ASECU South-Eastern Europe Journal of Economics 1 (2020) 101-113 SEEJE

RE-EXAMINING THE STABILITY OF MONEY MULTIPLIER FOR THE US: THE NONLINEAR ARDL MODEL

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Abstract
The rising uncertainties in the economy and the entwined global financial markets can easily cause nonlinear (asymmetric) behaviors among economic actors. Accordingly, this study re-considers the stability of the money multiplier from a different methodological perspective from that of prior studies, which assumed a linear relationship between money supply and monetary base. To this aim, the nonlinear ARDL model is applied for the US for the 2000M1-2018M9 period. Empirical findings of the nonlinear model indicate that only increases in positive monetary base shocks have a proportional relation with money supply. Additionally, the nonlinear ARDL detects proportional relationships between money supply and monetary base lower degree than the linear model.

JEL Classification: E510, E520
Keywords: Money Multiplier, Asymmetry, Linear and Nonlinear ARDL

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Introduction

Controllable money supply may help central banks achieve their monetary policy objectives effectively and as desired. On the other hand, controllable money supply may also require a stable money multiplier and a controllable monetary base. The long-run proportional relationship between money supply and monetary base implies and requires a stable money multiplier. There are two main approaches to the determination of money supply: the Money Multiplier Approach and the Portfolio Approach. The two approaches differ in their assumption of whether the money multiplier is stable or not, and the monetary base is controllable. However, there is no academic consensus on the matter. According to the Money Multiplier Approach (Friedman and Schwartz, 1963; Brunner and Meltzer, 1964), variations (changes) in the money multiplier, caused by the amount of currency in circulation, time-demand deposits and bank reserves, may dominate money supply in the short-run and become stable and predictable in the long-run (Brunner, 1961). According to the Portfolio Approach, the components of the money multiplier are determined by the portfolio choices of economic agents via cash demand, time deposits and excess reserves. These portfolio choices are sensitive to changes in relative return rates, risk levels, financial innovations, and the structure of financial markets. Thus, there is little reason to assume the validity of a stable money multiplier, since all these market forces may cause a money multiplier to be unstable (Goodhart, 1989).

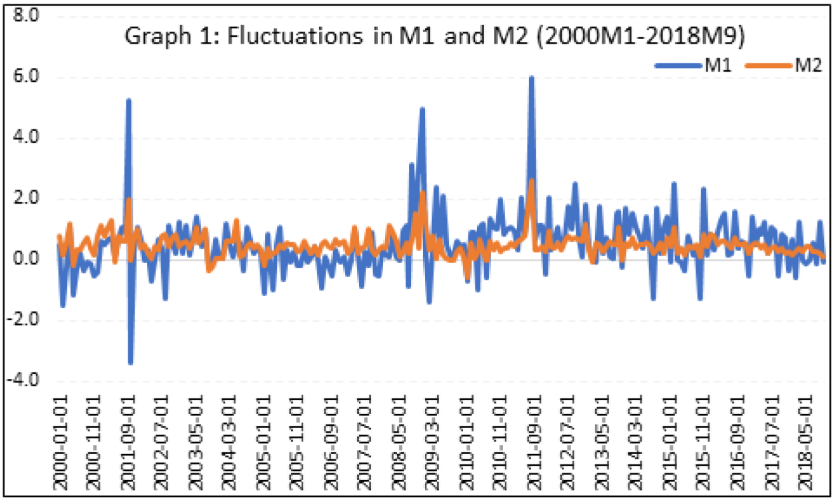
There are some empirical studies supporting the Money Multiplier Approach. For instance, Darbha (2002) applied the residual-based cointegration test by Gregory-Hansen (1996) for India and found a stable, but time-varying, long-run relation between money supply and monetary base. Rusuhuzwa (2015) used the Engle-Granger (1987) cointegration test and the Gregory-Hansen (1996) method for Rwanda and found a stable money multiplier. Tule and Ajilore (2016) applied the cointegration test for Nigeria and found a stable money multiplier. Lastly, Bhatti and Khawaja (2018) applied the cointegration tests of Engle–Granger (1987), Phillips–Ouliaris (1990) and Johansen and Juselius (1990) for Kazakhstan and found that the money multiplier was stable for the country.

However, the growing body of empirical studies is in favor of the latter approach, supporting an unstable money multiplier and uncontrollable monetary base. For instance, Nachnae (1992) for India, Ford and Morris (1996) for the UK, Baghestani and Mott (1997) for the US, and Sen and Vaidya (1997) for India applied the cointegration test and found that the money multiplier was not stable and the monetary base was uncontrollable for their respective countries. Furthermore, Uchendu (1995) applied the moving average regression technique for Nigeria and found an unstable money multiplier. Sahinbeyoglu (1995) used the unit root test for Turkey and found that the money multiplier was unstable. Moosa and Bhatti (1997) applied a battery of econometric tests for Kuwait and found an unstable money multiplier.

Howells and Hussein (1998) applied the causality tests based on cointegration and the Error Correction representation and found an unstable money multiplier for all G7 countries. Khan and Khan (2007) applied the cointegration test for Pakistan and found that the money multiplier was not stable. White (2006) applied the residual based cointegration test for Jamaica and found an unstable money multiplier. Downes *et al*. (2006) applied the descriptive statistics and unit root tests approach for six African countries and found that the money multiplier was not stable. Panagopoulos and Spiliotis (2008) used the Error Correction Vector Autoregressive (VAR) causality for the G7 countries and found an unstable money multiplier for most of the countries except France and Japan. Badarudin *et al*. (2013) used the Trivariate VAR and Granger causality for the G7 countries and found that the money multiplier was unstable for all countries except the UK and the US for two short time periods. Similarly, Odior (2013) applied the Generalized Method of Moments (GMM) model for Nigeria and found that the money multiplier was unstable. The reasons for this inconsistency among monetary economists and their empirical studies may lie in the different time horizons, economic sizes, and structures of financial markets of sample countries, as well as the different methodologies applied. However, it is also important to note that all these studies assume an expected long-run proportional relationship (change) on the money supply is determined by a linearly distributed monetary base series. Yet, this distribution may potentially be nonlinear (asymmetric) because rising uncertainties in the economy can easily cause nonlinear behaviors among economic actors. This means that increases and decreases in the monetary base may have different impacts on money supply. While increases (positive variations) in monetary base may have proportional impacts on money supply, decreases (negative variations) may not. Additionally, even if increases and decreases have the same effect, they may have different scale impacts on money supply. Accordingly, the stability of the money multiplier can also be determined via these increases and decreases, separately, in a nonlinear context. The nonlinear autoregressive distributed lag (ARDL) model by Shin *et al*., (2014) allows for this decomposition in the monetary base series.

Therefore, this study, differently from previous studies, aims to re-consider and test the stability of the money multiplier from this new methodological perspective for the US. Meanwhile, before starting methodological analyses, it would be better to look at the fluctuations in M1 and M2 for the US, which may correspond to some economic-financial crises and, thereby, change the stability of the money multiplier.

Graph 1 shows that money aggregates M1 and M2 continuously fluctuate. However, sharp fluctuations correspond to some structural break dates, such as the 2001 recession, the 2008 financial crisis and FED's 2012 quantitative easing (QE) policy. All may cause potential nonlinear behaviour of US money multipliers.



Source: Graph 1 was created from the data of the Federal Reserve Bank of St. Louis (FED)

The rest of this study is structured as follows: Section 2 explains the empirical methodology and data set, Section 3 provides empirical results, and Section 4 concludes the study.

2. Empirical Methodology and Data Set

The *money multiplier model (money multiplier relationship)* by Brunner (1961) and Brunner and Meltzer (1964) is the most frequently used model in empirical studies and it is usually written in the following proportional form:

$$M^S = k\,(.) * H \tag{1}$$

According to this model, money supply can be determined in two ways. First, a change in monetary base (H) proportionately changes money supply (M^s), if the money multiplier (k) is stable. This means that the money supply is exogenously determined by the central bank, in this case the U.S. Federal Reserve (FED). Second, both k and H change the money supply (M^s), if k is not stable, and it is a function of several endogenous factors, mentioned above in parenthesis. This means that the money supply process is endogenous. Eqn. 1 can be written in the following logarithmic form:

$$LogM^S = Logk + LogH \tag{2}$$

Under the assumption of a stable k (denotes $k = M_t^s/H_t$=1), Eqn. 3 is obtained in the following regression form:

$$LogM_t^S = \beta_0 + \beta_1 LogH_t + e_t \quad (3)$$

where e_t is the error term and β_0 is the logarithm of k. For a controllable or exogenous money supply process, k must be stable (stationary) and M_t^S and H_t must be stationary or cointegrated, if the series are not stationary at the same order of integration (Thenuwara and Morgan, 2017; Bhatti and Khawaja, 2018). This means that β_0 must be zero, implying a logarithmic k, and β_1 must be 1, implying a proportional relationship between M_t^S and H_t. We test this relationship for both M1 and M2, separately. The monthly data of money supply and monetary base were provided from the database of the Federal Reserve Bank of St. Louis (FRED). The sample period of this study was between 2000M1-2018M9, because the sharp fluctuations in M1 and M2, caused by different economic crises and the FED's monetary policy changes, were mostly seen after 2000. Therefore, this monthly period (223 observations) may give us more and clearer information about the stability of the US money multiplier through monetary aggregates.

In order to estimate both short-run and long-run impacts of changes in H_t on the M_t^S we apply bounds testing to cointegration and the error correction model (ECM) within the ARDL model developed by Pesaran *et al.* (2001). The ECM indicates the speed of adjustment toward the long-run equilibrium from the short-run. Thus, we obtain the following ECM in the linear form of the ARDL model in Eqn.4:

$$\Delta LogM_t^S = \beta_0 + \sum_{j=1}^{p} \beta_{1j}\Delta LogM_{t-j}^S + \sum_{j=0}^{q} \beta_{2j}\Delta LogH_{t-j} + \beta_3 LogM_{t-j}^S + \beta_4 LogH_{t-1} + e_t \quad (4)$$

In Eq.4, Δ is the difference operator. Short-run and long-run impacts of changes in H_t on M_t^S are determined by the scale and significances of β_{2j} and β_4 respectively. For the validity of potential nonlinear relationships, we follow Shin *et al.*, (2014) and decompose H_t as H_t^+ (increases) and H_t^- (decreases). This decomposition of H_t^+ and H_t^- is constructed with the concept of the partial sum process in the following form:

$$H_t^+ = \sum_{j=1}^{t} \Delta H_j^+ = \sum_{j=1}^{t} \max(\Delta H_j, 0) \quad (5)$$

$$H_t^- = \sum_{j=1}^{t} \Delta H_j^- = \sum_{j=1}^{t} \min(\Delta H_j, 0) \quad (6)$$

Hence, we obtain the following form of the nonlinear ARDL model in Eq.7.

$$\Delta LogM_t^S = \beta_0 + \sum_{j=1}^{p} \beta_{1j}\Delta LogM_{t-j}^S + \sum_{j=0}^{q} \beta_{2j}\Delta LogH_{t-j}^+ + \sum_{j=0}^{r} \beta_{3j}\Delta LogH_{t-j}^- + \beta_4 LogM_{t-j}^S + \beta_5 LogH_{t-j}^+ + \beta_6 LogH_{t-j}^- + e_t \quad (7)$$

The impacts of long-run increases and decreases in H_t on M_t^S are determined by the signs and significances of normalized long run coefficients, such as β_5/β_4 and β_6/β_4. Thus, with decomposed variables, we will be able to understand how M_t^S responds to the H_t^+ and H_t^- separately, in terms of stability of the money multiplier. Consequently, this model will also reveal whether changes in H_t^+ and H_t^- have symmetric or asymmetric effects on M_t^S . If the coefficient values of H_t^+ and H_t^- are of different scale or one of them is significant and the other one is not, this will imply asymmetric impacts. However, for a formal decision of asymmetry, we apply the Wald test for both the short-run (W_{SR}) and the long-run (W_{LR}). $\sum_{j=0}^{q} \beta_{2j} \neq \sum_{j=0}^{r} \beta_{3j}$ and normalized long run coefficients, such as $(-\beta_5/\beta_4) \neq (-\beta_6/\beta_4)$ will confirm short-run and long-run asymmetries, respectively.

3. Empirical Results

Before running the ARDL models, we must make sure that the series are stationary. To this aim, we apply Augmented Dickey Fuller (1981) (ADF) and Phillips-Perron (1988) (PP) Unit Root Tests. The results of these two tests are reported in Table 1.

Table 1. ADF and PP Unit Root Test Results

	ADF		PP	
	Level	First Difference	Level	First Difference
	Prob.	Prob.	Prob.	Prob.
$LogM1$	0.74	0.05*	0.67	0.00***
$LogM2$	0.35	0.00***	0.45	0.00***
$LogH$	0.77	0.00***	0.97	0.00***
$LogH^+$	0.53	0.02**	0.64	0.00***
$LogH^-$	0.99	0.30	0.99	0.00***

Note: ***, ** and * denote statistical significances at 1%, 5% and 10% level respectively. Optimal lags were automatically selected by using the Modified Akaike Information Criterion. For the levels and first differences, trend-intercept and intercept models were used, respectively.

The results of the unit root tests indicate that all series are *I*(1). Hence, M_t^S and H_t must be cointegrated for a long-run stable money multiplier. To test the cointegration relationship between these two variables, we applied bounds testing. Results of the bounds testing for the linear and nonlinear models are reported in Table 2.

Table 2. Test Results of Bounds Testing

Dependent Variable	*k*	*F stat.*	Critical Values: I0 Bound			Critical Values: I1 Bound		
			10%	*5%*	*1%*	*10%*	*5%*	*1%*
Linear								
LogM1	1	8.96***	*3.02*	*3.62*	*4.94*	*3.51*	*4.16*	*5.58*
LogM2	1	10.33***	*3.02*	*3.62*	*4.94*	*3.51*	*4.16*	*5.58*
Nonlinear								
LogM1	2	7.87***	2.63	3.1	4.13	3.35	3.87	5.00
LogM2	2	7.84***	2.63	3.1	4.13	3.35	3.87	5.00

Note: k is number of regressors. ***; denotes cointegration at 1% significance level.

The critical bounds have been tabulated *by* Pesaran *et al.* (2001). The test results of the bounds testing indicate that the series are cointegrated at the 1% level for both linear and nonlinear models, since the F-statistics of M1 and M2 exceed the critical values. The results of the linear ARDL model for the short-run and the long-run, as well as diagnostic tests are reported in Table 3.

The long-run estimates of the linear model in Table 3 indicate that changes in the monetary base (H_t) have a cointegrated proportional relationship with money supply (for both M1 and M2, since their coefficients are significantly positive. However, the coefficient values of for both M1 and M2 are less than 1 (*one-to-one relation*), implying that the money multiplier is unstable for both of them. On the other hand, M1 responds to changes in the monetary base (H_t) more than M2 (0.70 and 0.39). Short-run estimates indicate that there is no considerable proportional relationship between and in the short-run. Furthermore, the Error Correction Term (*ECT*) mechanisms for M1 and M2 work, since their coefficients are significantly negative. This means that short-run variations converge (adjust) with long-run values. The speed of M1 adjustment is higher than that of M2. The results of the nonlinear ARDL model, both in the short-run and the long-run, as well as the diagnostic tests, are reported in Table 4.

Table 3. Linear ARDL Model Estimation Results

	Dependent Variable: (M1)		*Dependent Variable: (M2)*	
Variable	*Coef.*	*Prob.*	*Coef.*	*Prob.*
		Short-Run		
$\Delta LogM^S_{t-1}$	-0.19***	0.00	0.17**	0.01
$\Delta LogM^S_{t-2}$	0.03	0.56	0.03	0.60
$\Delta LogM^S_{t-3}$	0.19***	0.00	0.19***	0.00
$\Delta LogM^S_{t-4}$	-	-	-0.18***	0.00
$\Delta LogM^S_{t-5}$	-	-	0.08	0.22
$\Delta LogH_t$	0.06***	0.00	0.01*	0.09
$\Delta LogH_{t-1}$	0.03	0.20	0.001	0.88
$\Delta LogH_{t-2}$	0.01	0.57	0.01*	0.07
$\Delta LogH_{t-3}$	-0.02	0.32	-0.01	0.11
$\Delta LogH_{t-4}$	-0.03	0.20	0.01	0.17
$\Delta LogH_{t-5}$	0.007	0.80	-0.01	0.29
$\Delta LogH_{t-6}$	0.03	0.17	0.01	0.22
$\Delta LogH_{t-7}$	-	-	-0.01	0.18
$\Delta LogH_{t-8}$	-	-	-0.0007	0.94
$\Delta LogH_{t-9}$	-	-	-0.01*	0.08
ECT_{t-1}	-0.01***	0.00	-0.005***	0.00
		Long-Run		
$LogH_t$	0.70***	0.00	0.39***	0.00
$Constant$	2.65***	0.00	6.79***	0.00
		Diagnostic Tests		
	Test Stat.	*Prob.*		
R^2	0.99	-	0.99	-
$\bar{R}^2$	0.99	-	0.99	-
F	35272.10	0.00	104.13	0.00
DW	1.98	-	2.01	-
χ^2_{SC}	0.11	0.94	1.11	0.57
χ^2_{HET}	19.58	0.07	32.88	0.11
χ^2_{FF}	0.68	0.40	0.31	0.57

Note: ***, ** and * denote statistical significances at 1%, 5% and 10% levels, respectively. CUSUM and CUSUM of Squares test graphs are reported in Appendix 1. High R^2 and $\bar{R}^2$ values show that explanatory powers of the models are high. DW, χ^2_{SC} and χ^2_{HET} statistics indicate that there is no autocorrelation or heteroscedasticity problems in the models. χ^2_{FF} statistics indicates there is no model misspecification error. Models are stable, since CUSUM and CUSUMQ graphs in Appendix 1 are within confidence intervals.

Table 4. Nonlinear ARDL Model Estimation Results

	Dependent Variable: (M1)			*Dependent Variable: (M2)*	
Variable	*Coef.*	*t-stat.*	*Variable*	*Coef.*	*t- stat.*
$LogM_{t-1}$	-0.06***	-5.04	$LogM_{t-1}$	-0.021**	-2.35
$LogH^+_{t-1}$	0.02***	5.98	$LogH^+_{t-1}$	0.006***	2.76
$LogH^-_{t-1}$	-0.008	-0.89	$LogH^-_{t-1}$	-0.0002	-0.08
$\Delta LogM_{t-1}$	-0.22***	-3.54	$\Delta LogM_{t-1}$	0.14**	2.34
$\Delta LogM_{t-3}$	0.16**	2.01	$\Delta LogM_{t-5}$	0.11**	1.96
$\Delta LogH^+_t$	0.11***	5.27	$\Delta LogH^+_{t-6}$	0.02**	2.35
$\Delta LogH^+_{t-4}$	-0.08***	-3.39	$\Delta LogH^+_{t-7}$	-0.02**	2.35
$\Delta LogH^+_{t-10}$	-0.05**	-2.18	$\Delta LogH^+_{t-9}$	-0.02***	-2.68
$\Delta LogH^+_{t-12}$	-0.07***	-3.03	$\Delta LogH^+_{t-11}$	-0.02***	-2.88
-	-	-	$\Delta LogH^-_{t-1}$	-0.02**	-2.25
-	-	-	$\Delta LogH^-_{t-3}$	-0.02**	-2.32
$\Delta LogH^-_{t-11}$	0.16***	2.70	$\Delta LogH^-_{t-4}$	0.03***	2.58
$Constant$	0.43***	5.07	$Constant$	0.19**	2.40
ECT_{t-1}	-0.25**	-2.18	ECT_{t-1}	-0.17**	-2.25
Normalized Long-Run Coefficients					
$LogH^+_t$	0.39***	8.91	$LogH^+_t$	0.29***	6.11
$LogH^-_t$	-0.14	0.97	$LogH^-_t$	0.013	0.91
Diagnostic Tests					
	Test Stat.	*Prob.*		*Test Stat.*	*Prob.*
R^2	0.29	-	R^2	0.28	-
$\bar{R}^2$	0.25	-	$\bar{R}^2$	0.24	-
F	8.26	0.00	F	6.59	0.00
DW	2.00	-	DW	1.97	-
χ^2_{SC}	0.19	0.90	χ^2_{SC}	4.87	0.08
χ^2_{HET}	12.32	0.26	χ^2_{HET}	14.76	0.25
χ^2_{FF}	0.79	0.37	χ^2_{FF}	11.75	0.17
W_{LR}	28.17	0.00	W_{LR}	-0.30	0.00
W_{SR}	0.12	0.07	W_{SR}	0.042	0.05
EG_{MAX}	-9.80	0.00	EG_{MAX}	-10.83	0.00

Note: ***, ** and * denote statistical significances at 1%, 5% and 10% levels respectively. W_{LR} and W_{SR} are long and short-run Wald tests. Normalized long-run coefficients are obtained with $LogH^+_t = -\beta_5/\beta_4$, $LogH^-_t = -\beta_6/\beta_4$. EG_{MAX}; Engle and Granger cointegration test statistics. Critical *t*-table values are 2.57, 1.96 and 1.64 at 1%, 5% and 10%. CUSUM and CUSUM of Squares test graphs are reported in Appendix 2. High R^2 and $\bar{R}^2$ values show that the explanatory powers of the models are high. *DW*, χ^2_{SC} and χ^2_{HET} statistics indicates that there is no autocorrelation or heteroscedasticity problem in the models. χ^2_{FF} statistics indicates the there is no model misspecification error. Models are stable, since CUSUM and CUSUMQ graphs in Appendix 2 are within confidence intervals. The long-run (W_{LR}) and short-run (W_{SR}) Wald tests confirm asymmetry both in the long-run and the short-run. EG_{MAX} statistics confirm cointegration relationships between variables.

The normalized long-run estimates of the nonlinear model in Table 4 indicate that only increases in the monetary base (H_t^+) have cointegrated proportional relationships with money supply (M_t^S) for both M1 and M2, since their coefficients are significantly positive. This means that the FED's only expansionary monetary policy, which increases the monetary base (H_t^+), leads to an increase in money supply (both in M1 and M2). However, the coefficient values of (H_t^+) for M1 and M2 are lower than 1, thereby implying that the money multiplier is not stable in terms of increases in the monetary base (in expansionary monetary policy). On the other hand, decreases in monetary base (H_t^-) (contractionary monetary policy) do not have a cointegrated proportional relationship with the money supply (M_t^S) for both M1 and M2 in the long-run, since their coefficients are insignificant. Thus, it can be concluded that the money supply process for both M1 and M2 is not *exogenous* for the US *because the coefficient values of* H_t^+ and H_t^- are lower than 1 or insignificant, respectively.

The comparative result of the linear and nonlinear ARDL models is that the nonlinear model detects a weaker proportional relationship between money supply and monetary base than the linear model for both M1 (0.39) and M2 (0.29) in the long run. These coefficients were found to be 0.70 and 0.39 by the linear model. This may be interpreted to mean that the money supply determination process (mechanism) in the US exhibits a nonlinear character. Furthermore, the nonlinear model indicates that increases (H_t^+) and decreases (H_t^-) in the monetary base have asymmetric impacts on money supply (M_t^S) for M1 and M2, since $(-\beta_5/\beta_4) \neq (-\beta_6/\beta_4)$ in the long-run and $\sum_{j=0}^{q} \beta_{2j} \neq \sum_{j=0}^{r} \beta_{3j}$ in the short-run.

4. Conclusion

Understanding the money supply determination process in detail is extremely important for a country. If a nation's central bank (such as the FED in the US) increases or decreases the monetary base more or less than the amounts required, this can easily cause undesirable inflation or deflation rates and, thereby, lead to unwanted results concerning all other macroeconomics variables. Therefore, this study reconsiders the stability of the money multiplier via the traditional *money multiplier model* from a different methodological perspective. Contrary to previous empirical studies, this study assumes that there may be a potentially asymmetric (nonlinear) proportional relationship between money supply and monetary base, because of potentially asymmetric (nonlinear) behaviors of financial actors in response to rising uncertainties in the economies and entwined financial markets of countries. To this aim, the nonlinear ARDL model is applied for the US alongside the linear ARDL model. The empirical findings of this study are three-fold. First, both linear and nonlinear models indicate that the money multiplier in the US is not stable for both M1 and M2, therefore, implying that the money supply process is not exogenous for the FED. Second, the nonlinear model detects a weaker proportional relationship between money supply and the monetary base than the linear model. Third, the nonlinear model indicates that the FED's only expansionary monetary policy has impacts on money supply, while the contractionary monetary policy of the FED has no impact on the money supply determination process.

In conclusion, new methodological approaches in the nonlinear context, such as the nonlinear ARDL model, may help central banks understand how money supply responds separately to increases and decreases in the monetary base. This study also shows the need for more empirical studies conducted using different methodologies in a nonlinear context for other countries as well.

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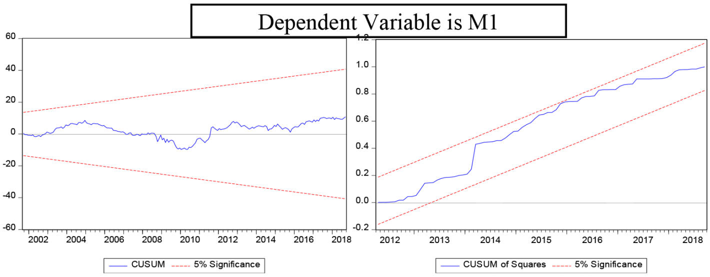
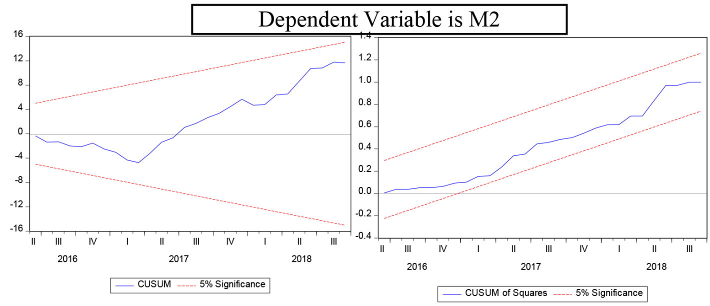
Appendix

Appendix 1. Cusum and CusumQ Figures of Linear ARDL Models





Appendix 2. Cusum and CusumQ Figures of Nonlinear ARDL Model