

## Money demand in Mexico: a nonlinear ARDL approach

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### Abstract

This paper examines the relationship between Mexican money demand and three economic factors: real income, inflation rate and exchange rate, and the relationship between exchange rate and money demand is the most concerned. Using the quarterly data of Mexico from 2000 to 2022, we explore whether the exchange rate will symmetrically affect the demand for money in the short and long term. The results show that in the long run, the impact of real income and inflation rate on money demand is the same as the conjecture, both are positive. However, the present paper does not find an asymmetric effect of the exchange rate, possibly due to the lack of research data or the short time span.

*Keywords:* money demand, nonlinear ARDL, stability, Mexico

*JEL Classification Codes:* E41, E44

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### 1. Introduction

The study of money demand has always occupied an important position in the field of economics. This can help countries better formulate monetary policies and promote overall and healthy economic development. Ansari and Ahmed (2007) illustrate the importance of money to the Mexican economy, they explore the causality of money output in Mexico and illustrate the effectiveness of monetary policy in Mexico. Before 2015, few researchers used the nonlinear ARDL approach to study money demand, so it exposed limitations. Samreth (2008) study on the currency demand function in Cambodia, the function could not pass the t-test for the long-term currency substitution phenomenon due to the combination of long-term currency substitution and wealth effects. However, after 2015, the concept of "nonlinear" began to be introduced into this topic, that is, studies began to discuss the asymmetry of impact. Mundell (1963) proposed that the exchange rate is another determinant of money demand besides income and interest rates. On the asymmetric effect of exchange rates, papers by Arango and

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Nadiri (1981) and Bahmani-Oskooee and Pourheydarian (1990) show that changes in exchange rates can have two opposing effects on money demand. The former states the depreciation of the domestic currency means that the value of foreign assets held by citizens increases, so the increase in wealth leads to an increase in demand for money, while the latter believes that the depreciation of the domestic currency will lead to the desire of citizens to hold more foreign currencies due to the expectation of continuous appreciation of foreign currencies, then the demand for the local currency decreases. Just as Mahmood, Alkhateeb (2018) and Bahmani-Oskooee, Miteza and Tanku (2020) studied the currency demand functions of Saudi Arabia and Albania respectively, related studies began to focus on the impact of economic factors on currency demand. Symmetrical influence.

Bahmani-Oskooee and Bahmani (2015) introduced the concepts of nonlinear ARDL and partial sums and found that exchange rate changes have a huge impact on the demand for Iranian currency, and the expected benefit is very strong. Therefore, this paper will use the same research methodology as Bahmani-Oskooee and Bahmani (2015), introducing nonlinearities and partial sums to discover the effect of the Mexican exchange rate on money demand. However, the results of this paper show that in the long run, the impact of the Mexican exchange rate on currency demand does not have an asymmetric effect, which is inconsistent with the research result of Bahmani-Oskooee and Bahmani (2015).

## 2. Literature review

Mahmood and Alkhateeb (2018) find that the money demand estimation function can reflect the asymmetric effect of real exchange rate changes in Saudi Arabia. Bahmani-Oskooee, Miteza and Tanku (2020) study the asymmetry of the exchange rate's impact on the Albanian currency through the ARDL model, and their paper concludes that depreciation reduces money demand. Adil, Haider and Hatekar (2020) analyze quarterly data for India and find that no significant relationship between the exchange rate and demand for a stable currency can be found. After introducing asymmetry in the ARDL model, an asymmetric effect of the exchange rate on Indian currency is found, which affects money demand through the currency substitution effect. Alsamara and Mrabet (2019) use the quarterly data to illustrate the asymmetry of the impact of the exchange rate on the Turkish lira. Their paper indicate that currency demand responds more strongly to exchange rate appreciation, which also means that when the Turkish lira appreciates, individuals expect it to appreciate further.

Ongan and Ismet Gocer (2021) use monthly data to introduce the ARDL model, and discover the asymmetric impact of Japan's monetary policy uncertainty (MPU) on money demand and also when MPU rises, money demand in Japan falls. Alih, Sarmidi, Shaari and Said (2018) focus on the stability of Malaysian currency demand in the context of recent financial innovations. Authors examine the relationship between money demand and financial innovation agents in payment systems, including payment instruments, payment systems, and payment channels.

Alih, Sarmidi, Shaari and Said (2017) examine the relationship between financial innovation and money demand and find a long-run cointegrating relationship between the variables. The outcome of their paper suggests that, in the short-run, the number of ATMs does not affect money demand. Ahmad, Noureen, Ali, and Usman (2022) examine the asymmetric relationship between exchange rate volatility and demand for money in the United States. Authors conclude that when the dollar appreciates or depreciates, U.S. citizens tend to hold more dollars. Kayongo and Guloba (2018) first use the Generalized autoregressive conditional heteroscedasticity (GARCH) method to measure uncertainty, and then use the ARDL model to estimate the impact of economic uncertainty on base money, broad money M2 and broad money

M3. The results show that in the short run, economic uncertainty has no immediate effect on base money and broad money M2 but influences M3. By analyzing the data using combined cointegration, autoregressive distributed lag models, and Hansen's instability test, Adi, Hussain and Matuka (2022) study the stability of India's money demand function (MDF) by examining the effect of interest rate sensitivity on different monetary aggregates and find that from the second quarter of 1996 to the third quarter of 2016, there was a stable short-term and long-term money demand relationship in India.

Baharumshah, Mohd and Masih (2009) analyze China's demand for M2 money using the ARDL cointegration framework. The results show a stable long-run relationship between M2 and its determinants, including real income, inflation, foreign interest rates, and stock prices, noting that the stock price wealth significantly affects long-run and short-run M2 demand. In Samreth's (2008) paper, the ARDL method is used to verify the money demand function of Cambodia. The results show that there is a co-integration relationship among the variables in the money demand function. However, probably due to the combination of long-term currency substitution and wealth effects, this function cannot pass the t-test of long-term currency substitution phenomenon.

Hossain (2012) examines the stability and economic meaning of Australia's narrow monetary demand relationship by analyzing annual data and using the ARDL cointegration method. The author concludes that there is an equilibrium relationship between real narrow money balances, real income, domestic interest rates, and the nominal effective exchange rate of the Australian dollar. Nair, Samudram and Vaithilingam (2008) employ an unrestricted error-correction model and bounds testing to study the long-run and short-run money demand behavior in Malaysia. They point out that the demand for M1, M2 and M3 and their determinants are significantly co-integrated, and the 1997 Asian financial crisis did not have a significant impact on the co-integration relationship between money demand and its determinants.

Omotor (2010) uses the annual data to conduct cointegration analysis through the bounds test of the ARDL model and estimate the currency demand function including the factor of Nigeria's foreign exchange risk. The results are consistent with economic postulates. Using the ARDL approach, Budha (2013) examines the demand for money in Nepal from 1975 to 2011 and finds that real money aggregates (M1 and M2), real income, inflation, and interest rates are cointegrated. The error correction models suggest that deviations from long-run equilibrium are short-lived in M1 than M2. Tinoco-Zermeno et al (2014) conclude in their study on Mexico that economic growth and financial development get negatively affected by inflation rates. Authors point out a 0.007 percent decline in the long run output due to one percent rise in the inflation rate. Using quarterly data for Pakistan, Khan and Sajjid (2005) use the ARDL method and finds that real income, inflation, foreign interest rates, and real effective exchange rates have significant effects on Pakistan's real money balances in the long run, but the impact is small in the short term. Finally, Ghatak and Siddiki (2001) use the ARDL method for cointegration analysis to estimate India's "virtual exchange rate" (VER). Their results confirm that regardless of both the short and long term, VER is higher than the official exchange rate by around 10% and 16% respectively.

### 3. The model and methodology

The data used in this paper comes from Mexico, and the time span is from the last quarter of 2000 to the last quarter of 2022. By using a similar method to Bahmani-Oskooee and Sahar Bahmani (2015), the dependent variable in this paper is M2, which is real money, and the

independent variables are Y representing real income, INF representing inflation rate and exchange rate XR, these variables can be written as the equation (1):

$$LM2_t = a + bTrend + cLY_t + dLINF_t + eLXR_t + \epsilon_t \tag{1}$$

For the coefficients of the respective variables, this paper makes predictions. As real income increases, Mexican people's spending power will increase, which may lead to an increase in money demand, so b is considered positive. Since Mexico's inflation rate has been at a high level, the people's expectations for Mexico's inflation have been high, so when the inflation rate rises, the people may be more inclined to get more money to buy goods or services. Therefore, this paper predicts that the estimated value of c is also positive. As for the relationship between the exchange rate and the demand for money, it can be positive or negative, as explained in the introduction, depending on the expectations of Mexican residents for foreign currency.

It is worth noting that Equation (1) is a long-term model, and short-term coefficient estimation cannot be performed. However, the exclusion of short-run dynamics from long-run models is one reason that models of money demand may be destabilized. Therefore, this paper proposes an error-correction model that incorporates short-term effects into long-term estimates, equation (2):

$$\begin{aligned} \Delta LM2_t = & \beta_0 + \beta_1 Trend + \sum_{j=1}^k \beta_2 \Delta LM2_{t-j} + \sum_{j=0}^l \beta_3 \Delta LY_{t-j} \\ & + \sum_{j=0}^m \beta_4 \Delta LINF_{t-j} + \sum_{j=0}^n \beta_5 \Delta LXR_{t-j} + \theta_0 LM2_{t-1} + \theta_1 LY_{t-1} \\ & + \theta_2 LINF_{t-1} + \theta_3 LXR_{t-1} + u_t \end{aligned} \tag{2}$$

Equation (2) improves upon the previous model by using a differentiation approach to represent short-term dynamics and estimates of  $\theta_1$  to  $\theta_3$  and normalization of  $\beta_0$  to represent long-term effects<sup>1</sup>. Meanwhile, we adopt the method of Pesaran et al. (2001) to verify whether the model is valid in the long run<sup>2</sup>.

The above models are all based on the linear ARDL method. This paper will also introduce the concept of asymmetric impact and divide exchange rate changes into appreciation and depreciation of the dollar, which are represented by POS<sub>t</sub> and NEG<sub>t</sub> respectively.

$$\begin{aligned} POS_t = & \sum_{j=1}^t \Delta LXR_j^+ = \sum_{j=1}^t \max(\Delta LXR_j, 0), \\ NEG_t = & \sum_{j=1}^t \Delta LXR_j^- = \sum_{j=1}^t \max(\Delta LXR_j, 0) \end{aligned} \tag{3}$$

Then referring to Shin *et al* (2014), the appreciation and depreciation of the dollar are represented separately by the method of partial summation. The LXR in equation (2) is represented by POS plus NEG, and equation (4) is obtained:

<sup>1</sup> Bahmani-Oskooee and Tanku (2008) provides a detailed explanation for this procedure.

<sup>2</sup> Some relevant studies that use similar methodology; Bahmani-Oskooee et al. (2005), Bahmani-Oskooee and Hegerty (2007), Durmaz (2015), Bahmani-Oskooee and Durmaz, (2016, 2021).

$$\begin{aligned}
 \Delta LM2_t = & \beta_0 + \beta_1 Trend + \sum_{j=1}^{k1} \beta_2 \Delta LM2_{t-j} + \sum_{j=0}^{k2} \beta_3 \Delta LY_{t-j} \\
 & + \sum_{j=0}^{k4} \beta_5 \Delta LPOS_{t-j} + \sum_{j=0}^{k5} \beta_6 \Delta LNEG_{t-j} \\
 & + \theta_0 LM2_{t-\sum_{j=0}^{k3} \beta_4 \Delta LINF_{t-j}1} + \theta_1 LY_{t-1} + \theta_2 LINF_{t-1} \\
 & + \theta_3 LPOS_{t-1} + \theta_4 LNEG_{t-1} + \mu_t
 \end{aligned} \tag{4}$$

By equation 4 the asymmetric or symmetric impacts are examined for the short run and the long run money demand of Mexico. This hypothesis of symmetric is from Shin et al. (2014) by using Pesaran et al.’s (2001) bounds testing methodology. The final form of equation 4 is simply the application of partial sums to show the Nonlinear ARDL methodology.

Table 1. Full-Information Estimate of Linear ARDL Equation (2)

<b>Panel A: Short-Run Coefficient Estimates</b>					
	Lag Order				
	0	1	2	3	4
dLM2		0.32116 (3.6133)			
dLY	-0.049999 (-1.0255)	-0.090544 (-1.6014)	-0.099557 (-1.0891)	-0.098023 (-2.0250)	
dLINF	0.72516 (3.6957)				
dLXR	0.11645 (3.6140)				
dTREND	0.0066003 (5.4160)				

  

<b>Panel B: Long-Run Coefficient Estimates</b>					
INPT	LY	LINF	LXR	TREND	
16.1157 (10.5870)	0.37358 (3.7143)	2.1432 (3.1435)	-0.14742 (-3.0655)	0.019495 (29.5872)	

  

<b>Panel C: Diagnostic Statistic</b>						
F	ecm(-1)	LM	RESET	Normality	CUS (CUS <sup>2</sup> )	Adj. R <sup>2</sup>
5.4325	-0.33856 (-5.5969)	0.79376	2.9297	0.59461	S (S)	0.46620

Source: own elaboration.

#### 4. The results

First, based on the model of equation (2), table 1 was obtained using quarterly data from Mexico from 2000 to 2022. This table uses linear ARDL analysis and Akaike Information Criterion

(AIC) to measure goodness of fit. Panel A shows short-term coefficient estimates. Except for the case where the coefficients corresponding to real income are not significant (Prob>0.05), the coefficients of other variables are significant. Panel B is a long-term analysis that represents the long-term relationship between each variable and the dependent variable, and all coefficients are significant. The coefficients of real income and inflation rate are positive, with values of 0.37358 and 2.1432 respectively and this indicates that these two variables are positively correlated with money demand. While the coefficient of the exchange rate is -0.14742, which means that an increase in the exchange rate will lead to a decrease in money demand. In addition, the intercept of the model is 16.1157, and the trend is 0.019495.

Moreover, through the analysis of panel C, the model has a cointegration relationship, as the variable addition F test for joint significance of lagged level variables at optimal flags is 5.4325, which is greater than 5.2362 of the 5% level of significance. Meanwhile, according to Bahmani Oskooee and Tanku (2008), ecm (-1) is significant in this panel and can be used to replace the lag level variable of equation (2). In panel C, other important data is also displayed. The Lagrange multiplier (LM) is 0.79376, the RESET is 2.9297, and the residuals of the optimal model were also tested using CUSUM and CUSUMSQ, and the results were found to be stable. Plus, the adjusted R square is 0.46620, which means that the model can explain about 46.62% of the variance of the dependent variable.

Table 2. Full-Information Estimate of Nonlinear ARDL Equation (3).

<b>Panel A: Short-Run Coefficient Estimates</b>						
	Lag Order					
	0	1	2	3	4	
dLM2		0.24528 (2.9212)				
dLY	0.037193 (0.91318)					
dLINF	0.65999 (3.4957)					
dPOS	0.012715 (3.9216)					
dNEG	-0.0012073 (-0.62600)					
dTREND	0.0075868 (5.1026)					

  

<b>Panel B: Long-Run Coefficient Estimates</b>						
INPT	LY	LINF	POS	NEG	TREND	
19.3881 (9.9502)	0.12396 (0.94691)	2.1997 (2.8811)	-0.018597 (-2.7391)	-0.0040239 (-0.63867)	0.025286 (6.6669)	

  

<b>Panel C: Diagnostic Statistic</b>						
F	ecm(-1)	LM	RESET	Normality	CUSUM (CUSSUM <sup>2</sup> )	Adj. R <sup>2</sup>
5.0154	-0.30004 (-5.565)	2.1754	2.6518	0.029094	Stable	0.46258

Source: own elaboration

The above results assume that the relationship between variables is linear, and table 2 corresponding to equation (4) is analyzed after introducing nonlinearity. Similarly, panel A



represents short-term predictions, indicating a significant positive coefficient between the appreciation of the US dollar (dPOS) and currency demand, but the coefficient of the depreciation of the US dollar (dNEG) is not significant, which cannot demonstrate the asymmetry of exchange rate changes on currency demand in the short term. The long-term situation is reflected in panel B. As in the short term, dPOS still has a significant coefficient, while dNEG does not, so we use a 10% level of significance. At this point, both variables are significant, and the dPOS and dNEG coefficients have the same sign and are both negative. This indicates that in the long run, the appreciation of the US dollar tends to hold less domestic currency, while the depreciation of the US dollar tends to hold more domestic currency. Additionally, the coefficients of income and inflation rate are both positive as predicted. Panel C indicates a cointegration relationship between variables, and the Lagrange multiplier (LM) is 2.1754, the REST is 2.6518, CUSUM and CUSSUM<sup>2</sup> are stable. The adjusted R square is 0.46258, which means that the model can explain about 46.258% of the variance of the dependent variable.

## 5. Conclusion

This paper uses quarterly data from Mexico from 2000 to the first quarter of 2022 to try to find the impact of real income, inflation rate, and especially exchange rate on currency demand in the short and long term. The results indicate that real income and inflation rate are positively correlated with money demand in the long run, while exchange rate is negatively correlated with it. Using non-linear ARDL analysis, the relationship between exchange rate and currency demand does not have an asymmetric effect. The time span of the data used is only 23 years, and the limited amount of analyzed data may be the reason why the results of this paper differ significantly from expectations. At the same time, the different fiscal policies adopted by Iran and Mexico are also the main reason why this paper reaches different results from Bahmani-Oskooee and Bahmani (2015). As an example of foreign exchange policy, Iran has implemented foreign exchange controls, while Mexico has less intervention in the foreign exchange market. Foreign exchange controls may result in a relatively inflexible exchange rate, which means that Iran's exchange rate may not be able to adjust quickly in the face of external shocks, making the response of currency demand to exchange rate changes asymmetric. Mexico's foreign exchange market is relatively free, which may lead to a higher degree of capital freedom, and the market can reflect currency changes more quickly, so that asymmetry will not be reflected in the long term. However, this paper still has reference value and can to some extent help understand the relationship between various economic factors and monetary demand in Mexico, providing some reference for formulating fiscal policies. For example, since the results show that the impact of the Mexican exchange rate on currency demand is not asymmetric in the long term, this can be linked to the stability of Mexico's monetary policy. That is, when Mexico faces a turbulent economic environment, it is more appropriate to take a long-term view and maintain its original policy than to immediately adjust its monetary policy. The research results also have reference value for stabilizing inflation in Mexico. Based on this, policymakers can pursue the inflation target more stably without having to adjust monetary policy frequently, which helps maintain economic stability and predictability. Although it is true that the formulation of fiscal policy also needs to consider other factors, this article provides a reference in stability.

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