag{18}$$

where M is the log of real money and used as the dependent variable in the functional relationship which represents the money and quasi money. Log of real gross domestic product (ln GDP/P) will be used as scale variable (Y). It is expected to be positively related to the real demand for money. Inflation rate (Inf) also can be considered as a proxy of opportunity cost instead of discount rate and Exc stands for exchange rate.

The major determinant of demand for money is the volume of payments that must be undertaken. A good measure of the volume of payments, in turn, is the level of national income (Y). All things being equal, the higher the level of income, the greater the need for money and, vice versa [14]. Positive effect of income on money demand has been demonstrated in a study by Duca and VanHoose [29].

One important controversial variable is the interest rate. The traditional money demand models postulate that the demand for real cash balances is negatively related to the yield on financial assets (interest rate). The domestic interest rate represents the opportunity cost of holding money; thus, the public would prefer to hold more financial assets such as treasury bills, bonds, etc., during times of high interest rate. In the money demand function for the financially developed industrial countries, this is beyond controversy. However, the role of interest rate in developing economies deserves some attention [9]. Theoretical reasoning and empirical investigation have indicated the importance of interest rate in money demand function. One of the earliest tries was by Swellem's [63], indicated that the interest rate as an opportunity cost for holding money has a negative effect on the demand for money. Hamburger [38] specified the demand for real money as a function of real income, and three rates of return on commercial bank savings deposit. Also, a study by Bassha [10] show the significant effect of interest rate on the demand for money. On the basis of the results of several studies as well as the theoretical understanding of interest rate, one cannot determine that the rate of interest affects the demand for money in developing countries. So, in developing countries, due to the scarcity of interest rate data, the underdeveloped nature of money and capital markets, and the failure of government regulated interest rates to reflect actual alternative yields available, it seems appropriate to estimate the demand for money function using a measure of inflation as the opportunity cost of holding money [64]. Based on theory, an increase in inflation rate would reduce the attractiveness of holding money. The first introduction on money demand and inflation was supplied by Friedman [34]. He argued that the demand for real balances is universally related to the expected rate of inflation. So, an increase in the general price level erodes the real value of money and induces a portfolio shift. Akhtar [2] and Abe *et al.,* [1] emphasized on the significant effect of price on the demand for money in Pakistan. In another study Bahmani-Oskooee and Malixi [5] concluded that inflation rate is one of the major determinants for money demand function.

Given the openness of most economies, money demand functions should include the effect of external monetary and financial factors approximated by movements in foreign rate and exchange rate. An increase in foreign interest rates would induce domestic residents to increase their holdings of foreign assets which would be financed by drawing down domestic money holdings. Also, a change in exchange rate would affect portfolio decisions between domestic assets and foreign assets. It can be postulated that exchange rate may has a negative effect on the demand for money. Bahmani-Oskooee and Malixi [5] scrutinized the effect of exchange rate on money demand for developing countries. The results showed that in the long run a change in real exchange rate has a negative significant effect on demand for money function in nine out of eleven cases.

5 Threshold Model and Econometric Results

5.1 Threshold regression model

One of the most interesting forms of nonlinear regression models with wide applications in economics is the threshold regression model. The attractiveness of this model stems from the fact that it treats the sample split value (threshold parameter) as unknown. That is, it internally sorts the data, on the basis of some threshold determinant, into groups of observations each of which obeys the same model [48]. Three estimation approaches in threshold models are suggested in the literature namely Tsay's [65] and Chan's [93] methods and Hansen's [39] procedure.

Tsay [65] proposed recursive estimation method both for testing and modelling threshold autoregressive model for arranged data and determined the order of autoregression model using AIC, SIC, PACF or LM test. Chan [93] suggested the estimation of TAR model for each value of transition variable and comparing the estimated model with the linear one employing likelihood ratio test. If TAR model is selected then create a graph of sum of squared residuals of the estimated TAR models. If there is one (two) threshold(s) there will be one (two) through(s) in the graph showing the threshold value(s). The process produces a switching regression at the threshold and can easily be estimated by OLS. Hansen [39] argues that when the null hypothesis of linearity is tested against a TAR alternative, conventional tests have nonstandard distributions, as the threshold parameter is unidentified under the null hypothesis. He also points out that sampling distributions of threshold estimate is a problem. In terms of the broader literature, Seo and Linton [59] allowed the threshold variable to be a linear index of observed variables. They avoided the assumption of the shrinking threshold by proposing a smoothed least squares estimation strategy based on smoothing the objective function in the sense of Horowitz's smoothed maximum scored estimator. While they show that their estimator exhibits asymptotic normality it depends on the choice of bandwidth. The threshold regression can take the form:

$$\begin{aligned} &1)\quad y_t = \alpha_t x_t + e_t \qquad if\, q_t \leq h \\ &2)\quad y_t = \beta_t x_t + e_t \qquad if\, q_t > h \end{aligned} \tag{19}$$

where q_t is called the threshold variable, and is used to split the sample into two groups. The random variable e_t is a regression error and h denotes the sample split (threshold) value. If the threshold variable is smaller than the threshold value the equation takes the form (1), and vice versa for equation (2). In some cases, decisions must be made concerning what is the appropriate threshold.

Chan [19] under some regularity conditions, supplied the least squares estimator of a stationary threshold autoregressive model. In this procedure for obtaining each threshold value, one regression is embodied and total square error S(h) is calculated. The threshold of $\hat{h}$ is a variable that minimize S(h).

$$\begin{aligned} &min\ S(\hat{h}) = \hat{U}'\hat{U} \text{ or } max\ R^2 = 1 - \hat{U}'\hat{U} / TSS \\ &\hat{h} = Arg\ min\ S(h) \end{aligned} \tag{20}$$

In this study, inflation rate is included as a threshold variable and is estimated by the Chan method. Model estimated in this paper formulated and modified from the model developed by Khan and Senhadji [46] for the analysis of the threshold level of inflation for Iran. The variables of model are real money, real gross domestic product, inflation, and exchange rate. Threshold regression consisting of two linear segments is used. Money demand function will change its slope beyond the threshold level. Based on the data and value of the threshold level Inf*, the equation to estimate threshold level of inflation has been considered in the following form:

$$\begin{aligned} M_t = {} & \left[\beta_0 + \beta_1 Y_t + \beta_2 Inf_t + \beta_3 Exc_t\right] A\,(Z_t \leq h) \\ & + \left[\alpha_0 + \alpha_1 Y_t + \alpha_2 Inf_t + \alpha_3 \beta Exc_t\right] A\,(Z_t > h) + \varepsilon_t \end{aligned} \tag{21}$$

5.2 Testing for unit roots

Methods for detecting the presence of a unit root in parametric time series models have lately attracted a good deal of interest in both statistical theory and application [6]. This is because a unit root is often a theoretical implication of models, which postulate the rational use of information that is available to economic agents Philips and Perron, [56]. The literature on unit root testing is vast – see Diebold and Nerlove [28], Campbell and Perron [18], and Stock [62] for selective surveys, and Enders [30, Chapter 4] for a textbook treatment. In what follows, we shall only briefly illustrate the so-called Augmented Dickey–Fuller unit-root test (ADF).

The Dickey-Fuller test can be generalized to allow for higher-order autoregressive dynamics, in case that an *AR(1)* process is inadequate to render e_t white noise. Consider, for example, the zero-mean *AR(p)* process

$$y_t = \sum_{j=1}^{p} \alpha_j y_{t-j} + e_t \tag{22}$$

Which can be written as

$$\Delta y_t = \alpha y_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + e_t \tag{23}$$

where $k = p - 1$ and

$$\alpha = -\left(1 - \textstyle\sum_{j=1}^{p} \alpha_j\right) \text{ and } c_j = -\textstyle\sum_{i=j+1}^{p} \alpha_i \tag{24}$$

Of course, depending on whether a zero mean, a nonzero mean, or a linear trend is allowed under the alternative hypothesis, one can use either (23) or

$$\Delta y_t = \alpha_0 + \alpha y_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + e_t \tag{25}$$

or

$$\Delta y_t = \alpha_0 + \alpha y_{t-1} + Bt + \sum_{j=1}^{k} c_j \Delta y_{t-j} + e_t \tag{26}$$

The same $\hat{\tau}$, $\widehat{\tau_\mu}$ and $\widehat{\tau_\tau}$ Dickey-Fuller statistics are used to test the null that $a = 1$ in each of (23), (25), and (26), respectively. The k extra regressors are added to eliminate possible nuisance parameter dependencies of the test statistic caused by temporal dependencies in the disturbances. The optimal lag length, k, can be chosen using data-dependent methods that have desirable statistical properties when applied to unit root tests.

Based on such ADF unit root tests, Nelson and Plosser [51] argue that most macroeconomic and financial time series are better characterized as difference-stationary processes rather than trend-stationary processes. As a result, differencing rather than de-trending is usually necessary to achieve stationarity.

The results of the so-called Dickey–Fuller unit-root test are summarized in Table 1. The evidence indicate that the ADF test rejects the null hypothesis of a unit root except for one variable, and showing the necessity of using breaking trend test.

Table 1

Results of Augmented Dickey-Fuller unit root test

Variables	ADF	Critical values		
	I(0)	%1 critical values	%5 critical values	%10 critical values
M	-4.982 (0.000)	-3.653	-2.957	-2.617
Y	-3.080 (0.003)	-2.653	-1.953	-1.609
Inf	-4.050 (0.003)	-3.653	-2.957	-2.617
Exc	-0.315 (0.986)	-4.273	-3.557	-3.212

Source: Own calculation

* The optimal lag structure is determined by Schwartz Bayesian Criterion

** The p-values are in parentheses

5.3 Breaking trend functions

Perron [53] argues that most time series (and in particular those used by Nelson and Plosser [51]) are trend stationary if one allows for a one-time change in the intercept or in the slope (or both) of the trend function. The postulate is that certain 'big shocks' do not represent a realization of the underlying data generation mechanism of the series under consideration and that the null should be tested against the trend-stationary alternative by allowing, under both the null and the alternative hypotheses, for the presence of a one-time break (at a known point in time) in the intercept or in the slope (or both) of the trend function. In particular, Perron [53] uses the following modification to the ADF regression:

$$y_t = \mu + \theta DU_t + Bt + \gamma DT_t + \delta D(T_B)_t + \alpha y_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + e_t \quad (27)$$

where $DU_t = 1$ and $DT_t = t$ if t $>T_B$ and 0 otherwise, and $D(T_B)_t = 1$ if $t = T_B+1$ and 0 otherwise. T_B(with $1 < T_B < T$, where T is the sample size) denotes the time at which the change in the trend function occurs. In this framework, testing the null hypothesis of a unit root amounts to comparing the t statistic for testing (taking the break fraction, or break point, $\lambda = T_B/T$, to be exogenous) $\alpha = 1$, $t_a(\lambda)$,with the critical values tabulated by Perron over different values of λ. In particular, reject the null hypothesis of a unit root if $t_a(\lambda) < \tau(\lambda)$, where $\tau(\lambda)$ denotes the critical value from the asymptotic distribution of $t_a(\lambda)$ for a fixed λ.

Perron's [53]assumption that the break point is uncorrelated with the data has been criticized, most notably by Christiano [20] who argues that problems associated with 'pre-testing' are applicable to Perron's methodology and that the structural break should instead be treated as being correlated with the data. More recently, Zivot and Andrews [68], Perron and Vogelsang [54, 55] and Banerjee, *et al.,* [6], in the spirit of Christiano [20], treat the selection of the break point as the outcome of an estimation procedure and transform Perron's [53] conditional (on structural change at a known point in time) unit root test into an unconditional unit root test. For example, the Zivot and Andrews [20] estimation procedure involves using regression (27) without the dummy variable $D(T_B)_t$,

$$y_t = \mu + \theta DU_t + Bt + \gamma DT_t + \alpha y_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + e_t \tag{28}$$

and choosing λ to minimize the one-sided t-statistic for testing $\alpha = 1$, over all $T - 2$ regressions.

In general, existing empirical evidence indicates that the unit root hypothesis could be rejected if allowance is made for the possibility of a one-time break in the intercept or in the slope (or both) of the trend function, irrespective of whether the break point is estimated or fixed. Hence, whether the unit root model is rejected or not depends on how big shocks are treated. If big shocks are treated like any other shock, then ADF unit root testing procedures are appropriate and the unit root null hypothesis cannot (in general) be rejected. If, however, they are treated differently, then Perron–type procedures are appropriate and the null hypothesis of a unit root will most likely be rejected. The results of Perron test are indicated in Table 2. In this paper, due to Iran-Iraq war, the time of causing break was 1981. Based on results, since the critical value of t is less than the calculated, the null hypothesis is rejected and the existence of unit root for variable "exchange rate" is ignored.

Table 2

Results of Perron test

Variable	λ	τ	Critical value of t		
			%1	%2.5	%5
Exchange rate	0.2	-6.54	-5.63	-5.21	-4.78

Source: Own calculation

5.4 The linearity test

The statements of hypothesis for linearity in threshold regression are as follow:

$$H_0: \beta_i = \alpha_i \qquad \text{i}= 0, 1, \dots, \text{n}$$
$$H_1: \beta_i \neq \alpha_i \qquad \text{i}= 0, 1, \dots, \text{n} \tag{29}$$

The null hypothesis implies the existence of no threshold and the model is linear (Davidson and Mackinnon, 1999). By defining selection matrices R= (0,I) -in which I is unit matrix- and M(h)= $\sum(Y_t\,(h)Y_t'(h))$ and V(h)= $\sum(Y_t\,(h)Y_t'(h)\hat{e}_t^2)$ –Y_t is the explanatory variables matrix- the Wald statistics which is compatible with heteroskedasticity, can be introduced as follow:

$$W(H)= ((R\Theta\,(h))'[R(M(h)^{-1}\,V(h)M(h)^{-1}\acute{R}]^{-1}\,(R\Theta(h)) \tag{30}$$

in which Θ is coefficient vector. By utilizing the above statistics, appropriate statistic for linearity test in threshold regression can be extracted [61]:

$$W = Sup^{1}\ W(h) \tag{31}$$

Since the threshold parameter under the null of linearity is not achievable, the distribution of W is non-standard. Therefore, Hansen has introduced bootstrap test in order to approximate the asymptotic distribution of statistics. The bootstrap test is organized as follow [21]:

1. In the first step, a sample with zero average and unite variance is assembled, in which and $X_t^* = \hat{e_t}\eta_t$ and $\eta_t = NID(0,1)$.
2. With the aim of estimating restricted summation of squared residual $\widetilde{S^*}$, X_t^*, must be regressed on all variables in linear model.
3. Also, in order to assess the non- restricted summation of squared residual $S^*(h)$, X_t^* , must be regressed on $Y_t= (\acute{Y}_t\,\acute{Y}_t A(Z>h))\,'$(all variables in threshold model).
4. Let $W^*(h)$ be $\frac{T(\tilde{S}^*-S^*(h))}{S^*(h)}$, in which T is observations and $W^*= sup\ W^*(h)^2$. Steps 1 to 4 must be reiterated and W_b^* is the statistic for b. The p-value for W_b^* is as follow:

$$p\text{-}value= (\tfrac{1}{B})^* \textstyle\sum_{b=1}^{B} L(W_b^* \geq W) \tag{32}$$

After reiteration, it is possible to test the null hypothesis of linearity. The results of bootstrap test are summarized in Table 3. As can be seen, the null hypothesis based on the existence of linear model is rejected and threshold regression is appropriate.

[1]Sup implies Supremum Test, for more details see Francq *et al.,* (2008).

Table 3

Results of bootstrap test

Threshold variable	Critical value at %5	Critical value at %1	F statistic	Result
Inflation rate	-6.35	-7.18	17.58	Null hypothesis has been rejected

Source: Own calculation

5.5 Likelihood ratio test

Where there is a threshold effect, Chan [19] and Hansen [39] show that h is consistent withh_0 (the true value of h) and that the asymptotic distribution is highly non-standard. Hansen [39] argues that the best way to form confidence intervals for h is to form the "no-rejection region" using the likelihood ratio statistic for tests on h. To test the hypothesis H_0: $h= h_0$, under the auxiliary assumption $e_i \approx iid\ N(0, \sigma^2)$, the statistic for likelihood ratio is:

$$LR_n(h) = n\frac{S_n(h) - S_n(\widehat{h})}{S_n(\widehat{h})} \tag{33}$$

where $LR_n(h)$ is likelihood ratio statistic, $S_n(h)$ and $S_n(\hat{h})$ are sum of squared error. The likelihood ratio test of H_0 is to reject for large values of $LR_n(h)$. Under some assumptions[1], Hansen (2000) lets:

$$LR_n(h_0) \rightarrow_d \eta^2 \xi \tag{34}$$

where

$$\xi = max[2W(s) - |s|]$$

and

$$\eta^2 = \frac{c'Vc}{\sigma^2 c'Dc}$$

The distribution function of ξ is $P(\xi \leq x) = (1 - e^{\frac{-x}{2}})^2$.

[1]1. (x_i, q_i, e_i) is strictly stationary, ergodic and p-mixing, with p-mixing coefficients satisfying $\sum_{m=1}^{\infty} p_m^{1/2} < \infty$
2. $E(e_i | F_{i-1}) = 0$
3. $E|x_i|^4 < \infty$ and $E|x_i e_i|^4 < \infty$
4. For all $h \in \Gamma$, $E\left(|X_i|^4 e_i^4 | q_i = h\right) \leq C$ and $E\left(|X_i|^4 q_i = h\right) \leq C$ for some $C < \infty$, and $f(h) \leq f < \infty$,
5. $f(h), D(h)$ and $V(h)$ are continuous at $h = h_0$
6. $\delta_n = cn^{-\alpha}$ with $c \neq 0$ and $0 < \alpha < \frac{1}{2}$
7. $c'Dc > 0, c'Vc > 0,$ and $f > 0$
8. $M > M(h) > 0$ for all $h \in \Gamma$

If homoscedasticity $(E(e_i^2 \mid q_i) = \sigma^2)$ holds, then $\eta^2 = 1$ and the asymptotic distribution of $LR_n(h_0)$ is free of nuisance parameters. If heteroskedasticity is suspected, η^2 must be estimated. The abovementioned equations give the large sample distribution of the likelihood ratio test for hypotheses on h. The asymptotic distribution is nonstandard, but free of nuisance parameters under $E(e_i^2 \mid q_i) = \sigma^2$. Since the distribution function is available in a simple closed form, it is easy to generate p-values for observed test statistics. Namely,

$$P_n = 1 - (1 - exp(-\tfrac{1}{2} LR_n(h_0)^2))^2 \quad (35)$$

is the asymptotic p-value for the likelihood ratio test. Critical values can be calculated by direct inversion of the distribution function. Thus a test of H_0: $h=h_0$ rejects at the asymptotic level of a if $LR_n(h_0)$ exceeds $c_\xi(1- a)$, where $c_\xi(Z) = -2ln(1-\sqrt{Z})$. Selected critical values are reported in Table 4.

Table 4

Asymptotic critical value

	.80	.85	.90	.925	.95	.975	.99
$P(\xi \leq x)$	4.50	5.10	5.94	6.53	7.35	8.75	10.59

Source: Hansen (2000).

For confidence interval, we use following likelihood ratio statistic:

$$LR_n = LR_n(\hat{h})[1 + \frac{LR_n}{n}] \quad (36)$$

By using the likelihood ratio and critical valuse presented in the above table, the results of confidence interval are presented in Table 5. As can be seen, due to confidence interval the quantity of threshold is significant.

Table 5

Confidence interval of threshold

Threshold variable (Inflation rate)	Level of threshold	Upper limit of confidence interval	Lower limit of confidence interval
At 1% level	0.325	0.374	0.316
At 5% level	0.325	0.364	0.305

Source: Own calculation.

5.6 Threshold analysis

The final step in estimating the effect of inflation on money demand is the nonlinear regression. The results are presented in Table 6-8.The results of residual normality test and model specification are not satisfactory and this leads to the fact that nonlinear approach is more valid for this model.

Table 6

Results of linear regression

Variables	Coefficient	Prob.	t-statistic
Y	0.236	0.000	10.47
Inf	-0.547	0.003	-6.78
Exc	-0.784	0.002	-11.65
R^2= 0.97	SSR= 0.00	AIC= -8.23	SBC= -7.88
DW= 2.11	LM test= 0.82	Ramsey RESET test= 0.05	White Het test= 0.56
Normality test	Prob= 0.06		
	Jarque Bera= 4.45		

Source: Own calculation.

Table 7

Threshold regression for values less than threshold value

Variables	Coefficient	Prob.	t-statistic
Y	0.006	0.001	6.75
Inf	0.009	0.000	9.57
Exc	-0.047	0.000	-13.54

Source: Own calculation.

Table 8

Threshold regression for values higher than threshold value

Variables	Coefficient	Prob.	t-statistic
Y	0.250	0.01	3.54
Inf	-0.751	0.00	-6.25
Exc	-0.365	0.03	-4.41
R^2= 0.96	SSR= 0.01	AIC= -6.75	SBC= -5.75
DW= 1.91	LM test=.097	Ramsey RESET test= 0.38	White Het test= 0.31
Normality test	Prob= 0.41		
	Jarque Bera= 1.78		

Source: Own calculation.

The threshold regression indicates that the overall goodness of fit of the model is excellent and that the individual variables contribute significantly to the explanation of behaviour of real money.

As we expected, the coefficient of real output has a positive sign meaning that an increase of 1% in the output generates an increase of 0.25% in the demand for real money. This is an expected result since based on the underlying theory the income (GDP) elasticity of money demand should be positive.

Based on results, the p-value on coefficient of inflation rate indicates that by moderate inflation level or less than 0.325 percent (INF*≤0.325) there is a positive significant relationship between money demand and inflation. For higher inflation rate or more than 0.325 percent, the relationship between both variables becomes inverse. This is consistent with the fact that relationship between inflation and money demand is nonlinear in Iran. As these results show, a 1 percent increase in the inflation rate led on the average to 0.009 percent increase in money demand until the threshold level. The positive relationship between inflation and demand for money is translating into negative relationship when inflation increases above threshold level. Over 0.325 percent of inflation rate, if inflation rate goes up by 1 percent, on average, the money demand goes down by -0.751 percent. Under higher inflation or over 0.325 percent, the result is consistent with the studies conducted by Friedman [34] and Cagan [16]. Also the view of Jusoh [42], who claimed if there is an increase in inflation, the level of cash balances must be raised to keep up with the anticipated increase in future transactions under moderate inflation. After the moderate inflation, when people expect general price level to rise, there is a mad rush to purchase commodities and hence less demand for money balances. The uncertainty and instability in the level of prices reduces people desire to hold more of cash by increasing panic demand for goods and other properties hence lesser demand for money [14].The estimated coefficient for exchange rate is negative, implying that there exist an inverse relationship between exchange rate and demand for money in Iran. The results indicate that a possible depreciation of the exchange rate expected return from holding foreign currency will decrease, which will reduce the demand for money. Our result is in line with studies by Darrat's [24, 25], and Ghamdi [35] who found that exchange rate has significant negative effect on the demand for money function in Saudi Arabia. Thus ignoring the effect of exchange rate not only leads to misspecification of the demand for money, but also to the implicit conclusion that monetary authorities have very little room to offset changes in the inflow of capital caused by changes in exchange rates.

6 Conclusion

Inflation plays an important role in demand for money. A correctly specified money demand function is very important in the determination of the optimal way in which the central bank formulates and conducts its monetary policy. The stability of money demand is prerequisite for any policy-driven change in monetary variables to have predictable effect on output, interest rate and ultimately prices through the transmission mechanism of monetary policy. The purpose of the paper is to estimate the demand for money function in Iran that could be used for policy analysis. The model is estimated by using long data set (i.e., 1980–2013). Money is a function of inflation rate. The high and moderate inflation have different influence on demand for money, following the empirical results of threshold model. The estimated model suggested that a 0.325 percent inflation rate is an optimal threshold level. The positive relationship between inflation and demand for money is translating into negative relationship when inflation increases above threshold level. Result of the findings leads us to the conclusion that an inverse relationship exist between interest rate and demand for money in Iran.

In the analysis, there are several factors that determine the demand for money in both developing and developed economies. Factors such as income, interest rate, price level, deposit rate, wealth, required reserve, and individual preference. In any case, the development of the financial system of a country determines which factors are more relevant in determining the demand for money in that country. When the financial system is underdeveloped, these factors work less or are not effective in determining the demand for money. Therefore, any policy aimed at moping liquidity through these factors will likely not yield any result. In this paper, we try to introduce those factors which determine the desire of people to hold cash such as exchange rate and real income. The regression results show that in Iran real income and exchange rate have significant positive and negative effects on money demand, respectively.

Based on the specified money demand function, in conducting monetary policy in the Iran, monetary policy makers in the Central Bank of the Iran should consider real income, inflation rate and exchange rate as key policy factors.

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