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Tests of the functional form, the substitution effect, and the wealth effect of Mexico's money demand function

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Abstract. M1, M2, and M3 demands in Mexico are positively influenced by output and stock prices and negatively associated with the saving rate, the U.S. interest rate, and the expected inflation rate. Peso depreciation affects M1 demand negatively and M2 and M3 demands positively. The log-linear form cannot be rejected for M1 demand and can be rejected for M2 and M3 demands, while the linear form can be rejected for M1, M2, and M3 demands. The CUSUMSQ test shows that M1, M2, and M3 demands are stable; while the CUSUM test indicates stability in M1 and M3 demands and instability in M2 demand.

Key words: Box-Cox transformation, currency substitution, wealth effect, stability tests.

JEL classification: E41, F41, O54.

Resumen. Las demandas M1, M2 y M3 en México son influenciadas positivamente por el producto y el precio de las acciones, y están asociadas negativamente con la tasa de ahorro, la tasa de interés estadounidense y la tasa de inflación esperada. Por su parte, la depreciación del peso afecta negativamente la demanda M1 y positivamente las demandas M2 y M3. La forma log-lineal no puede ser rechazada para la demanda M1 y puede ser rechazada para las demandas M2 y M3, mientras que la forma lineal puede ser rechazada para las demandas M1, M2, y M3. La prueba CUSUMSQ muestra que las demandas M1, M2 y M3 son estables; mientras la prueba CUSUM indica estabilidad en las demandas M1 y M3 e inestabilidad en la demanda M2.

Palabras clave: transformación de Box-Cox, sustitución monetaria, efecto riqueza, pruebas de estabilidad.

Clasificación JEL: E41, F41, O54.

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1. Introduction

During the 1994-95 crisis, the Mexican peso suffered a substantial depreciation of 121.7%, the deposit rate rose to a high of 57.5%, the stock price plunged 43.5%, and the inflation rate rose 48.4%. Largely due to these developments, M1 declined from 145.1 billions in 1994.M12 to 109.7 billions in 1995.M5, while M2 and M3 were relatively stable or rising. It is significant to examine the demand for money for Mexico to have a better understanding of its behavior and impacts on the country's economic activities. This paper has several focuses. First, financial stock prices in Mexico have advanced a great deal in the last decade and may affect the demand for money negatively due to the substitution effect or positively due to the wealth effect (Friedman, 1988). The peso/USD exchange rate fluctuated in the short run and increased in the long run. The 1994-95 peso crisis caused significant concerns about how to protect peso-denominated assets from declining. The impact of peso depreciation on money demand may be negative due to the substitution effect or positive due to the wealth effect (Arango and Nadiri, 1981; McKinnon, 1982; Bahmani-Oskooee and Malixi, 1991; Bahmani-Oskooee and Ng, 2002). Because the signs for the financial stock price and the nominal exchange rate in the money demand function are ambiguous, empirical estimation is required to determine whether a change in the stock price or the exchange rate would affect money demand negatively or positively. Second, the Box-Cox transformation (Box and Cox, 1964; Greene, 2003) is applied to determine which functional form is appropriate (Sarno, Taylor, and Peel, 2003). Most previous studies chose the log-linear form in empirical work partly because the coefficient is the elasticity. Whether the log-linear or linear form is appropriate may need to be tested. Third, comparative static analysis will be applied to find possible impacts of a change in the financial stock price or the nominal exchange rate in the money demand function on the equilibrium real output.

Several seminal works (Tobin, 1958; Chow, 1966; Goldfeld, 1973, 1976; Judd and Scadding, 1982; Gordon, 1984; Laidler, 1990; Goldfeld and Sichel, 1990) have contributed substantially to the understanding of the demand for money. Small and Porter (1989), Hetzel and Mehra (1989), Hafer and Jansen (1991), Mehra (1993, 1997), Duca (2000), Carlson, Hoffman, Keen and Rasche (2000), and others examined the behavior and stability of M2 for the U.S. For example, Mehra (1997) indicated that the demand for M2 shifted leftward during the early 1990's and that the behavior of M2 has remained relatively stable since 1994 and may be useful for the analysis of monetary policy. Duca (2000) showed that the decline in M2 and the rise in M2 velocity in the early 1990's were matched by the increase in bond mutual funds. He suggested that M2 demand can be modeled better if the market for bond mutual funds is also taken into consideration. Sarno, Taylor, and Peel (2003) indicated that the money demand function for the U.S. was stable during 1869-1997 and that there existed a nonlinear relationship that was adjusted toward long-term equilibrium.

There are several recent studies of the demand for money for Mexico or

neighboring countries. Bahmani-Oskooee and Malixi (1991), based on the Chow test, found that M1 demand in Mexico had a structural break in 1979 and that it had a positive relationship with real output and a negative relationship with the effective exchange rate and the inflation rate. Rogers (1992) showed that an expected depreciation in the peso would cause the relative demand for the U.S. dollar to decline due to the convertibility risk. Taylor (1991) and Phylaktis and Taylor (1993) found that the demand for money in five high-inflation Latin American countries can be modeled properly by the Cagan model, that the inflation tax would be maximized under the model, and that there was evidence of substitution of foreign assets for domestic portfolios. Choudhry (1995) reported that there was a stable long-term relationship for M1 and M2 demands for Mexico if currency depreciation was included in the regression. Thornton (1996) revealed that M1 and M2 demands in Mexico were cointegrated with the two explanatory variables and that M2 demand was a better measure of monetary aggregate for the Bank of Mexico to target. Khamis and Leone (2001) indicated that real money balances in Mexico were stable during and after the financial crisis and that substantial decline in real money demand during the financial crisis could be well explained by the included independent variables. Prock, Soydemir, and Abugri (2003) found that M1 demand in Mexico did not respond to a shock to the nominal exchange rate while Brazil and Argentina reacted positively. Rodríguez and Turner (2003) showed that there was strong evidence of currency substitution between broad money in Mexico and foreign currency deposits and U.S. dollar deposits.

2. The model

The demand for real money balances in Mexico can be written as

$$MD = L\left(Y, R^d, F, E, R^w, \pi^e\right), \tag{1}$$

$$L_Y > 0,\ L_{R^d} < 0,\ L_F \neq 0,\ L_E \neq 0,\ L_{R^w} \neq 0,\ L_{\pi^e} < 0,$$

where

MD	=	demand for real money balances,
Y	=	real GDP,
R^d	=	domestic interest rate,
F	=	financial stock price,
E	=	nominal exchange rate,
R^w	=	world interest rate, and
π^e	=	expected inflation rate.

L_X in equation (1) denotes the partial derivative of the demand for money with respect to any of the explanatory variables. We expected MD to have a positive relationship with real output, a negative relationship with the domestic interest rate and the expected inflation rate, and an unclear relationship with

the real stock price, the nominal exchange rate, and the world interest rate. Friedman (1988) included the real stock price in the money demand function and tested the wealth effect and the substitution effect of a change in real stock price on real money demand.

The signs of the partial derivative of the demand for money with respect to the financial stock price and the nominal exchange rate in equation (1) are important because they may influence the equilibrium real output differently. Suppose that the goods market equilibrium is written as

$$Y = A\left(Y, R^d, G, T, F, E\right), \tag{2}$$

where A, G, and T are aggregate spending, government spending, and government tax revenues. Based on the goods and money market equilibrium, an increased financial stock price would shift LM rightward and raise real output if the demand for money responds to a higher stock price negatively:

$$\frac{\partial \bar{Y}}{\partial F} = \frac{(-A_F L_{R^d} + A_{R^d} L_F)}{|J|} \quad \begin{cases} > 0, & \text{if } L_F < 0, \text{ and} \\ \neq 0, & \text{if } L_F > 0, \end{cases} \tag{3}$$

where A_F is the partial derivative of aggregate spending with respect to the financial stock price, A_{R^d} is the partial derivative of aggregate spending with respect to the domestic interest rate, and $|J|$ is the Jacobian with a positive value.

The impact of peso depreciation on the equilibrium real output is given by

$$\frac{\partial \bar{Y}}{\partial E} = \frac{(-A_E L_{R^d} + A_{R^d} L_E)}{|J|} \quad \begin{cases} < 0, & \text{if } L_E > 0, \text{ and} \\ > 0, & \text{if } L_E < 0, \end{cases} \tag{4}$$

where A_E is the partial derivative of aggregate spending with respect to the nominal exchange rate. If L_E is negative, peso depreciation would shift LM downward and cause the equilibrium real output to rise. The Box-Cox model (Box and Cox, 1964; Greene, 2003) is employed to transform the dependent and independent variables as follows:

$$MD^{(\lambda)} = \frac{MD^{\lambda} - 1}{\lambda}, \tag{5}$$

$$X^{(\lambda)} = \frac{X^{\lambda} - 1}{\lambda},$$

where X is any of the right-hand side variables with positive values and λ is the transformation parameter. It can be shown that when λ approaches zero, equation (1) reduces to a double-log form, and when $\lambda = 1$, equation (1) becomes a linear form. The log-likelihood function can be written as

$$\ln L(\lambda) = -\frac{N}{2}\left[1 + \ln(2\pi) + \ln\left(\sigma^2(\lambda)\right)\right] + (\lambda - 1)\sum \ln MD_t. \tag{6}$$

The test statistic has a χ^2 distribution with one degree of freedom and is given by

$$J(\lambda) = 2\left[L\left(\hat{\lambda}\right) - L\left(\lambda = 0 \text{ or } 1\right)\right] \sim \chi^2_{(1)}. \tag{7}$$

3. Empirical results

The data source came from the *International Financial Statistics* published by the International Monetary Fund. Real M1, M2, and M3 demands are equal to the nominal values divided by the CPI and measured in million pesos. Real GDP is measured in billion pesos at the 1993 price. The interest rate on savings is selected to represent the domestic interest rate. An increase in the nominal exchange rate means a depreciation, and vice versa. The 10-year U.S. treasury bond rate is chosen to represent the world interest rate. The expected inflation rate is the average inflation rate of the last four quarters based on the percent change in the CPI. Due to lack of data for the saving rate before 1993, the sample runs from 1993.Q1 to 2005.Q3.

The functional form is tested first. For M1 demand, the value of $L(\hat{\lambda})$ is -582.921 with an estimated λ of -0.1079. The value of $L(\lambda = 0)$ for the log-linear form is -582.990. The critical value with a χ^2 distribution and one degree of freedom is 3.841 and 6.635 at the 5% and 1% levels, respectively. Hence, the log-linear form cannot be rejected at the 1% level. On the other hand, the value of $L(\lambda = 1)$ for the linear form is -593.486. Comparing the test statistic of 21.130 with the $\chi^2_{(1)}$ value of 6.635 at the 1% level, the linear form can be rejected. For M2 demand, both the log-linear and linear forms can be rejected at the 1% level. For M3 demand, the log-linear form can be rejected at the 5% level and the linear form can be rejected at the 1% level.

The ADF unit root test is performed. The critical values are -3.50, -2.89, and -2.58 at the 1%, 5%, and 10% levels. All the variables in levels have unit roots, and all the variables in first difference are stationary. For M1 demand, the DF cointegration test shows that the test statistic of 5.46 is greater than the critical value of 4.07 at the 1% level. The ADF test is not used since the coefficients for Δu_{t-p} are insignificant. For M2 and M3 demands, the ADF tests with $p = 1$ in Δu_{t-p} show that the respective test statistics are 4.80 and 4.95 compared with the critical value of 3.77 at the 1% level. Hence, M1, M2, and M3 demands are cointegrated with the explanatory variables.

Table 1 presents the estimated regression and related statistics. The paper does not employ the first-difference form because the results would become obscure due to the loss of important information (Greene, 2003). The Newey-West (1987) method is employed in empirical work to derive HAC estimates when the forms of heteroskedasticity and autocorrelation are unknown. As shown, the respective regressions for M1, M2, and M3 demands can explain 96.45%, 99.23%, and 99.14% of the variation in money demand. All the coefficients are significant at the 1% or 5%, but the coefficient for the real stock price for M1 demand is significant at the 10% level. The demands for M1, M2, and M3 are positively associated with real GDP and the real stock price and negatively influenced by the saving rate, the U.S. bond rate, and the expected inflation rate. M1 demand responds to peso depreciation negatively while M2 and M3 demands react to peso depreciation positively. Several comments can be made. The positive sign of the real stock price implies that the wealth effect is greater

than the substitution effect (Friedman, 1988). The negative sign of the nominal exchange rate in M1 demand indicates that the substitution effect dominates the wealth effect (Bahmani-Oskooee and Malixi, 1991; Bahmani-Oskooee and Ng, 2002). The positive sign of the exchange rate for M2 and M3 demands shows that the depreciation of the peso leads to an increase in the demand for money and implies that the wealth effect is greater than the substitution effect (Arango and Nadiri, 1981). The negative sign for the nominal exchange rate in M1 demand is probably caused by a high degree of multicollinearity as the correlation coefficients between M1, M2, and M3 demands and the nominal exchange rate are all positive and significant. When the U.S. dollar appreciates and the peso depreciates, Mexican immigrants in the U.S. may send U.S. dollars back to their families to deposit in the banks in Mexico because more pesos can be exchanged. It suggests that different conclusions regarding the impact of peso depreciation on real output may be drawn depending upon which monetary aggregate is used. If M1 demand is selected, peso depreciation would raise output. If M2 or M3 demand is chosen, peso depreciation would shift LM upward and IS rightward and may or may not raise real output.

The negative sign of the U.S. bond rate suggests that the capital mobility effect is greater than the cost of borrowing effect (Márquez, 1987; Bahmani-Oskooee and Ng, 2002). According to the CUSUM test in Figure 1 (Bahmani-Oskooee and Chomsisengphet, 2002; Bahmani-Oskooee and Rehman, 2005), there is evidence of stability in M1 and M3 demands and some degree of instability in M2 demand as the cumulative sum of the recursive residuals falls outside of the 5% critical lines. The CUSUMSQ test shows evidence of stability in M1, M2, and M3 demands.

These results are in contrast with the findings of Thornton (1996) and Prock, Soydemir, and Abugri (2003) that M2 demand was a better monetary aggregate and that money demand in Mexico did not react to a shock to the nominal exchange rate. The results in this study are consistent with the findings of Taylor (1993) and Rodríguez and Turner (2003) that there was currency substitution. Choudhry (1995) and Khamis and Leone (2001) indicated that the demand for money was stable. In this study, whether the demand for real money balances would be stable depends upon the definition of monetary aggregates. M1 and M3 demands are stable under either the CUSUM or CUSUMSQ test while M2 demand indicates stability under the CUSUM test and instability under the CUSUMSQ test. Different results are due to the use of different monetary aggregates, sample periods, or models. These empirical results would be helpful in analyzing the impact of a change in the stock price, the exchange rate, or the foreign interest rate on real output in Mexico when the goods and money markets are considered.

4. Summary and conclusions

This study has examined M1, M2, and M3 demands in Mexico with the focuses to test the appropriateness of the log-linear and linear forms and whether

Figure 1. The CUSUM and CUSUMSQ tests

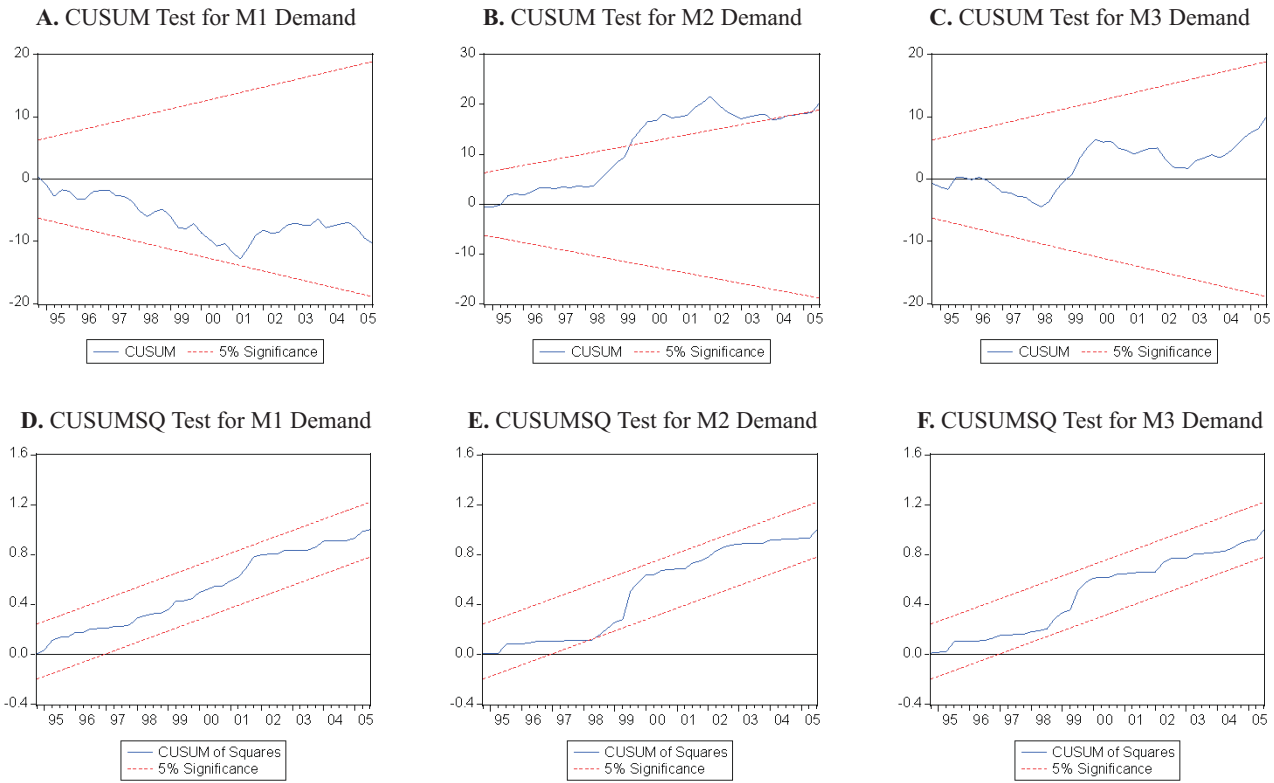

Table 1. Estimated regressions of the demand for real money balances for Mexico: 1993.Q1-2005.Q3

	M1 Demand Log-linear Form	**M2 Demand General Form**	**M3 Demand General Form**
Constant	3.1906	462.9837	246.3465
	(6.3368)	(4.6805)	(7.8627)
Real Output	0.7915	16.0352	4.7402
	(7.4419)	(8.0688)	(4.0470)
Saving Rate	-0.0215	-40.7109	-10.4542
	(-2.4941)	(-7.2190)	(-5.8539)
Real Stock Price	0.0328	9.1285	4.4392
	(1.7697)	(4.8762)	(5.2714)
Nominal Exchange Rate	-0.0808	39.1608	7.4139
	(-6.0359)	(5.9582)	(3.2224)
U.S. T-Bond Rate	-0.0659	-48.1153	-9.6410
	(-3.3598)	(-4.9616)	(-3.8093)
Expected Inflation Rate	-0.0145	-14.6521	-8.1650
	(-2.2567)	(-4.8769)	(-7.8679)
R^2	0.9645	0.9923	0.9914
$\hat{\lambda}$	-0.1079	0.4405	0.3407
$L(\hat{\lambda})$	-582.921	-619.266	-618.371
$L(\lambda = 0)$	-582.990	-624.075	-621.492
$L(\lambda = 1)$	-593.486	-628.868	-631.844
D-W	1.6416	1.4258	0.9305

Note: The Newey-West (1987) method is employed in empirical work to provide estimates for standard errors and covariance which are heteroskedasticity and autocorrelation consistent.

higher financial stock prices and peso depreciation would cause the demand for real money balances to increase or decrease. The regression was estimated by the Newey-West method. The results show that M1, M2, and M3 demands have a positive relationship with real output and the real stock price and a negative relationship with the domestic saving rate, the U.S. T-bond rate, and the expected inflation rate. Peso depreciation would cause M1 demand to decrease and M2 and M3 demands to increase.

The log-linear form cannot be rejected for real M1 and can be rejected for M2 and M3 demands at the 5% level. The linear form can be rejected for M1, M2, and M3 demands at the 1% level. The CUSUM and CUSUMSQ tests indicate the stability in M1 and M3 demands. The CUSUM test shows instability in M2 demand while the CUSUMSQ test reveals the stability in M2 demand. Hence, M1 or M3 demand consistently show stability in either of the tests.

There may be areas for future research. The expected inflation rate may be constructed in different manners. Other estimation methods may be considered. Other model specifications and methodologies may be considered.

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