

3. Empirical Model-Methodology

We add the monetary policy uncertainty (MPU) index, as a new independent variable, to the following standard money demand function model in logarithmic regression form:

$$\text{LogMD2}_t = \beta_0 + \beta_1 \text{LogMPU} + \beta_2 \text{GBR}_t + \beta_3 \text{LogIPI}_t + \varepsilon_t \quad (1)$$

In Eqn.1, $MD2$ is the real money balance for broad money ($M2$)⁵ deflated by the CPI, MPU is monetary policy uncertainty index of Greece, GBR is both 10-year and 20-year Greek Government Bond rates and IPI is the Industrial Production Index as a proxy for income. The reason for using this index⁶ instead of the GDP is that we wanted to study with monthly data since GDP data are not collected and released monthly, only quarterly and yearly. Another reason for using monthly data and the IPI index is that financial transactions in today's modern financial markets are open 24 hours. Any disruption in a country's stock easily affects the other countries stock exchanges quickly. Therefore, at this point, even monthly data may have difficulty capturing the impact of many shocks in financial markets. According to our expectations, the sign of β_1 is to be positive or negative. This means that rises and falls in the MPU index may increase or decrease demand for money. The sign of β_2 is to be negative. This means that higher government bond rates lead to lower demand for money. Finally, the sign of β_3 is to be positive since rises in income should lead to increase in demand for money (transaction motive). ε_t is the stochastic error term. In this study, for Greek Government 10-year and 20-year bond rates, the following two separate models were constructed in Model 1 and Model 2, respectively. The data set of the study is presented in the Appendix.

$$\text{Model 1: } \text{LogMD2}_t = \beta_0 + \beta_1 \text{LogMPU} + \beta_2 \text{GBR10}_t + \beta_3 \text{LogIPI}_t + \varepsilon_t \quad (2)$$

$$\text{Model 2: } \text{LogMD2}_t = \alpha_0 + \alpha_1 \text{LogMPU} + \alpha_2 \text{GBR20}_t + \alpha_3 \text{LogIPI}_t + e_t \quad (3)$$

⁵ In this study, Greece's monetary aggregate ($M2$) refers to the so-called "Greek Contribution (GC)" to the *Euro Area* aggregates since This Country joined the *Euro Area* in January 2002. However, the European Central Bank (ECB) adjusted the series of $M2$ for pre January 2002, as well. The GC is defined by the ECB in the three following manners. It equals to: (a) the deposits held by Greek and other *euro area* countries' residents in Greek monetary financial institutes (MFIs); (b) the banknotes put into circulation by the Bank of Greece (BoG); (c) debt securities issued by Greek MFIs minus the debt securities issued by all *euro area* MFIs. Hence, in this study, we assume that $M2$ can be accepted and used as a Greek money aggregate. It should be noted that the empirical findings of this study should be considered and interpreted within this assumption. The term *euro area* is used to describe the member countries of the European Union (EU) that use the Euro (€) as their national currency.

⁶ This index is used in a wide range of studies (Bahmani-Oskooee and Saha (2017); Bahmani-Oskooee and Durmaz (2020); Ongan and Gocer (2021b).

In Eqns. 2 and 3, *GBR10* and *GBR20* are 10-year and 20-year bond rates, respectively. The empirical methodology of this study is based on the nonlinear ARDL model. With this model we can decompose changes in the MPU index into its increases (MPU^+) and decreases (MPU^-) as two new series. Hence, we get the chance to examine the separate effects of MPU index increases and decreases on demand for money. However, the nonlinear ARDL model is the asymmetric (nonlinear) form of the linear ARDL model. Therefore, first, we present the linear form of the ARDL model. To this aim, we apply bounds testing to cointegration within the ARDL model by Pesaran et al. (2001). Hence, we obtain the following Eqn. 4 in error correction format for both 10-year and 20-year bond rates in Model 1 and Model 2 in Eqns.2 and 3, respectively.

$$\begin{aligned} \Delta \text{LogMD2}_t = & \beta_0 + \sum_{j=1}^p \beta_{1j} \Delta \text{LogMD2}_{t-j} + \sum_{j=0}^q \beta_{2j} \Delta \text{LogMPU}_{t-j} + \sum_{j=0}^r \beta_{3j} \Delta \text{GBR}_{t-j} + \sum_{j=0}^s \beta_{4j} \Delta \text{LogIPI}_{t-j} \\ & + \beta_5 \text{LogMD2}_{t-1} + \beta_6 \text{LogMPU}_{t-1} + \beta_7 \text{GBR}_{t-1} + \beta_8 \text{LogIPI}_{t-1} + \varepsilon_t \end{aligned} \quad (4)$$

In this equation, Δ is the difference operator. The short-run and long-run effects of changes in the MPU index on demand for money (*MD2*) are determined by the signs and significances of β_{2j} and β_6 , respectively. β_{3j} and β_{4j} stand for *GBR* and *IPI* in short-run and β_7 and β_8 in long-run.

Following the linear ARDL model, we apply the nonlinear model for asymmetric effects of MPU index increases (MPU^+) and decreases (MPU^-) on demand for money (*MD2*). This model will show us how MPU^+ and MPU^- , in the MPU index, separately affect the *MD2*. This means that we will learn whether the effects of MPU^+ and MPU^- on *MD2* are symmetric or asymmetric. Symmetric effects are defined by the same size and same sign decomposed coefficients (MPU^+ and MPU^-). However, the Wald test for short-run (W_{SR}) and long-run (W_{LR}) will formally give us symmetry or asymmetry decisions. Decomposed MPU^+ and MPU^- are obtained from the concept of the following partial sum process:

$$\text{LogMPU}_t^+ = \sum_{j=1}^t \Delta \text{LogMPU}_j^+ = \sum_{j=1}^t \max(\Delta \text{LogMPU}_j, 0) \quad (5)$$

$$\text{LogMPU}_t^- = \sum_{j=1}^t \Delta \text{LogMPU}_j^- = \sum_{j=1}^t \min(\Delta \text{LogMPU}_j, 0) \quad (6)$$

where MPU^+ and MPU^- are the partial sum processes of increases (+) and decreases (-) in the MPU index. Following the decomposition process, we obtain the nonlinear ARDL model in Eqn.7 for both Model 1 and Model 2, below:

$$\begin{aligned} \Delta \text{LogMD}2_t = & \beta_0 + \sum_{j=1}^p \beta_{1j} \Delta \text{LogMD}2_{t-j} + \sum_{j=0}^q \beta_{2j} \Delta \text{LogMPU}_{t-j}^+ + \sum_{j=0}^r \beta_{3j} \Delta \text{LogMPU}_{t-j}^- + \sum_{j=0}^s \beta_{4j} \Delta \text{GBR}_{t-j} \\ & + \sum_{j=0}^k \beta_{5j} \Delta \text{LogIPI}_{t-j} + \beta_6 \text{LogMD}2_{t-1} + \beta_7 \text{LogMPU}_{t-1}^+ + \beta_8 \text{LogMPU}_{t-1}^- + \beta_9 \text{GBR}_{t-1} \\ & + \beta_{10} \text{LogIPI}_{t-1} + \varepsilon_t \end{aligned} \tag{7}$$

In Eqn.7, the short-run effects of MPU^+ and MPU^- on demand for money are determined by the signs and significances of β_{2j} and β_{3j} , respectively. Similarly, the long-run effects of MPU^+ and MPU^- are determined by the signs and significances of normalized $-\beta_7/\beta_6$ and $-\beta_8/\beta_6$, respectively. The same is true for GBR and IPI for β_{4j} , β_{5j} in short-run and β_9 and β_{10} in long-run. Normalized coefficients of GBR and IPI are obtained via $-\beta_9/\beta_6$ and $-\beta_{10}/\beta_6$, respectively.

4. Empirical Findings

In this section of the study, we first apply the Carrion-i-Silvestre, Kim and Perron (2009) Unit Root Test with Multiple Structural Breaks to confirm whether the series are stationary or not. The results of this test are reported in Table 1.

Table 1. Carrion-i-Silvestre, Kim and Perron (2009) Unit Root Test with Multiple Structural Breaks Results

Variable	Test Statistics and Critical Values					Structural Break Dates
	PT	MPT	MZA	MSB	MZT	
<i>LogMD2</i>	12.81 (8.00)	12.19 (8.00)	-23.71 (-35.49)	0.14 (0.11)	-3.41 (-4.20)	2002:M03; 2009:M08; 2014:M12
<i>LogMPU</i>	3.87** (7.10)	3.54** (7.10)	-63.94** (-31.68)	0.08** (0.12)	-5.64** (-3.96)	2010:M04; 2013:M01; 2015:M07
<i>LogMPU⁺</i>	5.62** (7.24)	5.49** (7.24)	-46.42** (-34.20)	0.10** (0.12)	-4.80** (-4.12)	2006:M12; 2010:M02; 2015:M06
<i>LogMPU⁻</i>	4.59** (7.06)	4.59** (7.06)	-48.27** (-31.66)	0.10** (0.12)	-4.91** (-3.96)	2010:M03; 2012:M03; 2014:M12
<i>GBR10</i>	9.78 (7.19)	9.17 (7.19)	-24.96 (-32.09)	0.14 (0.12)	-3.53 (-3.99)	2009:M11; 2012:M02; 2014:M08
<i>GBR20</i>	26.81 (7.24)	24.81 (7.24)	-9.21 (-31.93)	0.23 (0.12)	-2.14 (-3.98)	2010:M03; 2012:M02; 2015:M06
<i>LogIPI</i>	4.08** (8.13)	4.03** (8.13)	-77.57** (-35.93)	0.07** (0.11)	-6.17** (-4.22)	2001:M12; 2008:M01; 2011:M09
$\Delta \text{LogMD}2$	2.59** (7.61)	2.47** (7.61)	-108.42** (- 35.00)	0.06** (0.11)	-7.36** (- 4.17)	2002:M03; 2008:M09; 2015:M05

$\Delta GBR10$	2.26** (7.04)	2.12** (7.04)	-108.43** (-32.40)	0.06** (0.12)	-7.35** (-4.01)	2009:M06; 2011:M11; 2015:M05
$\Delta GBR20$	2.10** (6.97)	1.95** (6.97)	-111.07** (-31.52)	0.06** (0.12)	-7.45** (-3.95)	2009:M10; 2011:M10; 2013:M09

Note: ** denote statistical significance at 5% level. Δ denotes the first differences of the series. The above structural break dates successfully detect the pre-post effects of 2008 Global Financial Crisis and Greece's switching to the Euro in 2002. *LogMD2*: the real broad money balance (*M2*). *GBR10*: 10-year bond rates. *GBR20*: 20-year bond rates. Critical values in this test were obtained with 1000 repetition in bootstrap.

The test results in Table 1 indicate that *LogMPU*, *LogMPU⁺*, *LogMPU⁻* and *LogIPI* are I(0) and *LogMD2*, *GBR10* and *GBR20* are I(1). Hence, for testing cointegration relationships, we apply bounds testing developed by Pesaran et al. (2001). The results of bounds testing and structural break dates by Bai and Perron (2003), for both linear and nonlinear models, are reported in Table 2.

Table 2. Test Results of Bounds Testing and Structural Break Dates

	<i>k</i>	<i>F stat.</i>	Critical Values						Structural Break Dates	
			I0 Bound			I1 Bound				
			10%	5%	1%	10%	5%	1%		
Linear	Model 1	3	6.74***	2.37	2.79	3.65	3.20	3.67	4.66	2005:M03; 2008:M02; 2011:M07
	Model 2	3	6.07***	2.37	2.79	3.65	3.20	3.67	4.66	2004:M08; 2008:M02; 2015:M08
Nonlinear	Model 1	4	6.13***	2.20	2.56	3.29	3.09	3.49	4.37	2007:M01; 2010:M04; 2015:M02
	Model 2	4	5.98***	2.20	2.56	3.29	3.09	3.49	4.37	2008:M11; 2012:M03; 2015:M02

Note: *k* is number of regressors. ***; denotes cointegration at the 1% significance level. Model 1: 10-year bond rates. Model 2: 20-year bond rates.

Test results in Table 2 indicate that series are cointegrated at the 1% significance level, since calculated *F*- statistics are above the upper bounds. Hence, we can now estimate the coefficients of the linear model. Structural break dates were detected by the Bai and Perron (2003) method. These dates were added to successive analyses with dummy variables (D_{it}). The linear ARDL model's test results and its diagnostics are reported in Table 3.

Table 3. Linear ARDL Model Estimation Results

Variables	Short-Run Coefficients		Variables	Long-Run Coefficients	
	Model 1	Model 2		Model 1	Model 2
$\Delta \text{LogMD2}_{t-1}$	-0.15** (0.01)	-0.18*** (0.00)	LogMPU_t	-4.77* (0.08)	-1.27** (0.03)
$\Delta \text{LogMD2}_{t-2}$	-0.07 (0.25)	-0.09 (0.12)	GBR_t	-4.83* (0.08)	-0.16** (0.03)
$\Delta \text{LogMD2}_{t-3}$	-0.29*** (0.00)	-0.30*** (0.00)	LogIPI_t	14.75** (0.03)	4.37*** (0.00)
ΔGBR_t	-0.001** (0.04)	-0.001 (0.33)	D_{2004t}	8.41* (0.09)	2.82* (0.05)
ΔGBR_{t-1}	-0.0009 (0.26)	-0.005 (0.77)	D_{2008t}	-7.93* (0.09)	-3.26** (0.02)
ΔGBR_{t-2}	0.001** (0.03)	0.0004** (0.01)	D_{2011t}	66.48* (0.08)	-
ΔGBR_{t-3}	-	0.0003** (0.02)	D_{2015t}	-	-10.10** (0.02)
ΔD_{2008t}	0.001 (0.90)	0.007 (0.60)			

ΔD_{2011t}	0.02 (0.10)	-			
ECT_{t-1}	-0.0006*** (0.00)	-0.003*** (0.00)			
Diagnostic Tests					
R^2	0.99	0.99	χ_{FF}^2	0.87*** (0.34)	0.10*** (0.74)
$Adj. R^2$	0.99	0.99	χ_{NOR}^2	3.42*** (0.18)	2.76*** (0.25)
DW	2.04***	2.03***	χ_{HET}^2	21.69*** (0.29)	124.17** (0.06)
χ_{SC}^2	1.57*** (0.20)	0.76*** (0.38)			

Note: ***, ** and * denote statistical significances at 1%, 5% and 10% levels respectively. Values in parentheses are probabilities. DW ; Durbin-Watson autocorrelation test, χ_{SC}^2 is Breusch-Godfrey LM test for autocorrelation, χ_{NOR}^2 is the Jarque-Bera test for normality, χ_{FF}^2 is Ramsey test for functional form misspecification, χ_{HET}^2 for Breusch-Pagan-Godfrey heteroscedasticity test. All model specification test results are reliable. Model 1: 10-year bond rates. Model 2: 20-year bond rates.

Test results in Table 3 for the linear model indicate that changes in the MPU index have negative effects on demand for money in Greece in the long run, since the coefficients of MPU in both models are significantly negative. This means that rises in the MPU index lead to decreases, while falls lead to increases in demand for money in Greece. However, the responsiveness of demand for money to the changes in the MPU index in 10-year bond rates (-4.77) is higher than in 20-year bond rates (-1.27). This can lead to the interpretation that rises in the MPU index decrease demand for money more in the changes of shorter-term bond rates than longer term bond rates. This may mean that Greek people hold far less money in rising uncertainties when the maturity of alternative investments (Greek Government bond) gets shorter (10-year bond rates). Furthermore, rises in income (IP) lead to increases in demand for money (as expected) for both 10-year and 20-year bond rates. On the other hand, Greek people hold far less money (-4.83) in increasing bond rates (GBR) when the maturity of bond rates gets shorter. The nonlinear ARDL model test results and its diagnostics are reported in Table 4.

Table 4. Nonlinear ARDL Model Estimation Results

Short-Run Coefficients			Normalized Long-Run Coefficients		
Variables	Model 1	Model 2	Variables	Model 1	Model 2
$\Delta \text{LogMD}2_{t-1}$	-0.18*** (0.00)	-0.11** (0.02)	LogMPU_t^+	-0.10** (0.02)	-0.16** (0.03)
$\Delta \text{LogMD}2_{t-3}$	-0.14*** (0.00)	-0.17*** (0.00)	LogMPU_t^-	-0.11** (0.02)	-0.16** (0.02)
$\Delta \text{LogMD}2_{t-4}$	0.53*** (0.00)	0.53*** (0.00)	GBR_t	-0.01*** (0.00)	-0.003** (0.01)
ΔLogMPU_t^+	-0.02*** (0.00)	0.01** (0.01)	LogIP_t	0.93** (0.01)	0.59** (0.03)
$\Delta \text{LogMPU}_{t-1}^+$	-	0.01*** (0.00)	D_{2008t}	-0.04 (0.20)	-0.10* (0.07)
ΔLogMPU_t^-	0.01*** (0.00)	-0.02*** (0.00)	D_{2013t}	-0.14* (0.09)	0.02 (0.67)
$\Delta \text{LogMPU}_{t-1}^-$	0.01*** (0.00)	-0.008* (0.08)	D_{2015t}	4.51*** (0.00)	0.23*** (0.00)
ΔGBR_t	0.009*** (0.00)	-			
ΔGBR_{t-1}	0.001*** (0.00)	-			
ECT_{t-1}	-0.003*** (0.00)	-0.02*** (0.00)			
Diagnostic Tests					
R^2	0.68	0.68	χ_{NOR}^2	60.22* (0.09)	108.84* (0.05)
$Adj. R^2$	0.66	0.65	χ_{HET}^2	38.73*** (0.31)	35.40*** (0.84)
DW	1.80*	1.84*	W_{LR}	0.004* (0.07)	0.0017 (0.50)
χ_{SC}^2	3.11*** (0.41)	5.75*** (0.41)	W_{SR}	-0.04*** (0.00)	-0.03*** (0.00)
χ_{FF}^2	0.33*** (0.56)	0.44*** (0.50)			

Note: ***, ** and * denote statistical significances at 1%, 5% and 10% levels respectively. Values in parentheses are probabilities. W_{LR} and W_{SR} are long and short-run Wald tests. DW ; Durbin-Watson autocorrelation test, χ^2_{SC} is Breusch-Godfrey LM test for autocorrelation, χ^2_{NOR} is the Jarque-Bera test for normality, χ^2_{FF} is Ramsey test for functional form misspecification, χ^2_{HET} for Breusch – Pagan - Godfrey heteroscedasticity test. All model specification test results are reliable. Model 1: 10-year bond rates. Model 2: 20-year bond rates.

The normalized long-run coefficients, in the nonlinear model, in Table 4 indicate that MPU index increases (MPU^+) and decreases (MPU^-) have significantly negative effects on demand for money ($MD2$) in Greece for both Models 1 and 2. While rises in the MPU index lead to decreases in demand for money, falls lead to increases. It should be noted that Ongan and Gocer (2021a) found the same negative relationship between demand for money and the MPU index for Japan. Furthermore, the effects of both MPU index increases and decreases on demand for money are much higher in 20-year bond rates (-0.16, -0.16) than in 10-year bond rates (-0.10, -0.11). Rises in income (IPI) lead to increases in demand for money (as expected) for both 10-year and 20-year bond rates. Rises in bond rates lead to slight decreases in demand for money. Furthermore, the sign of normalized long-run coefficients of 2015's structural break date (D_{2015_t}) for both models are significantly positive. This may show us that Greek people demanded more money with the third bailout package for Greece by the EU in 2015. This can be interpreted that this package increased the stability in Greek economy and thereby money demand.

The Wald tests in Table 4 formally confirm asymmetric effects of MPU index increases (MPU^+) and decreases (MPU^-) on the demand for money for 10-year bond rates in the long-run (Model 1). It is because, $W_{LR} = 0.004^*(0.09)$ for $GBR10$. On the other hand, the same test results for 20-year bond rates confirm symmetric effects in the long-run. It is because, $W_{LR} = 0.02(0.67)$ for $GBR20$ (Model 2).

The advantage for using this nonlinear methodology is that the relationship between Greek monetary policy uncertainty and the Greek real money balances can be asymmetric (nonlinear). Therefore,

5. Conclusion

This study examines the asymmetric effects of uncertainties in monetary policy on the demand for money in Greece. In doing so, it introduces and uses the MPU index as a very appropriate and robust explanatory variable for demand for money models. The reason for using this index is based on our assumption that demand for money is mostly determined by monetary policy-based uncertainties. This is because the effects of monetary policy implementation by central banks are expected to be seen firstly-quickly and more directly on

demand for money through money supply processes. Therefore, this assumption makes our study different from the previous empirical studies which use previously mentioned uncertainty-based variables (including the EPU index) in demand for money models. Empirical findings of this study, through the linear and nonlinear models, indicate that changes in MPU index have significant effects on demand for money in Greece. Therefore, it is believed that this index can be conveniently used in demand for money models, as an additional, successful, explanatory variable.

Additionally, the nonlinear model provides more detailed findings about the Greek people's demand for money preferences. Greek people demand less money when the MPU index rises and more money when this index falls. This leads to the interpretation that *when uncertainty increases, Greek people invest more in alternative financial instruments and/or spend their money rather than hold (demand) it (when uncertainty decreases, they invest less and/or do not spend)*. The effects of both MPU index increases and decreases on demand for money are much higher in 20-year bond rates than in 10-year bond rates. This means that *Greek people's money demand during both MPU index increases and decreases is predominantly determined by longer-term (20-year) bonds, which yield lower interest rates than 10-year bonds*. Hence, this leads to the interpretation that the effects of MPU index increases and decreases on the demand for money are higher on lower bond rates in Greece.

In conclusion, it is believed that the empirical findings of this study may help first the economic actors, including (investors) in Greece but also Greek policymakers and the Bank of Greece (BoG), to be more proactive if they understand the mechanism between the Greek monetary policy uncertainty and the Greek real money balances. This study also reveals the need for more empirical studies, which will use this index or alternative ones for future studies. These may help us better understand the actual relationships between changing uncertainties and demand for money in the related literature.

Appendix

The monthly data of the *MD2* and *GBR* were obtained from the data set of the Bank of Greece (BoG) and IMF Financial Statistics. The *IPI* and *CPI* were obtained from the data set of the Federal Reserve Bank of St. Louis. The *MPU* index was obtained from the website of www.policyuncertainty.com. The sample period of the study is between 2000M1-2019M1. Greece joined the *euro area* in January 2002. However, the European Central Bank (ECB)

adjusted the series of Greece's $M2$ for the period before January 2002, as well. This data set was used for the sample period.

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