MODELLING NONLINEARITIES IN EUROPEAN MONEY DEMAND: AN APPLICATION OF THRESHOLD COINTEGRATION MODEL

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ABSTRACT

MODELLING NONLINEARITIES IN EUROPEAN MONEY DEMAND: AN APPLICATION OF THRESHOLD COINTEGRATION MODEL

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The money demand function has been regarded as a fundamental building block in macroeconomic modelling, as it represents the link between the monetary policy and rest of the economy. The extensive literature on money demand function is concerned with the existence of a stable money demand function, which ensures adequate prediction of impact of a given change in money supply on other economic variables such as, inflation, interest rates, national income, private investment and other policy variables. This thesis employs both linear and nonlinear estimation methods to investigate the relationship between money demand, GDP, inflation and interest rates for the Euro Area over the period 1980-2010. The aim of this thesis is to compare the European money demand in linear and nonlinear framework. First a vector autoregression (VAR) model has been estimated. Then a threshold cointegration model has been employed and nonlinearity properties of the money demand relationship has been investigated. In contrast to the existing empirical literature, linear VEC model can find evidence of stability, however it has some conflicting results which can be explained by the nonlinearity of the model. Empirical results of MTAR type threshold cointegration specification verifies the nonlinearity in European money demand. The adjustment coefficient of lower regime suggests faster adjustment towards long run equilibrium compared to upper regime in nonlinear model. Moreover, the nonlinear model presents better fit to economic literature than linear model for European money demand.

Keywords: Euro Area, Money Demand, Nonlinearity, Threshold Cointegration, VECM.

ÖZ

AVRUPA PARA TALEBİNDE DOĞRUSALSIZLIKLARIN MODELLENMESİ: EŞİK EŞBÜTÜNLEŞİM MODELLERİ UYGULAMASI

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Para talebi fonksiyonu, para politikaları ile ekonominin geri kalan kısmı arasındaki bağlantıyı temsil etmesinden dolayı, makroekonomik modellemede önemli bir yapı taşı olarak kabul edilmiştir. Para talebi literatürünün önemli bir kısmı para arzına gelen bir şokun, enflasyon, faiz oranları, milli gelir, özel yatırımlar ve diğer politika değişkenlerine olan beklenen etkisini ölçmeyi sağlayan istikrarlı para fonksiyonu ile ilgilenmektedir. Bu tez çalışması, 1980-2010 döneminde Avrupa Bölgesi için para talebi, GSYIH, enflasyon ve faiz oranları arasındaki ilişkiyi ölçmek için hem doğrusal hem de doğrusal olmayan tahmin yöntemlerini kullanmaktadır. Bu tezin amacı, Avrupa para talebini doğrusal ve doğrusal olmayan çerçevede karşılaştırmaktır. Bu bağlamda, öncelikle vektör otoregresif (VAR) modeli tahmin edilmiştir. Daha sonra eşik otoregresif modeli tahmin edilmiş ve para talebi modelinin doğrusal olmayan özellikleri incelemiştir. Mevcut uygulamalı literatürün

aksine, doğrusal VEC modeli istikrarlılık belirtileri bulabilmiştir. Ancak, modelde ekonomik teori ile çelişkili, doğrusal olmayan modellerle açıklanabilen bazı sonuçlar bulunmaktadır. MTAR tip eşik kointegrasyon modellerinin sonuçları Avrupa Bölgesi para talebinde doğrusalsızlığı doğrulamaktadır. Doğrusal olmayan modelde, alt rejimin düzeltme katsayısı (ECM), üst rejime kıyasla uzun dönemde dengeye doğru daha hızlı bir hareket göstermektedir. Bu bağlamda, doğrusal olmayan model, Avrupa para talebi için ekonomik literatüre doğrusal modele göre daha iyi bir uyum göstermektedir.

Anahtar Kelimeler: Avrupa Bölgesi, Para Talebi, Doğrusalsızlık, Eşik Eşbütünleşim Modelleri, Vektör Hata Düzeltme Modeli (VECM).

to İhsan, Nuray, İsmail Korucu *and Kemal Gümüşoğlu*

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CHAPTER 1

INTRODUCTION

The money demand function has been considered as a fundamental building block in macroeconomic modelling, as it is important to connect the monetary policy with the rest of the economy. This thesis has two targets. At first, it empirically investigates European money demand nonlinearity over the period 1980-2010. Secondly, it aims to compare European money demand model in linear and nonlinear framework.

Existing asymmetries in money demand can not be represented by linear models with symmetric error distributions because such models can only generate realizations with symmetrical fluctuations, see for instance Terasvirta and Anderson (1992). One needs nonlinear models to characterize asymmetries. Nevertheless, although money demand is an old topic in economics, until recently economists have generally neglected nonlinearities in empirical money demand modelling by opting for linear time series specifications. Originally, this adherence to linearity is not on the basis of a common belief or statistical tests supporting the money demand symmetry, just only due to simplicity of the calculation of linear models in both theoretical and applied work.

Another important reason for the use of linear models is the lack of the appropriate nonlinear specifications. Given the estimation and evaluation difficulties of nonlinear models, it is not surprising that most of the empirical studies to date has focused on univariate models. More recently, attention has turned to multivariate systems. As this thesis aims to provide an empirical analysis of European money demand nonlinearity in the context of the multivariate system. The empirical literature reviewed in the thesis suggests that research on money demand should be considered within a nonlinear framework. Much of empirical studies focus on the United States and the United Kingdom. This study, in this respect, fills a gap by empirically examining the money demand nonlinearity within a set of traditional explanatory variables such as GDP, inflation and interest rates for the Euro Area.

When we examine the existing literature on money demand, besides the lack of nonlinear studies, the main objective of empirical studies is to investigate the stability of money demand function. Broadly speaking, most of the studies investigate the stability of money demand (see for example, Bruggeman, Donati and Warne, 2003; Calza, Gerdesmeier and Levy, 2001; Coenen and Vega, 2001; Golinelli and Pastorello, 2002). After 2002, the stability of money demand in Euro Area seems to be lost. Technically speaking, the empirical studies in the literature try to explain this unstability with not having the unit income elasticity which affects the cointegrating relationship in the long-run for money demand equation. To overcome this undesirable estimation results, the empirical studies try different estimation methods, cointegrating relationships with different explanatory variables, including other explanatory variables, data set and aggregation methods. The importance of monetary studies has begun to rise again after 2008 global economic crisis which still continues.

There is aggregated data availability problem before 1999. Thus, estimation of area-wide money demand function requires the aggregation of the national variables by employing different approaches. One of them to avoid aggregating problem is using other reference studies for the data set. Since there is no unique aggregation method agreed on, this thesis also opts for using an existing data set until 1999 than extend it according to the ECB and IFS database up to 2010.

Since the income elasticity of money demand is found to be higher than unity, researchers decide to include other variables than GDP as scale variables, such as wealth (see for example, Beyer, 2009; Boone and Noord, 2008; Dreger and Wolters, 2009, 2010; Greiber and Setzer, 2007; Setzer and Wolff, 2012). There are different approaches to measure the wealth variable such as housing prices (that is the most significant wealth variable), stock prices and other financial issues etc. However, including wealth variable to explain the money demand relationship creates complications due to measurement issues. Only a few countries like the UK and the

US have measures of wealth. As Arnold and Roelands (2010) states that due to the heterogeneity of housing prices and housing market developments across the European Union, the ECB should not use housing prices in policy implications. Various models and estimations techniques are employed to find stable money demand relationship. Moreover, the linear models still have some results that are not consistent with economic theory. This poor results can be attributed to data and model related issues but also adherence to linearity almost in all studies.

Laidler (1985, p.53) argues that "Keynes's analysis......suggest that money demand can not be treated as a simple, stable, approximately linear, negative relationship with respect to the rate of interest." In a world with various global economic crisis and shocks, economic literature shows that nonlinearity should not be neglected in analyzing economic variables, especially using macroeconomic variables namely GDP, exchange rate, unemployment rate, interest rate, inflation rate, finance equations and money demand[1]. The literature verifies the possible nonlinearity in macroeconomic variables. This nonlinearity should not be omitted while explaining the money demand relationship. Because the determinants of money demand, such as GDP, inflation and interest rates are found significantly nonlinear in the literature.

There are various approaches for regime switching models, first is Threshold Autoregressive (TAR) models, proposed by Tong (1977b) and detailed by Chan and Tong (1990), Tsay (1989) and Hansen (1997). TAR models specify sharp switch as a function of past values of a transition variable while its smooth transition generalisation, Smooth Transition(Auto)regressive (ST(A)R) models, allows smooth switch (See Terasvirta and Anderson, 1992; Granger and Terasvirta, 1994; Terasvirta, 1994, 1996a, 1996b). Third model is Markov Switching model by Neftçi (1982) and Hamilton (1989) which the regimes are associated with business cycle expansions and contractions while the switch between regimes is described in terms of a probabilistic function.

[1] See for example studies for GDP, Pesaran and Potter (1997); Enders, Falk and Siklos (2007); Öcal (2000); Öcal (2006); for exchange rate, Obstfeld and Taylor (1997); Sarno, Taylor and Chowdhury (2004); for unemployment, Hansen (1997); for interest rate, Tsay (1998); Sensier, Osborn and Öcal (2002); for finance, Tsay (1992); for money demand, Dreger and Wolters (2010); Wu and Hu (2007); Lutkepohl, Terasvirta and Wolters (1999); Sarno (1999); for inflation rate, Caporale and Caporale (2002).

These models have the advantage of capturing the phase-dependent properties of different shocks and fluctuations. Moreover, to analyze the responses of the series in short and medium run, the dynamic properties of the models are investigated for both linear and nonlinear framework. Unlike linear models, the impulse response function is allowed to be time varying. In other words, a current shock will have a different impact on future observations depending on the size and magnitude of the shock, as well as the history of the series, see Gallant, Rossi and Tauchen (1993), Potter (2000) and Koop, Pesaran and Potter (1996).

The specific objectives of this thesis can be listed as follows:

1. To define long span of data for Euro Area monetary aggregate and its determinants.

2. To estimate European demand for money and investigate their economic properties and their stability in linear framework.

3. To estimate European money demand in nonlinear framework and obtain dynamic effects by impulse responses. Compare and interpret them with linear models according to economic theory.

1.1 The Structure of the Thesis

The main content of the thesis is presented in Chapters 2-5. In the second chapter, we discuss the definition of monetary aggregates and theories of money demand from Fisher (1911), 'Classical Quantity Theory of Money' to Friedman (1956) 'Modern Quantity Theory of Money'. Estimation of an area-wide money demand function requires aggregation of the national variables. Cross-border monetary aggregation has both advantages and disadvantages, which are summarized in Chapter 2. We comparatively review existing studies in linear and nonlinear modelling. Our aim is at first to reveal the studies about European money demand and secondly to present the nonlinearity of the macroeconomic variables in the empirical literature. Empirical economic literature shows considerable evidence of nonlinearity. With the light of these discussions, we select the determinants of the money demand in order to employ in this thesis, namely GDP, inflation and interest rates.

Chapter 3 addresses methodologies used in the specification and estimation of money demand function focusing mainly on the vector autoregressive (VAR) model and threshold autoregressive (TAR) models for nonlinear VECM as those are employed in this thesis. The econometrics of the vector autoregressive model (VAR), its linkage with cointegration analysis and tested hypothesis according to economic theory are discussed. Cointegrated VAR modelling allows the data to determine the specifications of money demand functions given the set of explanatory variables in both long-run and short-run. Finally, our linear modelling cycle is given. Moreover, TAR models, especially MTAR type threshold cointegration models, following Enders and Granger (1998) are presented. TAR models can capture asymmetric dynamics in linear Autoregressive (AR) models. MTAR type threshold cointegration models enables us to characterize the deepness type asymmetry described in Sichel (1993), such that the series exhibits more momentum in one direction than the other. More specifically, deepness asymmetry is said to occur when throughs are sharp while peaks are relatively rounder. For economic data that sharp changes occur with high probability, and hence Momentum-TAR model can capture the asymmetric dynamics in the economy. Finally, Chapter 3 gives a brief definition of nonlinear impulse responses.

In Chapter 4, estimates of the demand for money in Euro Area are presented in linear framework. The estimated stationary long-run relationships, if any, between the nonstationary variables of the VAR model are obtained through cointegration analysis. Furthermore, a number of economic hypothesis about the behaviour of variables are tested in this context and short-run dynamics of the system is modelled. The long run and short run estimates of European money demand are compared with literature. The income elasticity of money demand is found greater than unity but relatively smaller than the ones found in empirical literature. To analyze short-run dynamics of the system, linear model presents some conflicting results according to economic theory that though GDP has positive coefficient but it has insignificant effect. Nonlinear models may give more plausible results and explain the short run dynamics of the model. Since the empirical literature on money demand focuses on the stability of the model, we check for the stability properties of the model and obtain stable relationship for European money demand over the period 1980-2010. The final part of the chapter presents the dynamic impulse responses which help to examine the responses of all variables in medium and short run. The life of shock is approximately 2 years in linear model. The response of money demand in one standard deviation shock in GDP seems negative in first quarters that conflicts with economic theory.

Chapter 5 provides the empirical results of Threshold VEC models with all variables being endogenous, and comparison with that of the linear VECM results discussed in Chapter 4. We first obtain the cointegrating vector from linear VEC model. Than test cointegrating vector for nonlinearity. After we have found evidence of nonlinearity, we estimate European money demand function by employing MTAR type threshold cointegration model. We compare different regime switching models that change according to the error correction term and all variables used in the estimation of money demand function as transition variables. The results show strong nonlinearities in all cases. The best TVECM is the one which uses first lag of error correction term as transition variable and assumes no change in short run dynamics. The adjustment coefficient of lower regime suggests faster adjustment towards long run equilibrium compared to upper regime. The life of shock is approximately 2.5 years in nonlinear model when compared to linear model which is nearly 2 years. Although the speed of adjustment towards long run equilibrium in linear and nonlinear models discussed do not show high differences, the reduced form of nonlinear specification show important differences to investigate the short-run dynamics of the model. It is also worth to note that the speed of adjustment towards long run equilibrium in upper regime is very low, that means deviations of the demand for money from its long-run equilibrium in upper regime are eliminated lower compared to other regime. The estimates of reduced form of Momentum TAR model seems more plausible and consistent with economic theory when we investigate GDP and money demand relationship. Moreover, the coefficient of GDP in nonlinear money demand model is found significant and positive which are consistent with economic theory. Furthermore, the response of money demand to one standard deviation shock in GDP and inflation seems more reasonable in nonlinear model.

Finally, Chapter 6 reviews and summarizes the findings from the earlier chapters and provides a conclusion.

This thesis is an empirical analysis of European money demand and seeks to reveal nonlinearity by modelling money demand with GDP, inflation and interest rates. It is shown that, although the linear model provides stable relationship between money demand, GDP, inflation and interest rates, linear model give conflicting results according to economic theory. The study finds that the European money demand model gives better results under the nonlinear estimation framework. Throughout the thesis, the estimated models are comprehensively elaborated on the basis of their statistical adequacy and their economic implications. We particularly focus on dynamic properties within linear and nonlinear framework by examining the models, the long run equation and impulse response functions.

CHAPTER 2

MONEY DEMAND

2.1 Introduction

The long-run relationship between money and prices has been studied for centuries as one of the main issues for policy makers (Hume, 1752). Monetary aggregates have an important role for two monetary policy strategies of the European Central Bank (ECB). One of them is about the economic analysis of the price risk in the short run while the second one is about the price stability of the monetary analysis in the medium and long run (Dreger and Wolters, 2010; ECB, 2003).

The purpose of this chapter is to define money, the demand for money and review literature. The plan of the chapter is as follows. The definition of money, theories and the determinants of money demand are discussed in Section 2.2 and different monetary aggregates are reviewed. Section 2.3 covers the definition and the structure of the European Union. The advantages and disadvantages of the aggregation methods are summarized in Section 2.4. Section 2.5 presents a brief review about the existing studies on the demand for money and nonlinearity. Finally, Section 2.6 concludes.

2.2 Money and the Demand for Money

Money plays a key role in economies for centuries. "It is certainly no exaggeration to say that, money makes the world go round and that modern economies could not function without money".[2]

[2] ECB (2011).

Instead of describing what money "is", economists deal with what money "does". As discussed in the literature, there are three major functions of money (Heijdra and van der Ploeg, 2002):

(1) as a medium of exchange

(2) as a store of value

(3) as a medium of account

Yet only the medium of exchange role is the distinguishing role of money. Any other commodity can serve as a medium of account and there are number of assets, which can be used as a store of value. These three essential roles of money provide macroeconomists the foundations for many theories of the money demand, giving rise to a transactions demand, a precautionary demand and a speculative demand for money (Goldfeld and Sichel, 1990; and Laidler, 1993). The use of money as the medium of exchange and the customary units in which prices and debts are expressed led to transaction models. These models assume that the level of transactions is known and net inflows are dealt with by others as uncertain. Moreover, money functions as a store of value and serves the purpose of preserving purchasing power. Money, being a permanent abode of purchasing power, is a convenient asset to hold, as it enables a person to avoid the time and effort which would otherwise have to be involved in synchronising market exchanges. Even though other assets can act as a store of value, they either have an uncertain nominal return because of capital gains and losses, such as equity and bond, or they involve transaction costs in order to be converted into money. Hence, the willingness to hold money could be due to the convenience and liquidity of money. Besides money is available as a unit of account, which means that prices will all be quoted in terms of money.

A monetary aggregate is defined in ECB Monthly Bulletin (1999)[3] "as the sum of currency in circulation plus the outstanding amounts of certain liabilities of financial

[3] European Central Bank Monthly Bulletin, February 1999, pp. 29-46.

institutions which have a high degree of liquidity in a broad sense".[4] The Euro system defines a narrow (M1), an intermediate (M2) and a broad aggregate (M3) of money. Detailed definitions of Euro Area monetary aggregates can be seen in Table 2.1. Narrow money (M1) includes currency such as banknotes and coins, as well as balances that can directly be converted into currency or used for cashless payments, i.e. overnight deposits, accounts, automatic transfer service accounts. Intermediate money (M2) covers narrow money (M1) together with savings and minor deposits,[5] overnight repurchasing agreements at commercial banks and non-institutional money market accounts. Broad money (M3) includes M2 plus long time deposits, repos of maturity greater than a day at commercial banks, marketable instruments issued by the Monetary Financial Institutions[6] sector. In addition, there are other monetary definitions namely, M3H, MB and MR, which are all independent from the currency of denomination. To define briefly, M**3H** is a harmonized kind of M3 broad monetary aggregate, which includes all short-run financial assets of the residents held with domestically located financial intermediaries. Other monetary aggregate **MB** includes all short-run financial assets held with financial intermediaries located in the European Monetary Union (EMU), regardless of the nationality of holder. Last monetary aggregate **MR** includes all short-run financial assets held by EMU residents, regardless of the location of the financial intermediary (Bruggeman, 2000).

The Governing Council of the ECB gives a key role to M3 in the monetary policy implications (ECB, 1999). Most of the money demand studies concerning Euro Area opt for M3 broad monetary aggregate since the ECB targets M3.[7] Fase (1994) indicates more stability in broad money than narrow money. This can be explained by M3 is not affected so much by substitution between various liquid asset categories than narrow definitions of money (M1 and M2) and is found more stable compared

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[4] For a detailed explanation of the money demand, see Goldfeld and Sichel (1990) in Handbook of Monetary Economics, Chapter 8.

[5] "Deposits with maturities of up to two years and deposits redeemable at notice of up to three months. Depending on their degree of moneyness they can be included into components of M1" (ECB, 1999).

[6] MFI.

[7] Hahn and Müller (2000).

to M1 and M2. That explains why M3 money demand definition is preferred for Euro Area studies. The components of M3 are given in Figure 2.1.

Table 2.1 Definitions of Euro Area Monetary Aggregates

Liabilities	**M1**	**M2**	**M3**
Currency in circulation	X	X	X
Overnight deposits	X	X	X
Deposits with agreed maturity up to 2 years		X	X
Deposits redeemable at notice up to 3 months		X	X
Repurchase agreements			X
Money market fund (MMF) shares/units and money market paper			X
Debt securities up to 2 years			X

Source: ECB (1999, p. 35).

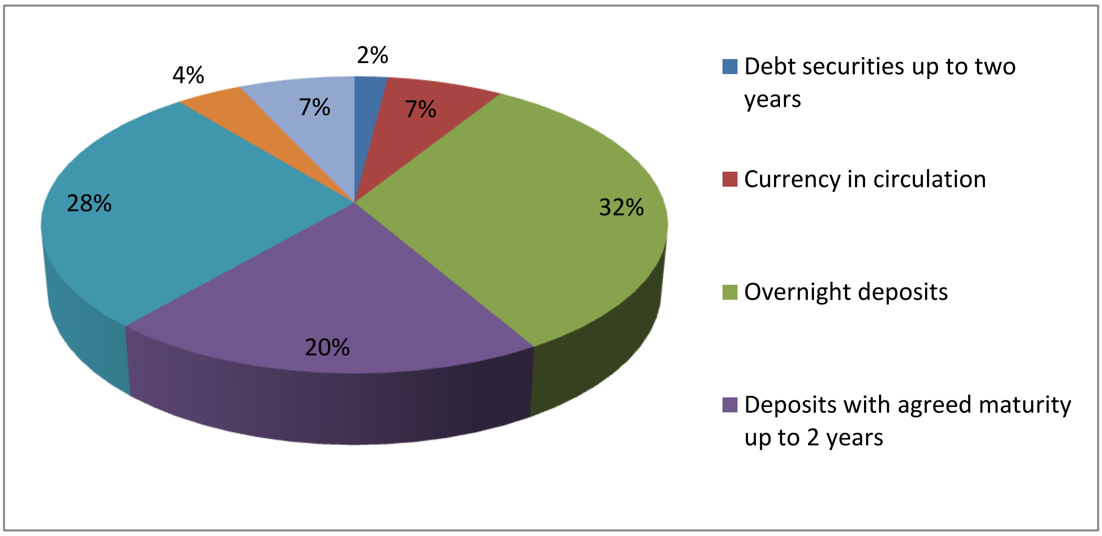

Figure 2.1 Percentage Shares of the Components of M3[8]

Source: ECB (1999, p. 36).

[8] Differences in totals of percentages are due to rounding.

2.2.1 Theories of Money Demand

According to Laidler (1993), two characteristic of money are always considered in theories that set it apart from other goods. First, money is convertible for exchanging with goods and services. Secondly, its market value is at least highly predictable, if not always stable. These two characteristics are usually called liquidity and are not exclusive properties of money. Money is the most liquid of all assets and this characteristic leads to its being demanded.

The development of modern monetary theory stretches back to the mid-eighteenth century or even earlier, though the quantity theory of money is popular until the beginnings of 1930's. The quantity theory is first used by Fisher (1867-1947). In fact, monetary theory deals with how much the individuals and the governments hold money. The oldest theory, called "classical version of the quantity theory of money", still have considerable relevance even today. Fisher (1911) gives a definition of this approach. Classical quantity theory is advanced by Alfred Marshall and Arthur C. Pigou[9] who are from University of Cambridge. Keynes (1923) is within the tradition of Marshall and Pigou, while in Keynes (1930, 1936), the Keynesian approach for demand for money is well developed. Friedman (1956) develops the classical quantity theory and conducts modern quantity theory.[10]

The main point of theories is how the demand for money response to changes in the interest rates. The velocity of money is constant, if the demand for money is not affected by interest rates, and the quantity of money is the primary determinant of nominal aggregate spending.

The first theory as mentioned in the literature is the Quantity Theory Demand for Money. The quantity theory of money has been presented by classical economists Fisher (1911) and Pigou (1917) under the classical equilibrium framework. They assume that money is neutral, with no consequences for real economic variables. The quantity theory of money emphasises the role of money as a medium of exchange,

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[9] In Pigou (1917).

[10] Laidler (1993).

stating that changes in the money supply induce proportional changes in the price level. Fisher analyze the institutional details of payment mechanism, which is known as Fisher's Equation of Exchange, which can be represented as:

$$M_S V_T \equiv PT \tag{2.1}$$

Equation (2.1) means that the value of purchases must be equal to the amount of money in circulation in the economy. Where M_s is the quantity of money, V_T is the number of times it turns over, P is the price level, and T is the volume of transactions. According to Fisher, the quantity of money, M_s, V_T and T are not dependent to the other variables. The theory discusses that the changes in money directly affect general price level. The demand for money is only based on income level and price. The demand for money is independent from interest rates in Classical Theory. The equation of exchange is an identity because it should provide that the quantity of money times how many times it is used to buy goods equals the amount of goods times their price.

Fisher considers that institutions and technology that do not change much over time, affect velocity, leading to the constant velocity assumption. Furthermore, he also believes that output Y stays constant in the short-run at its full-employment level. Hence, the quantity theory of money can be represented as follows:

$$\overline{M}_S \overline{V}_T \equiv P\overline{T} \tag{2.2}$$

Those variables with bars over are determined independently. Furthermore, the supply of nominal money is exogenously given, and in the equilibrium, the demand for money is equal to its supply. Therefore,

$$\overline{M}_S = M_d = k_T P\overline{T} \tag{2.3}$$

where

$$\overline{V}_T \equiv \frac{1}{k_T}$$

If both V and Y are constant, then changes in M_s should affect P to protect the MV and PY equality. The quantity theory of money states that a change in the money supply, M_s, causes an equal percentage change in the price level P. Fisher tries to answer the determinants of the amount of money that an economy needs to carry out for a given volume of transactions, but Cambridge economists discuss the determinants of the amount of money that an individual agent wishes to hold. Cambridge economists measure the demand for money in nominal terms varies in proportion to the price level. The major restriction of the Fisher approach is that velocity is not fixed; even in the short-run it is unstable. Thus, velocity is sensitive to changes in money supply.

Cambridge economists, Pigou (1917) and Marshall (1920) propose a different approach to the quantity theory of money, Cambridge approach which deals with the demand for money instead of supply of money. They argue that money yields utility as it is accepted as a means of exchange. They deal with the money that an individual willing to wish to hold rather than the amount that he/she has to hold. Generally, Neoclassical economists[11] in Cambridge University take a microeconomic approach that they take the effect of wealth and interest rates. Unlike the quantity theorists, the Cambridge economists allow for possible interest rate effects on the demand for money in the short-run.

Cambridge economists, particularly Pigou, assume the level of wealth, the volume of transactions and the level of income, over short term periods at least, move in stable proportions to one another (Laidler, 1993). Than, they write the demand for money as a proportion to the nominal level of income:

$$M_d = kPY \qquad \textbf{(2.4)}$$

[11] Neoclassical economists refer to Walras (1834-1910), Alfred Marshall (1842-1924) and Arthur C. Pigou (1887-1959).

where k = 1/V is the proportion of nominal income that an individual wants to hold as money. Incorporating the classical assumption of money market equilibrium,

$$M_d = \overline{M}_S \tag{2.5}$$

The Cambridge Approach leads to the quantity theory formulation. Under this approach, it is assumed that the real income Y is at full employment level, and income velocity (V) is fixed. Therefore, the price level moves proportional to the quantity of money, “money is neutral.”

Keynes recognizes the major shortcoming of the Quantity Theory of Money and argues that velocity of money is unlikely to remain the same over time. They emphasize the importance of interest rate in the money demand function. Although Fisher and Cambridge economists accept money, among other assets, as a means of exchange, Keynes assumes that money functions not only as a medium of exchange but also as a store of value. Keynes calls his theory of the demand for money “the liquidity preference theory” and distinguishes three motives for holding money that ‘a transaction motive’, a ‘precautionary motive’ and a ‘speculative motive’. Keynes lists “transactions motive” as an important factor for money demand. He also discusses the precautionary motive for holding money such as sudden emergencies caused by accidents or illness and speculative motive for uncertainty.

$$M_d = [kY + l(r)W]P \tag{2.6}$$

where the first term in brackets shows transactions and precautionary balances, and the second term represents speculative balances. The last and important motive is speculative demand for money. In this sense, the demand is an alternative asset to other interest-yielding assets. As the primary result for this theory, the demand for money depends negatively on the interest rate. Combining three separate demands for money- the transactions demand, the precautionary demand, and the speculative demand – Keynesian liquidity preference function is obtained, describing the total demand for money:

$$\frac{M^d}{P} = f(R, Y) \qquad \textbf{(2.7)}$$

$f_1<0$ and $f_2>0$, where f_i denotes the partial derivative of $f(.)$ with respect to its i^{th} argument. There is negative relationship between the demand for real money balances and nominal interest rate and positive relationship between the demand for real money balances and real income, Y (Serletis, 2007).

Friedman (1956) develops the Keynesian approach and analyzes the factors that determine how much money people hold under various circumstances. Friedman's theory is referred as the modern quantity theory, rather than the quantity theory. In contrast, Friedman (1956) does not see any motives for holding money. He assumes that money is a kind of wealth asset. He considers money as a durable good which yields a flow of non-observable services. Thus, he integrates an asset theory and a transactions theory within the context of neoclassical microeconomic theory of consumer and producer behaviour and assumes that money has abstract purchasing power[12].

He considers money as a durable good which yields a flow of non-observable services. He argued that demand for money should be treated in the same way as the demand for goods or services. Friedman (1956) categorized wealth as human and non-human wealth. Human wealth can be calculated as the present discounted value of labour income. The non-human wealth, on the other hand, consists of the individual's financial and physical assets. The demand for money is argued to be a function of the wealth and the other assets that people hold and the expected return rate. He uses permanent income as a proxy for total wealth. Accordingly, Friedman's theory of demand for money includes real permanent income, the difference of expected nominal rate of returns on bonds with money and on equity with money and expected inflation rate. In Friedman's view, when interest rates rise in the economy, other rate of returns also rise, so no change happens in the expected rates of return. Thus, interest rate changes do not affect the demand for money and the real

[12] Meaning people hold money for using for upcoming purchases of goods and services.

permanent income is the only determinant of real money demand. Friedman's money demand function can be approximated by

$$\frac{M^d}{P} = f\left(Y_p, r_m, r_b, r_e, \Delta_P^e, w, u\right) \tag{2.8}$$

where $\frac{M^d}{P}$ is the demand for real money balances; Y_p is the permanent income, Friedman's measure of wealth; r_m is expected return on money; r_b is the expected return on bonds; r_e is expected return on equity (common stock); Δ_P^e is expected inflation rate; w is proportion of human wealth and non-human wealth; u is the other factors influencing demand for money.

There is a positive relationship between demand for an asset and wealth; positive relationship between money demand and Friedman's wealth concept (permanent income), which has much smaller short-run fluctuations as many movements of income are transitory. Thus, the demand for money is not expected to fluctuate much with business cycle movements.

Friedman suggests that the function of demand for money is highly stable; implying that the quantity of money demand can be predicted.

Theoretical work on the transactions demand for money has been provided by Baumol (1952) and Tobin (1958) independently. Yet they reach to similar conclusions about it. They emphasize that the benefit of holding money is convenience and the cost is the forgone interest by not holding interest-yielding assets. They believe in the importance of transactions motive for holding monetary balances and they regard money as an inventory held for transactions purposes. The major assumptions in the model can be listed as follows: the individual receives a known lump sum cash payment of T per period and spends it all, evenly, over the period; there are only two assets, money and bonds, where bond holdings pay constant interest rate r per period and money pays zero interest; a fixed brokerage fee b (transaction costs) may be incurred when the individual sells bonds to obtain cash in equal amounts K; the key element in this inventory model is that all relevant information is known with certainty. The total transactions costs can be represented as follows:

$$TC = b\frac{Y}{K} + R\frac{K}{2} \qquad \textbf{(2.9)}$$

where $\left(\frac{Y}{K}\right)$ represents the number of withdrawals, $b\frac{Y}{K}$ is the sum of the brokerage fee, $\left(\frac{K}{2}\right)$ is the average amount of real money holdings $\left(=\frac{M}{P}\right)$, and $R\frac{K}{2}$ is the foregone interest if money is held instead of interest yielding assets.

The optimal money demand can be obtained by minimizing the total transaction costs with respect to K.

$$\frac{M}{P} = \frac{1}{2}\sqrt{\frac{2bY}{R}} \qquad \textbf{(2.10)}$$

Then the optimal demand for money depends on real income, transaction costs and interest rate. Thus, the demand for money emerges from a trade – off between transaction costs and interest earnings. However, there is uncertainty about timing of cash inflows and outflows.

2.2.2 The Determinants of the Demand for Money

The explanatory variables in the demand for money function are divided into three groups (Laidler, 1993). Firstly, there are scale variables, such as income and wealth; secondly, there are the opportunity cost variables, namely the yields on assets other than money and the yield on money. In the last group, there are the other relevant variables, such as the level of wages, the riskiness of bonds and so on. As scale variables, income and wealth are generally employed. The level of income is often preferred to measure the economy. In general, gross national product, net national product and gross domestic product variables are used to measure the income level. These variables move rather closely to each other, so that there may be no significant difference between using any of them. Instead of national income, the level of consumer expenditure can also be used. Actually, the details of main determinants of the demand for money are based on the country's financial system. There are many studies that include additional different determinants, such as oil prices and exchange rates. The demand for money means demand for real balances. Therefore, the nominal terms are converted to real terms by using an appropriate price index. This index can be a gross national product index, consumer price index or producer price index depending on the availability and the financial system of the country.

However, using a wealth variable has an important shortcoming that there is no common measurement of wealth in empirical analysis. Wealth is usually measured by expected or permanent income. Opportunity cost variables, rates of return on bills and bonds and on financial intermediaries' liabilities are discussed in detail in Laidler (1993). There are different variables used for opportunity costs of money demand such as short term interest rate, long term interest rate and own rate of monetary aggregate. Actually, there are different approaches in the literature for selecting the interest rates, interest rates differentials or the inflation rate as a proxy for the opportunity costs. The short-run interest rate can be thought of as an approximation of the own rate of return on monetary aggregate as they exhibit similar trend. In the literature, there are different approaches such as some of the studies may include three opportunity costs and they compare the spread between long-run government bond yield and own rate of monetary aggregate and the spread between short-run interest rate and own rate of monetary aggregate. While some of them consider the spread between short-run interest rate and long-run government bond yield only.

It follows that the demand for money depends positively on a scale variable such as GDP or wealth, but is negatively to the returns on assets or money and the rate of inflation. Such as:

$$\frac{M^d}{P} = f(I, R, \dot{P}) \quad \textbf{(2.11)}$$

Where M^d denotes money demand, P price level, I scale variable (GDP), R a vector of interest rates on alternatives of money (short run interest rates), $\dot{P}$ denotes the percentage change in the price level. The function is increasing in GDP (or wealth), decreasing in inflation and the elements of R. If we rewrite the equation (2.11) in logarithms (lower case variables denote the logarithms) as:

$$m^d - p = \propto + \delta gdp + \acute{\gamma} R + \beta \Delta p \quad \textbf{(2.12)}$$

where Δp denotes inflation, The parameters γ and β are negative. According to Friedman's quantity theory of money, the coefficient of scale variable (δ) is equal to one. This refers to unit income elasticity. δ takes the value 0.5 in Baumol and Tobin's transaction demand theory.[13] There are controversies in the literature about the income elasticity of the demand for money. Income elasticity can vary according to the definition of monetary aggregates. Whereas narrow money has income elasticity lower than unity, while broad money has excess unity. Especially wealth elasticities can be greater than unity (Yıldırım, 1997). In the literature, the income elasticity is significantly larger than one in some studies especially for Germany, namely Issing and Tödter (1995); Yıldırım (1997); Scharnagl (1998); Lütkepohl and Wolters (2003); for the Euro Area, see the survey in Golinelli and Pastorello (2002); Bruggeman, Donati and Warne (2003).

2.3 The European Union

In 1957, six European countries –Belgium, France, Germany, Italy, Luxembourg and the Netherlands- decide to organize a European market where people and goods can

[13] The difference in the value of the elasticity δ is only one of many differences between these two theories. Friedman and Schwartz (1982) describes Friedman's version of the quantity theory of money.

move freely. After nine more countries participate to the Union[14], the European Union (EU) is established in . In the beginnings of the Union, they have a standard of living close to the United States (Blanchard, 2003).

What to call the group of countries that join the Euro is defined in Blanchard (2003) that “Euro zone sounds technocratic. Euroland reminds some of Disneyland. Euro Area seems to be gaining favor, and this is the expression that is used in this book”. Euro Area term is commonly used also in the literature. After the common currency Euro is defined in 1999, only 11 countries participated to EMU. Common currency means a common monetary policy, which means the same interest rate across the Euro countries.

In 1991, at the EU Council meeting in Maastricht, the heads of state or government agree on a set of criteria, which would be applied to select the countries that will become the members of a single currency area, EU. These criteria concern main economic indicators such as price stability, public finances, exchange rate stability and long-term interest rates. The structure of the European Central Bank (ECB) and the first years of the ECB are detailed in Issing (2004). After seven months of the establishment of the ECB, on 1 January 1999, eleven European countries transfer monetary power to the new institution and the ECB starts to manage a new unique monetary policy[15] for the Euro Area. With the entrance of eleven countries into a new monetary community, monetary policies for these countries begin to be set by the newly-formed ECB. The main steps towards the Euro and the EU are given in Table 2.2. As can be seen from Table 2.2, the idea that the Europe should have a single, unified and stable monetary system has its roots dating back to 1962 (ECB, 2011, p. 50).

There are discussions about the data period of the European Union. It is worth to note that data period begins at the end of 1970s because the important milestone of the European Monetary System (EMS) started its operations in March 1979. After

[14] Austria, Denmark, Finland, Greece, Ireland, Portugal, Spain, Sweden and the United Kingdom.

[15] See Fischer, Lenza, Pill and Reichlin (2006) for the analysis of new monetary policy of ECB for 1999-2006.

signing the Maastricht Treaty on European Union in 1992,[16] EMU and ECB are formed in 1999. So the Euro Area data has become available only since 1999 and Euro coins and notes become available in 2002.

Table 2.2 The Road To The Single Currency, The Euro[17]

1962	The European Commission makes its first proposal (Marjolin Memorandum) for economic and monetary union.
May 1964	A Committee of Governors of the central banks of the Member States of the European Economic Community (EEC) is formed to institutionalise the cooperation among EEC central banks.
1971	The Werner Report sets out a plan to realise an economic and monetary union in the Community by 1980.
April 1972	A system (the "snake") for the progressive narrowing of the margins of fluctuation between the currencies of the Member States of the European Economic Community is established.
April 1973	The European Monetary Cooperation Fund (EMCF) is set up to ensure the proper operation of the snake.
March 1979	The European Monetary System (EMS) is created.
February 1986	The Single European Act (SEA) is signed.
June 1988	The European Council mandates a committee of experts under the chairmanship of Jacques Delors (the "Delors Committee") to make proposals for the realisation of EMU.
May 1989	The "Delors Report" is submitted to the European Council.
June 1989	The European Council agrees on the realisation of EMU in three stages.
July 1990	Stage One of EMU begins.
December 1990	An Intergovernmental Conference to prepare for Stages Two and Three of EMU is launched.
February 1992	The Treaty on European Union (the "Maastricht Treaty") is signed.
October 1993	Frankfurt am Main is chosen as the seat of the EMI and of the ECB and a President of the EMI is nominated.
November 1993	The Treaty on European Union enters into force.

[16] Anderson, Dungey, Osborn and Vahid (2008).

[17] www.ecb.int

Table 2.2 (Continued**)**	
December 1993	Alexandre Lamfalussy is appointed as President of the EMI, to be established on 1 January 1994.
January 1994	Stage Two of EMU begins and the EMI is established.
December 1995	The Madrid European Council decides on the name of the single currency and sets out the scenario for its adoption and the cash changeover.
December 1996	The EMI presents specimen Euro banknotes to the European Council.
June 1997	The European Council agrees on the Stability and Growth Pact.
May 1998	Belgium, Germany, Spain, France, Ireland, Italy, Luxembourg, the Netherlands, Austria, Portugal and Finland are considered to fulfil the necessary conditions for the adoption of the Euro as their single currency; the Members of the Executive Board of the ECB are appointed.
June 1998	The ECB and the ESCB are established.
October 1998	The ECB announces the strategy and the operational framework for the single monetary policy it will conduct from 1 January 1999.
January 1999	Stage Three of EMU begins; the Euro becomes the single currency of the Euro Area; conversion rates are fixed irrevocably for the former national currencies of the participating Member States; a single monetary policy is conducted for the Euro Area.
January 2001	Greece becomes the 12^{th} EU Member State to join the Euro Area.
January 2002	The Euro cash changeover: Euro banknotes and coins are introduced and become sole legal tender in the Euro Area by the end of February 2002.
May 2004	The NCBs of the ten new EU Member States join the ESCB.
January 2007	Bulgaria and Romania bring the total number of EU Member States to 27 and join the ESCB at the same time. Slovenia becomes the 13th Member State to join the Euro Area.
January 2008	Cyprus and Malta join the Euro Area, thereby increasing the number of Member States to 15.
January 2009	Slovakia joins the Euro Area, bringing the number of Member States to 16.
January 2011	Estonia joins the Euro Area, increasing the number of Member States to 17.

Source: ECB (2011, p. 51).

The key aspect of the ECB's monetary policy is to aim to pursue price stability over the medium term, and its importance is summarized in ECB monthly Bulletin

(January, 1999). The first argument is that price stability helps to improve the transparency of the market by avoiding distortions and allocating real resources efficiently both across uses and across time. By maintaining the price stability, the efficiency of the markets can be most effective. Second issue is to try to minimize the inflation risk in long-term interest rates by lowering long-term rates and helping to prompt investment and growth. The third point is to make certain the future price level for investments and growth. Price stability makes investment decisions efficient and eliminates real costs. The last issue pointed is that maintaining price stability avoids inconsistent distribution of the wealth and incomes that arises in inflationary as well as deflationary environments.[18]

The current economic crisis[19] in European Union shows the importance of monetary policies and the difficulties of managing different economies by identical policy and single monetary system. After World War II, the current economic crisis has the biggest impact on global economy compared to the other economic crisis and the shocks. The most effective global crisis until now is Great Depression of the 1930s. There are some significant similarities between the 1907-08, 1929-35 and 2007-2009 crises in terms of initial conditions and geographical origin.[20]

2.4 Aggregation Methods

Since the Euro is defined in 1999, no long time series data is available before 1999 for the Euro Area. To make historical Euro Area-wide series available, national data must be aggregated.

Researchers obtain the data by using several aggregation methods. However, existing methods of reconstructing historical Euro Area data by aggregation of the individual

[18] ECB (2011)

[19] For detailed information about European Economic Crisis, please see European Comission Report, Economic Crisis in Europe: Causes, Consequences and Responses, 2009, http://ec.europa.eu/economy_finance/publications/publication15887_en.pdf.

[20] European Comission Report, Economic Crisis in Europe: Causes, Consequences and Responses, 2009.

countries has several difficulties, especially due to the past exchange rate changes (Beyer, Haug and Dewald, 2009). In fact, fluctuations in exchange rates may cause bias in aggregated data. On the other hand, aggregation reduces the specification bias. Because of the trade-off between aggregation and specification bias, aggregated data may provide better estimates than single-country ones (Fase and Winder, 1998). Fagan and Henry (1998) show that aggregation bias is not a major problem. Actually, there is no unique aggregation method that is adopted by the literature for linking Euro Area pre- and post- 1999 data (Coenen and Vega, 2001).

In order to aggregate data of the individual countries, we need to convert the national currencies' data into a common currency. With the establishment of the EMU, there are many discussions in the literature about the alternative aggregation methods. There are two alternatives for converting the data, one is using the exchange rates; the other one is using the purchasing power parity (PPP) rates. Four main aggregation methods are detailed in Winder (1997):

1. Current exchange rates at each period,

2. Fixed base-period exchange rate,

3. Current purchasing power parity rate,

4. Fixed base-period purchasing power parity rate.

The use of current exchange rate or purchasing power parity rates to convert the national data into Euro, introduces an extra and unwanted component in the growth rate series (Bosker, 2003). By using the fixed base-period rates, real version of the variable is obtained. With fixed base-period exchange rates, the growth of nominal EU-output is not affected by changes of the exchange rate of the countries' currencies (Winder, 1997). There are not so much differences between choosing either fixed base- period exchange rates or fixed base-period PPP rates. However, it is recommended to try both of the aggregation methods and compare the sensitivity of the estimates. PPP rates give more smoothly estimates over time than the exchange rates estimates. Actually, the differences depend on the base year, the choice of the common currency and the variable that is aggregated such as the output, inflation rate or money demand (Winder, 1997). The Euro Area M3 data presented in the ECB is aggregated by using the fixed base-period exchange rates.

Brand, Gerdesmeier and Roffia (2002) states that “using the fixed exchange rates instead of current exchange rates avoids having very volatile aggregate series. However, especially in the short term, results using current exchange rates may mirror fluctuations in the exchange rates, rather than the sought underlying movements in the variables”. Brand, Gerdesmeier and Roffia (2002) compare two aggregation methods based on fixed exchange rates and fixed GDP weights based on PPP exchange rates.

The other aggregation method used in Brand, Gerdesmeier and Roffia (2002) is based on fixed GDP weights, where the weights are the share of the country GDP at market prices measured at PPP exchange rates. The growth rate of Euro Area wide aggregate variable is the weighted averages of the growth rates of other member countries. However, this calculation method has some shortcomings that calculated area-wide values do not satisfy the balance sheet identities.

Fagan and Henry (1998) compare two aggregation methods for national and area-wide M3H equations (current exchange rates and a fixed-weight index method) and conclude that the aggregation is not a big problem despite the marked differences in equation coefficients across countries.[21] Beyer and Juselius (2010) reestimate the monetary model in Coenen and Vega (2001) base on fixed weights using flexible real and nominal GDP weights and obtain robust results.

Detailed discussions about advantages and drawbacks of aggregation methods can be found in Winder (1997), Marcellino (2004) and Beyer, Doornik and Hendry (2000, 2001), Fagan, Henry and Mestre (2001) and Brand, Gerdesmeier and Roffia (2002). In general, aggregation of economic relationship is first examined by Grunfeld and Griliches (1960), Zellner (1962) and Pesaran, Pierse and Kumar (1989).[22]

[21] For details of aggregation methods, see Fagan and Henry (1998).

[22] Discussed in Kremers and Lane (1990).

Besides different aggregation methods, aggregating the data has many drawbacks, as listed in Marcellino (2004) and reviewed in Bruggemann and Lütkepohl (2006), that some data can not be available in desired frequency for some periods or areas; for seasonally adjusted data, there are some differences in working day adjustments within countries and the method of aggregation have an important effect. Different aggregation methods may have a substantial impact on the parameter estimates. Various aggregation methods have different remarkable estimates (Fase, 1993). A common property of aggregated money demand functions seems to be that they exhibit better stability properties compared to national data.[23]

Because there is not a unique aggregation method agreed on by the literature, there are many studies using different aggregation methods. For example, Coenen and Vega (2001) use fixed base period PPP rates for 1995 and Golinelli and Pastorello (2002) use fixed base exchange rates for 1999. In papers on aggregate Eurozone data by Beyer, Doornik and Hendry (2000, 2001) employ another aggregation method. They suggest using summation of the levels data or the growth rates and fixed or variable weights, in any combination. Bosker (2003) also compares two aggregation methods that are fixed weight level aggregation and variable weight growth rate aggregation in his study. Because the interest rates in both methods are very close to each other, the aggregations are also close to each other. However, according to the estimates, variable weight growth rate aggregation seems providing better results.

Bruggeman, Donati and Warne (2003) employ two aggregation methods and compare them.[24] First method includes two aggregation techniques that one of them convert national M3 and real and nominal GDP into Euro and then sum. While the second aggregation method is the index method discussed by Fagan and Henry (1998) such that all variables are aggregated according to weights calculated from the share of each country in Euro Area GDP at PPP exchange rates. The aggregation across countries is performed based on M3 or GDP weights. Index method is also

[23] Hahn and Müller (2000).

[24] For another alternative aggregation method, see Beyer, Doornik and Hendry (2001) who suggest using the average national growth rates as weights.

discussed in Fagan, Henry and Mestre (2001)[25]. For some variables, (for example ratios), the aggregated data is calculated by the weighted sum of the ratios. In the other hand, for some series (such as employment), it is calculated just by taking summation of the series.

Aggregating causes some problems in the data such as structural breaks. Structural breaks are an essential problem in the Euro Area. Despite all drawbacks, to employ area wide models, aggregating the data set is fundamental framework. It also smoothes the data set and increases the stability properties, though might distort nonlinear structure if any.

2.5 Existing Studies

2.5.1 Linear Models

This section of the chapter includes the review of the money demand studies. Generally speaking, the main purpose of the studies is to find a stable money demand relationship. The stability seems to be lost according to some economic fluctuations. However, the empirical studies try to investigate stability by trying different aggregation methods, estimation methods and including additional explanatory variables. Estimating a reliable, stable, at least predictable money demand function is still extremely essential for the price stability target of the ECB (ECB, 2011). Many countries follow stability-oriented monetary policy framework. For this reason, Central Banks prefer to use inflation targeting strategy.[26] Therefore, the stability is a popular subject for researchers and policy makers for decades. Because, stable equilibrium demand for money is a necessary, but not sufficient condition for monetary policies. Since the beginning of 1990s, until the beginning of 2000s, many studies find evidence of stability for European broad money demand (Golinelli and Pastorello, 2002).

[25] p.53.

[26] ECB (2011).

The majority of the money demand studies generally focus on the industrial countries such as the United States and the United Kingdom. Rose (1985), Baba, Hendry and Starr (1992), Hendry and Ericsson (1991b) and Mehra (1997) analyze the demand for money for the US while Adam (1991), Hendry and Ericsson (1991b), Hendry (1995) analyze the system for the UK.

According to the studies, the US money demand exhibits stability properties until the early 1990s. Main difference of the study of Hendry and Ericsson (1991b) is that they include a different scale variable and interest rates other than suggested by the literature. They use M1 as money aggregates; real total final expenditure as a scale variable instead of income and three-month local authority interest rate and the retail sight-deposit interest rate. They model money demand by equilibrium correction model (EqCM).[27] Ericsson, Hendry and Prestwich (1997) update the data set and model money demand in UK for more than a century. Hendry and Ericsson (1990) model the demand for narrow money (M1) for the UK and the US. Ericsson (1999) analyzes narrow money in the UK by including the inflation. Especially the studies on the UK money demand find stable relationship,[28] while the demand for money, M4, can be unstable.[29]

Elger, Jones and Nilson (2006) estimate US nominal money growth from 1992 to 2004 by applying different method[30] in addition to vector autoregressive (VAR) model, which is discussed in Chapter 3. However, their method does not give significant estimates for forecasting inflation four quarters ahead.

Berument and Taşçı (2002) investigate money-income relationship for seven OECD countries and Sims (1992) analyzes the money-income relationships for France, Germany, Japan, the UK and the US. Both of the studies include six variables to model monetary policy. These variables are short term interest rates, the exchange

[27] Hendry and Ericsson (1991b) refer to their model as ECM but technically it is an equilibrium correction model. See Hendry (1995, p.213) for the difference between the two types of models.

[28] Fisher and Vega (1993).

[29] Fiess and MacDonald (2001).

[30] Regime Switching (RS) VAR model.

rate, world level commodity prices, a money supply measure (M1), the consumer price index and industrial production. The role of targeted inflation in monetary policy of Turkey is analyzed by Berument and Taşçı (2004). They find no significant effect of targeted inflation on monetary policies for Turkey. The effect of monetary policy on long-term interest rate for the US is analyzed in Berument and Froyen (2009). Thus, inflation rate, interest rate and the income are important determinants for the monetary policies of Central Banks in the US.

The US money demand (M2) seems to be stable until the early 1990s (Carlson and Parrott, 1991; Duca, 1995; Whitesell, 1997; Dotsey, Lantz and Santucci, 2000; Carlson, Hoffman, Keen and Rasche, 2000). Due to the problems in US financial institutions, the stability seems to be lost for M2 from 2000s. Lanne and Lutkepohl (2008) also try to identify the US monetary policy shocks by using changes in volatility. Hendry and Mizon (1998) find different regimes in velocity of money and interest rates but conclude stable long-run relationship between these variables.

The demand for money is a popular subject by the Central Banks and researchers in all over the world as well as the UK and the US. There are many studies in area wide and individual manner in the literature. Studies about the other countries (Spain, Greece, Sweeden, Finland, Norway, Canada, China, Japan, South Africa etc.) are not detailed in this thesis. As this thesis focuses on European money demand, the demand for money is mostly studied for the Euro Area. Before analyzing the Euro Area studies in detailed, the studies about German economy are discussed. Germany has an essential role for the European Union therefore German economy stands for the Euro Area in some studies. When the ECB is established, it is organized and modelled according to the structure of Deutsche Bundesbank (Germany's Central Bank) (Hamori and Hamori, 2008). This may explain why early literature is based on Germany.

As in general, most of German money demand studies rely on M3,[31] (as Euro Area target M3 money definition), while Wolters, Terasvirta and Lutkepohl (1998)

[31] This may be explained as both of the Central Banks publish M3 growth as their target (Hamori and Hamori, 2008).

employ M1. For instance, Gaab and Seitz (1988)[32] estimate M1 for the period 1963:1-1985:4; Rüdel (1989) also estimates M1 for the period 1961:1-1987:4 and find stable relationship. Buscher and Frowen (1993) use both M1 and M3 money aggregates for the period from 1973:1-1987:4. Hansen and Kim (1995) also estimate both stable M1 and M3 money demand for the period 1960:1-1992:4. The stability of an EU wide money demand function can be attributed to the stability of German money demand function (Wesche, 1997a). Confirming this hypothesis, Brüggemann and Lütkepohl (2006) use German data before 1998 period standing for Euro Area data set. They conclude that the general dynamics of the estimated models for the German and the Euro Area period are quite similar. Money demand in German is more stable than all other European countries.[33] Wesche (1997a) compares the stability of money demand for group of countries[34] in Euro Area with and without Germany. Main finding of Wesche (1997a) is that money demand loses stability properties when Germany is excluded from the area aggregate data set. Three main causes of German stability is specified in Calza and Sousa (2003)[35] as "(1) the relatively early liberalisation of the financial sector; (2) the stabilising effect of price stability; and (3) the discouragement of potentially destabilising forms of financial innovation by the Bundesbank." The liberalisation of the financial sector is largely completed in Germany by the beginning of the 1970s.

Lütkepohl and Wolters (1999) utilize quarterly, seasonally unadjusted data in their study for the period 1976 to 1996 for Germany. They build a VEC[36] model for M3, GNP, inflation rate and interest rate spread variable to model opportunity costs of holding money. For the German money demand Wolters, Terasvirta and Lütkepohl (1998); Wolters and Lütkepohl (1997) find a stable equation by modelling real M3

[32] The details of the studies, Gaab and Seitz (1988); Rüdel (1989) can be found in Lutkepohl, Terasvirta and Wolters (1999) as they are in German.

[33] See Fase and Winder (1998).

[34] France, Italy, the UK and Germany.

[35] Calza and Sousa (2003) is a background study for the evaluation of the ECB's Monetary Policy Strategy.

[36] The details of the methods can be found in Chapter 3.

on real GNP, GNP deflator, long term interest rate and own rate of M3.[37] Unlikely, Lütkepohl, Terasvirta and Wolters (1999) analyze M1 money demand for German data. Scharnagl (1998) also analyzes the stability of German money demand.

Some of the studies review the literature while the others model money demand. Knell and Stix (2006) summarize almost 1000 money demand estimations. Other review studies are Fase (1994), Monticelli and Strauss-Kahn (1993), Sriram (2001), Bruggeman (1997) and Browne, Fagan and Henry (1997). Sriram (2001) presents an extensive review study about the demand for money that includes the theory, literature, functional form and the other studies categorized by their methods, variables and other determinants.

In the review studies, we can see that there are different monetary aggregates, namely M1, M2, M3, M4 that are employed according to the country's financial system. However, especially M3 is used for the Euro Area due to some properties of M3 as discussed before. Fagan and Henry (1998) analyze the long-run properties of Euro wide monetary aggregates, currency, M1 and M3H for 1981:1 to 1994:4. They compare the dynamics of different money definitions. For M3H money demand, they estimate a long run stable relationship. They find no cointegrating relationship between M1, notes and coins and other explanatory variables. Clausen (1998) also finds stable money demand functions for M1 and M3 for the period 1980-1996.

The European money demand studies especially accumulate around the end of the 1990s. Since then Euro Area money demand becomes an important issue and popular research area. The Euro Area studies treat the Euro as a single economy. Econometric analysis covering the entire Euro Area has to be modelled by using synthetic historical data for the period prior to the establishment of Monetary Union, before 1999. The historical data is obtained by aggregating the national data. The studies combine the data set before the period 1999 and after 1999. This synthetic data cause some aggregation problems that are mentioned in Section 2.4.

The first study[38] that uses aggregate demand for money in Euro Area (7 countries, namely Belgium, Denmark, France, Germany, Ireland, Italy and the Netherlands) is

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[37] $(R\text{-}r)_t$ represents the opportunity costs of holding M3 rather than longer term bonds.

the study of Kremers and Lane (1990). Actually, the group of the countries which are included in the analysis varies according to the data availability. They express a stable relationship between money demand, inflation, interest rates and the exchange rates of Euro/Dollar for narrow money (M1) including period 1979:1-1984:4.

Not aggregating but comparing 10 Euro Area countries, Arnold and Roelands (2010) model money demand using panel data for the period 1999 to 2008. They include the wealth variable to estimate the money demand, that the most significant wealth variable is housing prices. Hamori and Hamori (2008) also model M1, M2 and M3 monetary aggregates in a panel analysis framework for 1999-2006 period including eleven EU countries (Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain). They establish stability for all M1, M2 and M3 monetary aggregates.

Marcellino, Stock and Watson (2003) compare country level and aggregate data set for eleven EMU countries over the period 1982-1997. They use fifty variables of monthly data of EMU countries (excluding Greece) to forecast Euro Area aggregates by employing two different forecasting approaches that one of them uses pooled country-specific forecasts while the other one uses aggregate variables. Their findings imply better fit of the pooled and multivariate models forecasts than the forecasts from univariate models and aggregate series. Fair (1987) estimate money demand for 27 countries. They compare the estimations and find structural instability before and after 1973.

To avoid the aggregation problems, some studies do not use aggregated data set for the Euro Area. For instance, Brüggemann and Lütkepohl (2006) use German data set for proxy of Euro Area data before 1999 period. They combine quarterly German data set till 1998 period and Euro Area data for 1999-2002 period. A stable long-run money demand relation is found for the full sample period. They extend the German sample by EMU series and find that stability properties and other dynamics are the same.

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[38] Bekx andTullio (1987) estimate a model of the demand for nominal money that includes the price level, real GNP, long-term interest rates and exchange rate to capture the effect of currency substitution (Kremers and Lane, 1990).

In the literature, most of the European money demand studies analyze the stability of the model. Coenen and Vega (2001), Brand and Cassola (2000), Hahn and Müller (2000), Calza, Gerdesmeier and Levy (2001), Golinelli and Pastorello (2002) and Kontolemis (2002) find a stable M3 monetary aggregate. Hayo (1999) and Funke (2001) find both money demand definition (M1 and M3) stable. Bruggeman (2000) finds stability in EMU-wide money demand.

Fagan and Henry (1998) analyze three monetary aggregates (Currency, M1 and M3H). They use 14 EU countries except Luxembourg due to the data availability problem. They apply Hansen's (1992) three stability tests for M3H and find a stable long run relation and also a cointegrating relationship between real M3H and real income. There is no cointegrating relationship between M1 and other variables. Hayo (1999)[39] estimates a European money demand for narrow (M1) and broad (M3) money for 10 EMU countries[40] from 1964 to 1994 annually. He finds a stable money demand for Euro used both restricted and unrestricted VAR analysis.

Golinelli and Pastorello (2002) model the demand for M3 in the Euro Area for period 1980:3 to 1997:4. The comparison of all studies show that area wide money demand is more smooth and less subject to shocks than single country ones. They also find weak exogeneity in output and interest rate.

Bruggeman, Donati and Warne (2003) investigate the stability of the demand for Euro Area M3. Mainly they point out three issues, the aggregation method for the scale variables and the interest rates; the measurement of the own rate of return of M3 and the analysis of parameter constancy. They find a stable long run relationship between money and output for the period of 1981-2001. Their estimates are robust for the aggregation method and the sample.

Coenen and Vega (2001) analyze the Euro Area M3 money demand. They find cointegrating and stable relationships in the variables. Filosa (1995) investigates the

[39] I am grateful to Prof. Bernd Hayo for kindly providing his dataset.

[40] Germany, France, Netherlands, Belgium, Ireland, Austria, Finland, Italy, Spain Portugal.

stability of money demand for the period 1980-1992 in Six European Countries.[41] The money demand in the six countries is found to be stable and economically well-behaved. Yildirim (2003) investigate currency substitution in the five EU countries, which could bring instability in national money demand functions while an EU-wide money demand function could be more stable. In the paper, 5 monetary aggregates, France, Germany, Italy, the Netherlands and the UK are defined and area-wide aggregated data is obtained. Country based analysis and area wide analysis are compared. The structures of the estimates are nearly similar, except the Netherlands. They have all unit income elasticities and homogenous of degree one in prices with the exception of Germany and the area-wide aggregates.[42]

Bruggeman (2000) include four monetary aggregates for EMU countries in his study such as, M1, M3H, MB and MR.[43] All monetary aggregates are found to be stable. The study conclude that there exist a stable demand for narrow money function, both in the long-run and in the short-run for EMU-11 countries but M1 money aggregate should not be used as an intermediate target variable of monetary policy. M3H monetary aggregate can be thought as a target variable and found stable for both country groups both in the long-run and in the short-run. MB monetary aggregate can be found stable for long-run in all EU but stable only in the short-run for EMU-11 countries. Thus MB money demand can be target variable for monetary policy. While, MR money demand shows a stable long-run demand but unstable short-run demand (from 1992 onwards). Than MR money demand can not be considered as an intermediate target variable for monetary policy.

As the literature can not identify the stability properties of the money demand relationship after 2001, there has been a decline in money demand studies. Especially after 2001, the Euro Area monetary growth exceeds its target (Dreger and Wolters, 2010). This may be the reason for empirical evidence of instability. The instability might be linked to the introduction of Euro coins and banknotes after 2001. Arnold

[41] Belgium, France, Germany, Italy, the Netherlands, The United Kingdom.

[42] Detailed definition and implications of currency substitution can be seen in Yildirim (2003).

[43] Definitions of money demand aggregates are discussed in Section 2.2

(1994) states that the stability of European money demand is a statistical myth that when the Euro Area gets larger day by day, the stability seems to be lost.

Recently, there are several studies that try to examine the stability and model structure of the money demand (See for example, Belke and Czudaj, 2010; Nautz and Rondorf, 2011; Dreger and Wolters, 2010; Boone and Noord, 2008; Setzer and Wolff, 2012) especially after the European economic financial crisis, 2007.

However, during the global financial and economic crisis that starts in 2007, the stability issue gains even more interest (Belke and Czudaj, 2010) and the money demand studies begin to be more popular again. Dreger and Wolters (2010) investigate M3 money demand in the Euro Area and identify a stable long run money demand relationship for the period 1983-2004. Their paper is one of the few studies that can find stable Euro Area money demand relationship this may be due to the fact that the European Monetary System is initiated in 1983 and the financial markets of the member countries are much more integrated since then. There is a strong indication of cointegrating relation between interest rate and inflation in real money balances, real income, interest rates and inflation system. Dreger and Wolters (2010) include long and short term interest rates together in addition to money, annualized inflation rate and income. As discussed above, Brüggemann and Lütkepohl (2006) employ different data set and they find an evidence of stability. Carstensen (2004) uses the data from the EMU period and find unstable relationship for M3.

For stability properties of the demand for money, some studies include additional explanatory variables into the model or try different estimation methods. One of the most used variables is the wealth as a scale variable. However, using wealth variable creates complications due to measurement issues. Only a few countries like the United Kingdom and the United States data exist on aggregate measures of wealth (Sriram, 2001).

Beyer (2009) includes housing wealth and finds a stable relationship in M3 money demand for Euro Area for period 1980-2007. The importance of wealth for modelling money demand is presented in Gerdesmeier (1996). Greiber and Setzer (2007) include real house prices and housing wealth and obtain stable relationship.

Beyer (2009) also examines for the effect of housing wealth on money demand. Fase and Winder (1998) show the effect of wealth on money demand, M2 and M3, over the period 1971-1995 whereas no effect of wealth on M1 is found for the data of all present members of the European Union with the exception of Luxembourg. They find no effect of wealth on M1 but on M2 and M3 there is a substantial effect of wealth. A demand for M3 is found more stable than the demand for M2 and M1.

Boone and Noord (2008) also include house and share prices in the long run money demand equation. Greiber and Lemke (2005) impose uncertainty as an additional variable in their model. Calza, Gerdesmeier and Levy (2001) extend their basic model with the world oil price index as a proxy of import prices for open economies.

Beside wealth, asset prices are also used. Cassola and Morana (2002) find evidence that asset prices have important role for monetary policy mechanism in the Euro Area. They try to find out the relationships between nominal interest rates, inflation, real output, real M3 and the Euro Area real stock price index by structural VECM. de Bondt (2009) analyzes the effect of equity and labour markets on money demand. The study finds a relationship between equity and money demand through wealth effects. Housing and financial wealth appear to be statistically and economically significant for Euro Area money demand for the period 1983-2007. The study also captures the effect of precautionary motive for holding money by the unemployment rate in the Euro Area.

Almost all of the studies that find stable relationship employ the data of the pre-Euro period. Studies for EMU period (Carstensen, 2004) report instability. Thus, when EMU period is included into the analysis, there is not a unique and uncontroversial answer to the stability question.

The summary of the properties of previous empirical studies of area wide money demand functions for group of EU countries are summarized in Table 2.3. These studies are concerned with two issues: the existence of a stable money demand function for the Euro Area or a subset of EU countries, and the comparison of the estimation method of the money demand functions.

Table 2.3 Euro Area Money Demand Studies[44]

Author(s)	Sample	Monetary Aggregates	Data	Stability	Method
Artis and Beyer (2004)	1983:1-2000:4	M3	EU11	Stable	VEC
Belke and Czudaj (2010)	1980-2009/ 1995-2009	M3	Euro Area	Unstable/ Stable	ARDL
Beyer (2009)	1980-2007	M3	Euro Area	Stable	VEC
Boone and Noord (2008)	1970:1-2004:4	M3	Euro Area	Stable	VEC
Brand and Cassola (2000)	1980:1-1999:3	M3	Euro Area	Stable	VEC
Bruggeman (2000)	1980:1-1994:4	M1-M3H-MB-MR	EMU-11 EMU-15	Stable	VEC
Bruggeman, Donati and Warne (2003)	1980-2001	M3	EU11	Stable	VEC
Calza, Gerdesmeier and Levy (2001)	1980:1-1999:4	M3	Euro Area	Stable	VEC
Carstensen (2004)	1980:1-2003:2	M3	EU11	Unstable	OLS-FIML
Clausen (1998)	1980:1-1996:4	M1-M3	E10	Stable	VEC
Coenen and Vega (2001)	1980:4-1998:4	M3	EU11	Stable	ARDL/ ECM
Dedola, Gaiotti and Silipo (2001)	1982-1999	M3	Euro Area	Stable	ECM
Dreger and Wolters (2010)	1983:1-2004:4	M3	Euro Area	Stable	ECM
Fagan and Henry (1998)	1981:1-1994:4	M1-M3H-currency	EU14	Stable(not currency)	VAR
Fase and Winder (1998)	1972:1-1995:4	M1-M2-M3	EU14	Stable	VAR
Filosa (1995)	1980-1992	M3	EU6	Stable	VEC

[44] Studies are listed according to the alphabetic and chronological order.

Table 2.3 (Continued)					
Funke (2001)	1980:1-1998:4	(M1)-M3	EU 11	(Un)Stable	OLS
Golinelli and Pastorello (2002)	1980:3-1997:4	M3	Euro Area	Stable	ARDL-VAR
Hahn and Müller (2000)	1984:1-1998:2	M3	EU11	Stable	VEC
Hayo (1999)	1964:1-1994:4	M1-M3	EU11	Stable	VAR-VEC
Holtemöller (2004)	1984:1-2001:4	M3	Euro Area	Stable	VEC
Johansen and Juselius (1990)	1974:1-1987:3 / 1958:1-1984:3	M2 M1	Denmark Finland	Stable	VEC
Kontolemis (2002)	1980:1-2001:3	M3	Euro Area	Stable	VAR
Kremers and Lane (1990)	1978:4-1987:4	M1	EU7	Stable	VEC
Setzer and Wolff (2012)	2001:2008	M3	EU12	Stable	OLS
Wesche (1997a)	1973:1-1993:4	M3	EU3	Stable	VEC
Wesche (1997b)	1973:3-1993:4	M3	EU4	Stable	VEC
Yildirim (2003)	1978:1-1993:4	M3	EU5	Stable	VEC

All these findings suggest that, although there appears to be a stable (and stationary) linear combination between these variables, there is some uncertainty about the correct or true functional form. Significant amount of work is used in estimating money demand functions for both developed and developing countries and increasingly in the Euro Area as discussed in the chapter.

2.5.2 Nonlinear Models

Since 1990s, there are many studies, providing a comparative approach to linearity and nonlinearity. In this part of the chapter, the existing empirical literature about the

TAR models and ST(A)R models[45] on univariate and multivariate models are discussed.

Threshold autoregressive models have major application area in economics. Especially macroeconomic time series are modelled by using TAR models namely output growth, interest rates, prices, exchange rates, unemployment rate and finance especially stock returns.

One popular application of TAR models in economics is to GNP growth rates. Beaudry and Koop (1993) is first paper that analyzes the asymmetric effect of GNP. Potter (1995) estimates the U.S. GNP nonlinearity and finds the asymmetric effects of shocks over the business cycles by using SETAR model and concludes that economy is more stable than the Pre-1945 period. Pesaran and Potter (1997) also use TAR model to show the US GNP nonlinearity. Enders, Falk and Siklos (2007) estimate US GDP growth and add confidence intervals for the parameter estimates. They compare different confidence intervals methods and conclude that different methods lead to different results. Tiao and Tsay (1994) suggest that the U.S. GNP can be modelled as a SETAR process.

Exchange rate nonlinearity is also commonly analyzed under the framework of TAR modelling. Obstfeld and Taylor (1997); Sarno, Taylor and Chowdhury (2004) investigate exchange rate nonlinearity by using TAR models. They employ five major bilateral US dollar exchange rates to test the validity of the law of one price and find strong evidence of asymmetries.

The other macroeconomic variable is the unemployment rate. Hansen (1997) shows the U.S. unemployment rate nonlinearity for the period 1959:1-1996:7. They develop new methods to show how to test for threshold effects, estimate the threshold parameter, and formulate asymptotic confidence intervals for the threshold parameter. Rothman (1998) compares the forecasting performance of nonlinear autoregression models (six various methods namely “exponential autoregressive (EAR), generalized autoregressive (GAR), self-exciting threshold autoregressive (SETAR), smooth transition autoregressive (STAR), bilinear and time-varying

[45] The details of the methods can be seen in Chapter 3.

autoregressive (TVAR) models")[46] for the U.S. unemployment rate and concludes that nonlinear forecasts dominate the linear ones. The model that gives the best performance is EAR (exponential autoregressive) process.

As interest rates and prices are important variables for macroeconomic models, there are many studies analyzing the interest rates and the prices. Tsay (1998) applies multivariate threshold model for the US monthly interest rates. Chan and Cheung (2005) apply bivariate threshold autoregressive (BTAR) model for modelling monthly Australian interest rates. They find asymmetric structure in the interest rates. In general, the relationship between short and long run interest rates is preferred for modelling. For this term, multivariate models are chosen such as threshold VECM for both interest rates and prices. Wu and Chen (2006) apply different types of TAR specifications to model how price indices are affected from deviations of purchasing power parity (PPP) for the UK and New Zealand. They conclude that there is nonlinearity in mean-reverting adjustment toward purchasing power parity which is found sensitive to price indices.

Applications of TAR models are also very common in finance. Cao and Tsay (1992) measure the volatility of stock returns in monthly data and find evidence of nonlinearity in volatilities of large stock returns.

TAR models are also used for forecasting. Chong, He and Hinich (2008) use TAR model to forecast currency crises using a panel data set of eight Asian countries[47] from 1990 to 2003. They point out the connection between dynamics of reserves and currency crises. Clements and Smith (1997) compare the number of forecasting methods for SETAR models according to different assumptions. They analyze US growth rate and the unemployment rate. Stock and Watson (1999) and van Dijk (2011) state that forecasting performances of nonlinear models are rather poor. Van Dijk (2011) explains the possible reasons for 'forecast failure' that:

[46] The structure of these models is "state dependent" in the sense that they are sensitive to the past behaviour of the process (See Rothman, 1998 for details).

[47] China, India, Indonesia, Korea, Malaysia, Philippine, Singapore and Thailand.

a. the nonlinearity may be spurious; b. the nonlinearity may be relevant for only a small part of the observations; c. the nonlinearity ‘does not show up’ in the forecast period; d. Nonlinear models may not improve upon point forecasts, but might render superior interval and density forecasts.

Threshold models are also developed in multivariate framework and threshold cointegration models are employed. They are discussed below:

There is a growing literature about threshold cointegration models since multivariate linear models, VECMs, are so popular for decades. There are different approaches combining the linear VEC and VAR models with TAR models. Than the obtained methods are called, threshold VEC (TVEC), Threshold VAR (TVAR), Asymmetric VAR, nonlinear VAR, threshold cointegration etc. The logic of all studies is to consider different regimes with sharp changes from one to another.

This growing literature and applications can be viewed in Altissimo and Violante (1998), Baum and Karasulu (1998), Enders and Granger (1998), Martens, Kofman and Vorst (1998), Weise (1999), Balke (2000), Enders and Siklos (2001), Escribano and Mira (2002), Hansen and Seo (2002), Escribano (2003), Atanasova (2003), Seo (2004), Calza and Sousa (2006), Haug and Tam (2007), Chowdhury and Ham (2009), Lin and Liang (2010), Sarno (2001), Sarno, Taylor and Peel (2003), Becker, Osborn and Yıldırım (2010), Öcal and Yıldırım (2009), Larue, Philippe and Rancourt (2010).[48] Threshold cointegration models are used in different economic applications; such as unemployment, money demand, growth, exchange rate, inflation and finance equations.

Many studies analyze economic growth in nonlinear framework. Esso (2010) models causality relationship between energy use and growth in five African countries (Cameroon, Cote d’lvoire, Ghana, Nigeria and South Africa). He finds evidence of nonlinearity for the period pre-1988 that economic growth has a significant positive effect on energy use and this effect becomes negative after 1988 in Ghana and South

[48] A review of literature can be found in Lo and Zivot (2001).

Africa. Chowdhury and Ham (2009) examine the relationship between growth and inflation for Indonesia by taking inflation as a transition variable. Altissimo and Vilante (1998) apply a bivariate VAR model to output growth and changes in the unemployment rate for the US economy. They find nonlinearity only in the unemployment rate equation. Hecq (2009) examines unemployment nonlinearity by using threshold VAR method for Canada and the US for period 1960Q1-2004Q3.

Nakagawa (2010) analyzes the nonlinearities in real exchange rate by threshold VECM and uncovers the nonlinear adjustment. Aslanidis and Kouretas (2005) test for two-regime threshold cointegration in different markets for monthly US dollars in Greece during the period April 1975-December 1993. They find that the error correction is effective only in parallel markets for both linear and threshold VECM. The speed of adjustment is different between two regimes. Sollis and Wohar (2006) model the relationship of the real exchange rate and real interest rate for 11 countries. For six of the countries, they find evidence of nonlinear long-run relationship. Al-Abri and Goodwin (2009) consider threshold cointegration model for effective nominal exchange rates and import prices for 16 OECD countries. They find evidence of asymmetry that the responses of import prices to nominal exchange rate shocks is faster and larger. Wu and Hu (2007) find evidence of nonlinearity for broad money demand in Taiwan when the exchange rate is included in a nonlinear ECM.

In finance literature, threshold cointegration models are also used. Such as, Shen, Chen and Chen (2007) consider the asymmetry in Chinese Shanghai and Shenzhen stock markets by using asymmetric cointegration test; Chung, Ho and Wei (2005) analyze the relationship between stock prices by two-regime threshold vector error correction model. Their findings support the nonlinear relationship.

Enders and Siklos (2001) compare the nonlinear threshold cointegration test with Engle and Granger (1987) linear cointegration test. They show the asymmetry of the interest rate for the US by using M-TAR type threshold cointegration model[49]. Following the method of Enders and Siklos (2001), Öcal and Yildirim (2009) apply

[49] For M-TAR model details, see Section 3.3.2.1.

M-TAR type threshold cointegration method to defence economics. They characterize the relationship between military expenditures of Turkey and Greece by nonlinear M-TAR model. They find evidence of asymmetric adjustment between two countries.

For inflation studies, Caporale and Caporale (2002) examine asymmetric effects of negative and positive inflationary shocks on inflation uncertainty. Negative inflationary shocks have greater impact on inflation uncertainty. As the price indices are affected by purchasing power parity, the study by Heimonen (2006) support nonlinearity in purchasing power parity for Finland and Sweden by using M-TAR threshold cointegration.

Nonlinear modelling of interest rate is also quite popular in the literature. Nesmith and Jones (2008) apply a nonlinear VECM to the interest rates. They find that the system is linearly cointegrated but cointegration relations show nonlinear dynamics so the system's short-run dynamics are nonlinear.

There are also other economic models applying threshold cointegration models. Such as, Balke (2000) applies threshold VAR (TVAR) for modelling inflation, output growth, the Fed funds rate and a measure of credit market conditions in the U.S. financial markets. He finds the asymmetric effects of shocks on output in different credit regimes.

Following method used by Balke (2000), Calza and Sousa (2006) analyze the relationship of output and inflation responses with credit shocks in the Euro Area**.** They find asymmetric effects of credit shocks in the Euro Area but credit shocks are found less effective than the US, the reason is probably the features of its banking sector. Afonso, Baxa and Slavik (2011) analyze financial stability by using threshold VAR analysis. They also follow the approach used by Balke (2000). They employ quarterly data set for the period 1980:4-2009:4 for the U.S., the U.K., Germany and Italy including macro, fiscal and financial variables and investigate the possibility of nonlinear responses depending on different financial market regimes. Atanasova (2003) analyzes the asymmetries in the effects of monetary policy on output growth by employing threshold VAR (TVAR). There is evidence of asymmetry in the effects of monetary policy in the credit constrained and unconstrained regimes. In the literature, nonlinear money demand studies are growing. Gonzalez and Garcia (2006) analyze the monetary policy in Mexico by nonlinear VAR model that allows for regime shifts.

For banking sector in the Euro Area, Gambacorta and Rossi (2010) model the nonlinearities in bank lending by using asymmetric Vector Error Correction Model (AVECM). While Chong, He and Hinich (2008) use TAR model to forecast currency crises using a panel data set of eight Asian countries[50] from 1990 to 2003. They point out the connection between dynamics of reserves and currency crises. For the EU fiscal policies, the stabilization of fiscal policies become the main instrument as Bajo-Rubio, Diaz-Roldan and Esteve (2006) state. They analyze the nonlinearities in Spanish fiscal policy. They estimate government expenditures and total government revenues by using Hansen and Seo (2002) threshold cointegration approach and obtain significant nonlinear effects.

Enders, Im and Lee (2008) propose a new test for cointegration by using instrumental variables. The method is applied in a nonlinear Taylor rule in Enders, Im, Lee and Strazicich (2010). Kwon, Bozdogan and Bensmail (2009) present a new modelling and model selection criteria for threshold vector autoregressive (TVAR) models. Pitarakis (2008) obtains a new formulation by using the same framework with Caner and Hansen (2001). Caner and Hansen (2001) provide a new limit theory for exploring the presence of threshold effects in autoregressive models with a unit root.

As nonlinear time series models gain importance in analyzing the relationship among economic variables for two decades, other nonlinear time series models namely smooth transition (auto)regressive (ST(A)R) models and Markov Chain models are also used widely.

[50] China, India, Indonesia, Korea, Malaysia, Philippine, Singapore and Thailand.

ST(A)R models have smoothness properties that they do not allow sharp changes between different regimes in the economy. They are especially used for modelling GDP, consumption, interest rate and money demand. Only some studies examining money demand in the empirical literature are reviewed in this part of the thesis.

Broadly speaking, Germany that has a vital role for Euro Area economy also has nonlinearity in the demand for money.[51] That is a supporting finding for hypothesis of Euro Area money demand nonlinearity. Lutkepohl, Terasvirta and Wolters (1999) analyze German M1 money demand by applying nonlinear error correction model with smooth transition. Using seasonally unadjusted data from 1961-1990, they find a stable and linear relationship. However, after 1990 period (due to the German unification), the data shows evidence of unstability and nonlinearity. As the German data is included into the model as a proxy for the Euro Area data set in some studies (Brüggeman and Lütkepohl, 2006), the nonlinearity of German data will affect the nonlinearity properties of Euro Area data.

Besides Euro Area, other European countries are heavily influenced by German monetary policy, for example, Italy and Spain. Ordonez (2003) estimates nonlinear dynamics for broad money in Spain in the period 1978-1998 by applying ESTR model. They find instabilities in the short run and such instabilities can be due to nonlinear adjustment of real balances. Sarno (1999) examines nonlinear dynamics in the demand for money in Italy for the period 1861-1991 annually by employing nonlinear ECM based on ESTR model. The model gives more significant estimates other than alternative specifications.

The demand for money in the US and UK also show evidence of nonlinearity. Rothman, van Dijk and Franses (2001) model multivariate case of STAR analysis. They report the nonlinear relationship between money and output by applying logistic smooth transition VECM (LSTVECM) for the U.S. They suggest that money does not nonlinearly granger cause of output. Weise's (1999) paper is similar to Rothman, van Dijk and Franses' (2001) paper. Weise (1999) shows the asymmetric

[51] See Chapter 2, for German money demand studies and importance of Germany for the Euro Area.

effects of monetary policy by employing logistic smooth transition VAR (LSTVAR) analysis for the US. Weise's (1999) study is a reference study for STVEC model (Rahman and Serletis (2010) and Telatar and Hasanov (2006) also apply Weise (1999) method). They find asymmetric effects on monetary shocks for the U.S. and Turkey.

Chen and Wu (2005) examine the nonlinearity in money demand (M1 and M2) for the US and UK by using exponential STAR model in a univariate framework. They find evidence of nonlinearity in money demand series and they report that nonlinear models always provide a better fit than linear models. Haug and Tam (2007) study U.S. money demand nonlinearity for money demand definitions of M0, M1 and M2 in a single equation ESTR and LSTR framework for the long period of data from 1869-1999. Their estimates show asymmetry in post-war period after 1946. They find that linear specification of M0 provides a better fit to post-war US data than M1. The linear M0 model also passes all diagnostic tests. Unlike M0 and M1 models, for the post-war period, M2 does not give a significant money demand specification. Sarno, Taylor and Peel (2003) also estimate nonlinear equilibrium[52] correction model for the US demand of money, by using exponential smooth transition regression (ESTR) with the lagged equilibrium error correction term as the threshold variable (in a multivariate framework). They find nonlinear model to be superior to linear model.

Khadaroo (2003) analyzes UK M0 money demand nonlinearity by applying Exponential Smooth Transition Regression (ESTR) model for 1970-1997 period. They find that interest rates changes are important factor to explain fluctuations in the model of the demand for UK M_0. Choi and Saikkonen (2004) employ cointegrated smooth transition model. They employ a new method to UK M4 money demand for the period 1982-1998 and they find evidence of nonlinearity in the UK money demand function.

[52] From 1998, the term "equilibrium correction" has begun to be used in the literature instead of 'error correction' (Clements and Hendry, 1998). Since equilibrium correction term presents the idea of the adjustment in the model quit well, Sarno, Taylor and Peel (2003) use this term.

Lee, Chen and Chang (2007) model money demand nonlinearity for G-7 countries[53] by cointegrating STR methodology of Choi and Saikkonen (2004). They find non-linear cointegrating relationship. By using same approach, they examine the nonlinearity of long-run money demand for Taiwan. Their findings support the evidence of nonlinearity. Huang, Lin and Cheng (2001) also analyze the money demand for Taiwan. They employ logistic smooth transition error correction model. Their findings support the nonlinearity hypothesis for Taiwan money demand relationship. Nakashima (2009) employ cointegrating smooth transition model by Choi and Saikkonen (2004). He finds evidence of nonlinearity in Japanese money demand. Choi and Saikkonen (2010) model US money demand (M1) using smooth transition cointegrating relation for the sample 1959Q1-2000Q4.

Error correction models based on STAR framework (STAR-ECM or STECM) are originally proposed by Terasvirta and Anderson (1992) and developed more recently by Van Dijk, Terasvirta and Franses (2002). Rahman and Serletis (2010) examine the asymmetry in oil price and monetary policy developments by applying logistic smooth transition VAR (LSTVAR) model for the U.S. They conclude that the price of oil and monetary policy shocks have asymmetric effects on macroeconomic activity in the US. Terasvirta and Eliason (2001) apply nonlinear Error Correction Model as a STR type specification. They reestimate Ericsson, Hendry and Prestwich (1997) money demand model for the UK. Their model is nonlinear and performs an improvement performance.

For a comparison study, see Terasvirta, van Dijk and Medeiros (2005). They compare linear models, STAR models and neural network[54] models. They find evidence of nonlinearity in 47 monthly macroeconomic variables for G7 economies that STAR models generally outperform linear AR models. Potter (1999) reviews three basic models, TAR, STAR and Markov Switching models.

[53] Canada, France, Germany, Italy, Japan, UK and USA.

[54] The artificial neural network models are not included; see for details White (1989). For an application, see Andreou, Pavlides and Karytinos (2000) and Terasvirta, van Dijk and Medeiros (2005). For TAR-cointegration neural network model (TAR-VEC-NN), see Bildirici, Alp and Ersin (2010).

Table 2.4 Nonlinear Money Demand Studies[55]				
Author(s)	**Sample**	**Monetary Aggregates**	**Data**	**Method**
Chen and Wu (2005)	1960:1-1999:1	M1-M2	UK-US	ESTAR
Calza and Zaghini (2006)	1971:4-2003:3	M1	Euro Area	Markov-Switching ECM
Choi and Saikkonen (2010)	1959:1-2000:4	M1	US	cointegrating STR
Dreger and Wolters (2010)	1983:1-2004:4	M3	Euro Area	TAR
Gonzalez and Garcia (2006)	1993:9-2005:2	Monetary policy	Mexico	Markov-switching VAR
Haug and Tam (2007)	1869(1900)-1999 (annual)	M0-(M1)-M2	US	STR
Khadaroo (2003)	1970:4-1997:2	M0	UK	ESTR
Lutkepohl, Terasvirta and Wolters (1999)	1961-1990	M1	Germany	STEC
Nakashima (2009)	1980:1-2001:1	M1	Japan	cointegrating STR
Ordonez (2003)	1978-1998	M3	Spain	ESTR
Rothman, van Dijk and Franses (2001)	1959:1-1999:12	M2	US	STVEC
Sarno (1999)	1861-1991 (annual)	M1	Italy	ESTR
Sarno, Taylor and Peel (2003)	1869-1997 (annual)	M1	US	ESTR
Telatar and Hasanov (2006)	1990-2004	M1	Turkey	STVEC
Terasvirta and Eliason (2001)	1878-1993w	M3	UK	STR
Weise (1999)	1960:2-1995:2	M1	US	STVAR
Wu and Hu (2007)	1962:1-2003:4	M2	Taiwan	STR

[55] Studies are listed according to the chronological and alphabetic order.

The review of the previous nonlinear literature about the demand for money is detailed above and summarized in Table 2.4. This review includes the data set, methods, periods and monetary aggregates of the studies in Table 2.4. Therefore, there is a lack of the nonlinear studies about the demand for money especially on Euro Area and multivariate framework. That is why, this study aims to fill the existent gap in the literature and model the Euro Area money demand in nonlinear framework by MTAR threshold cointegration approach for 1980-2010 period.

2.6 Conclusion

For monetary policies and policy makers, a stable or at least predictable relationship between money demand, output, inflation and interest rates is important. However, this role of the monetary aggregates on monetary policies begins to decline after 2000s. With the European economic crisis after 2007, emphasis of the monetary aggregates relationship for the economy has started to become popular again. As discussed in the literature, the growth in the monetary aggregates and their relationship manage the economy. Some studies compare the Asian and European countries' economies and conclude that as the monetary aggregates have positive trend after 2007, the economies is not in a recession in Asia in contrast to Europe and US. Also stated in the literature that, in general monetary policies dominate the fiscal policies in the economies. Recently, the European economic crisis jump to other Euro Area countries. In order to end the economic crisis, monetary policies should be emphasized more.

In this chapter, we survey literature on the determinants of the money demand, which plays important role in money demand analysis, and decide the determinants to employ in our modelling procedure in the following chapters. The existing studies are analyzed for the Euro Area and other countries in linear and nonlinear framework.

After the introduction of Euro coins and banknotes in 2001, only a few studies can find a stable relationship by including additional explanatory variables or trying different estimation methods. This poor results can be attributed to data and model related issues but also adherence to linearity almost in all studies.

The recent time series literature shows an important development in nonlinear adjustment mechanism. Much of the impetus for this interest may come from a large number of studies showing that key macroeconomic variables such as real GDP, unemployment, interest rates and exchange rates display asymmetries adjustment over the course of business cycle.

According to the nonlinear literature, the findings can be summarized in two remarkable points. Firstly, the determinants of the money demand; interest rates, growth and inflation may have nonlinear pattern. Secondly, some of the important Euro Area countries (that manage the Euro Area economy, such as Germany) have nonlinear money demand relationship. These findings support the hypothesis that the Euro Area money demand may have nonlinear relationship.

CHAPTER 3

TIME SERIES MODELS

3.1 Introduction

Recent literature has witnessed a growing interest in use of both linear and nonlinear time series models in modelling economic relationships. As far as linear modelling is concerned, vector autoregression and vector error correction specifications have been used intensively in applied literature. The employment of the model is implicitly based on the assumption that data generating mechanism is symmetric.

This chapter discusses the linear and nonlinear time series models on which the empirical analyses in following chapters are based. More specifically, vector autoregression models, linear and nonlinear threshold vector error correction models are discussed. Threshold models can be used in various fields of study. Economics is only one of them. Some other examples can be seen in Tong (1983) such as radio engineering, marine engineering, steam engine, oceanography, population biology, hydrology and medical engineering.

The plan of the chapter is as follows. In Section 3.2, linear time series models that are employed in this thesis, Vector autoregressive (VAR) and Vector error correction (VEC) models are briefly summarized. Nonlinear time series models, especially Threshold autoregressive (TAR) models are reviewed in Section 3.3 within the context of this thesis. Section 3.4 concludes the chapter.

3.2 Linear Time Series Models

3.2.1 Vector Autoregressive (VAR) and Vector Error Correction (VEC) Models

In this part of the study, VAR models and the link between VAR models and cointegration analysis are discussed. VARs are used primarily in macroeconomics following the seminar paper of Sims (1980). It also appears in the microeconometrics literature (Chamberlain, 1980).[56] The model with cointegrating relationship is first used by Granger (1983). The general link between the concept of cointegration and error correction model, cointegrating VAR model is first established by Engle and Granger (1987). Gaussian approach based on maximum likelihood is developed by Johansen (1995) and his co-authors in a series of papers such as Johansen and Juselius (1990); Johansen (1988, 1991).[57] It is argued by the authors (Sims, 1980; Litterman, 1986) that VARs model would forecast better than the other structural equation models (Greene, 2003).

Several dynamic relationships can be captured using single equation time series models. However, when there are simultaneous relationships, single equation models are insufficient. In practice, many studies using contemporary time series research employ multi-equation models.[58] VAR model is the multivariate type of a single equation autoregressive model (Davidson and MacKinnon, 2004). The nature of the VAR is such that all endogenous variables are jointly determined.

A p^{th} order vector autoregression, referred as a VAR(p) model is expressed in Hamilton (1994) and Davidson and MacKinnon (2004) as:

$$Y_t = \alpha + \sum_{j=1}^{p} \phi_j Y_{t-j} + \varepsilon_t \tag{3.1}$$

[56] For a brief discussion, see Greene (2003).

[57] See for details, Warne (2006).

[58] For detailed explanations of VAR models, See Enders (2010), Chapter 5; Hamilton (1994); Davidson and MacKinnon (2004); Lütkepohl (2005).

where Y_t is an (1xn) vector of variables and denotes the t^{th} observation on a set of n variables in equation (3.1), α denotes a (1xn) vector of constant terms and ϕ_j an (nxn) matrix of autoregressive coefficients for j=1,2,………p. The (1xn) vector ε_t is a white noise series:

$$E(\varepsilon_t) = 0 \tag{3.2}$$

$$E(\varepsilon_t) = \begin{cases} \Omega & for\ t = \tau \\ 0 & otherwise \end{cases}$$

with Ω an (nxn) symmetric positive definite matrix. Thus, a vector autoregression is a system in which each variable is regressed on a constant, p lag of its own and p lag of the other variables in the VAR.

If y_{ti} denotes i^{th} element of Y_t and $\phi_{j,ki}$ denotes the ki^{th} element of ϕ_j, then the i^{th} column of (3.1) can be written as (Davidson and MacKinnon, 2004):

$$y_{ti} = \alpha_i + \sum_{j=1}^{p}\sum_{k=1}^{m}\phi_{j,ki}y_{t-j,k} + e_{ti} \tag{3.3}$$

Thus, VAR model has the form of a multivariate linear regression model as follows:

$$Y_t = \delta X_t + \varepsilon_t, \qquad \varepsilon_t \sim i.i.d.N(0,\Omega) \tag{3.4}$$

where

$$X_t \equiv [1 \quad Y_{t-1} \quad \ldots \quad Y_{t-p}] \quad \text{and} \quad \delta' \equiv [\alpha\,\phi_1\,\phi_2\,\phi_3 \cdots \phi_p] \tag{3.5}$$

The row vector X_t has $k \equiv np+1$ elements, and the matrix δ denotes [kxn] matrix.

If the disturbances are normally distributed, then least squares estimators are both the efficient Generalized Least Squares (GLS) estimator and the maximum likelihood estimator.[59] The sample log likelihood function is given as:

$$log\theta = \sum_{t=1}^{T} \log f_{Y_t|Y_{t-1},Y_{t-2},\ldots,Y_{-p+1}}(y_t|y_{t-1}, y_{t-2}, \ldots, y_{-p+1}; \theta) \qquad \textbf{(3.6)}$$

$$= -\left(T\frac{n}{2}\right)\log(2\pi) + \left(\frac{T}{2}\right) log|\Omega^{-1}| - (\frac{1}{2})\sum_{t=1}^{T} \left[(y_t - \acute{\hat{\delta}} X_t)\Omega^{-1}(y_t - \hat{\delta}X_t]\right)$$

where X_t is a [(np+1)x1] vector containing a constant term, deterministic conditioning variables and p lags of each of the elements of y. Maximum likelihood estimation of δ gives the estimated coefficient vector from an OLS regression of y_{jt} on p lags of all variables and dummy variables.

First consider the Maximum likelihood estimator (MLE) of δ:

$$\underset{[nxk]}{\hat{\delta}'} = \left[\sum_{t=1}^{T} y_t x_t'\right]\left[\sum_{t=1}^{T} x_t x_t'\right]^{-1} \qquad \textbf{(3.7)}$$

The j^{th} row of $\hat{\delta}'$ is:

$$\underset{[1xk]}{\hat{\delta}_j'} = \left[\sum_{t=1}^{T} y_{jt} x_t'\right]\left[\sum_{t=1}^{T} x_t x_t'\right]^{-1}$$

Thus, the MLE of the coefficients for the j^{th} equation of a VAR are found by OLS regression y_{jt} (Hamilton, 1994).

After the MLE of δ; the MLE of Ω at the estimate of $\hat{\delta}$[60] can be obtained by maximizing the log likelihood function (3.6), $Log(\Omega, \hat{\delta})$. The maximum value of equation (3.3) gives likelihood ratio test. Thus, consider:

$$Log(\Omega, \hat{\delta}) = -\left(T\frac{n}{2}\right)\log(2\pi) + \left(\frac{T}{2}\right) log|\Omega^{-1}| - (\frac{1}{2})\sum_{t=1}^{T} \hat{\varepsilon}_t'\Omega^{-1}\hat{\varepsilon}_t \qquad \textbf{(3.8)}$$

---

[59] Davidson and MacKinnon (2004)

[60] Where ^ denotes the maximum likelihood estimate.

The main objective of this derivation is to obtain a symmetric positive definite matrix Ω for which the equation (3.6) is large as possible. After the maximization with respect to the elements of Ω^{-1}, the value of Ω that maximizes the likelihood among the class of all symmetric positive definite matrices is given by:

$$\hat{\Omega} = (1/T)\sum_{t=1}^{T}\hat{\varepsilon}_t\hat{\varepsilon}_t' \qquad \textbf{(3.9)}$$

After the MLEs of both δ and Ω, likelihood ratio tests can be performed.

Substituting the $\widehat{\Omega}$ in eqn. (3.9) into (3.6), we obtain

$$Log(\widehat{\Omega},\widehat{\delta}) = -\left(T\frac{n}{2}\right)\log(2\pi) + \left(\frac{T}{2}\right)log\left|\hat{\Omega}^{-1}\right| - (\frac{Tn}{2}) \qquad \textbf{(3.10)}$$

This makes likelihood ratio (LR) test simple to perform. When specifying a VAR, it is important to determine how many lags to be included. It can be computed using the LR statistic. Then the null hypothesis of VAR model with p_0 lags against the alternative specification $p_1>p_0$ lags is tested. To estimate the system under the null hypothesis, a set of n OLS regressions of each variable in the system on a constant term and on p_0 lags of all the variables in the system is performed. The variance covariance matrix, $\widehat{\Omega}$, under the null and alternative hypothesis, $\widehat{\Omega}_0$ and $\widehat{\Omega}_1$, is used to perform the test. The maximum value for the log likelihood under the null hypothesis of p_0 lags is given by $\mathcal{L}_0^*$; while similarly, the maximum log likelihood under the alternative hypothesis (p_1 lag) is then $\mathcal{L}_1^*$. LR statistic is[61]:

$$(\mathcal{L}_1^* - \mathcal{L}_0^*) = T\{log\left|\widehat{\Omega}_0\right| - log\left|\widehat{\Omega}_1\right|\} \qquad \textbf{(3.11)}$$

The statistics calculated by the log likelihood ratio has an asymptotically χ^2 distribution with $n^2(p_1-p_0)$ degrees of freedom. The determination of the lag length is an important issue to restrict the number of variables in the VAR system, since each equation has the same explanatory variables. If a system of five variables is considered and four lags on each variable are imposed. Then each equation has 21

[61] Hamilton (1994).

parameters (including the intercept) to be estimated and thus would be 84 parameters to be estimated overall. This overparametrization is one of the major problems with VAR models especially for small samples (Madala and Lahiri, 2009). Likelihood ratio test statistic (LR), Akaike (AIC), Schwarz (SIC) and Hannan-Quinn (HQ) information criteria are used in determining lag length[62]. The Akaike information criterion (AIC) (Akaike, 1973) is defined as:

$$AIC(m) = log\left|\widehat{\Omega}\right| + \frac{2\mathrm{m}}{\mathrm{T}} \quad \textbf{(3.12)}$$

The Schwarz criterion (SIC) (also called Bayesian information criterion (BIC); Schwarz (1978)) is defined as:

$$SIC(m) = log\left|\widehat{\Omega}\right| + \mathrm{m}\,\frac{\log(\mathrm{T})}{\mathrm{T}} \quad \textbf{(3.13)}$$

and the Hannan-Quinn (HQ) criterion (Hannan and Quinn, 1979) is defined as:

$$\mathrm{H}Q(m) = log\left|\widehat{\Omega}\right| + 2\mathrm{m}\,\frac{\log(\log(\mathrm{T}))}{\mathrm{T}} \quad \textbf{(3.14)}$$

where m is the number of the coefficients in the model. For each criterion, one selects the order p that gives the min value, such that Information criteria,

AIC(p)= $min_{0\leq i\leq p0}\, AIC(i)$, where p_0 is a prespecified positive integer.

As can be seen in Lutkepohl (2005, p.327), in a VEC model, based on SIC and HQ no lagged differences may appear. Especially the lag order of AIC gives the highest order than HQ and SIC, SIC chooses the lowest order and HQ is in between SIC and AIC. Therefore, the HQ and SIC criteria are both consistent. Comparing the orders selected by the three criteria, $\hat{p}(AIC),\ \hat{p}(HQ)$ and $\hat{p}(SC)$, the following relations can be obtained although the sample is small of fixed size $T \geq 16$ (see Lutkepohl, 2005, p.135-155):

$$\hat{p}(SC) \leq \hat{p}(HQ) \leq \hat{p}(AIC) \quad \textbf{(3.15)}$$

[62] See for detailed description Lütkepohl (2005).

The presumption that the disturbances ε_t are stationary white noise series is only true when the variables are integrated. An (nx1) vector time series, y_t , is said to be cointegrated if each of the series is I(1) individually (nonstationary with a unit root), while the linear combination of the series is stationary, I(0). The concept of cointegration is introduced by Engle and Granger (1987). Cointegration refers to linear combination of nonstationary variables. Since the linear combination $y_{1t} - \phi_1 y_{2t} - \phi_2 y_{3t} = e_t$ is stationary, then it can be said that $y_t = (y_{1t}, y_{2t}, y_{3t})'$ is cointegrated with the cointegrating vector $(1, -\phi_1, -\phi_2, -\phi_3)$. Cointegrating relationship in money demand equation is one of the necessities of a stable money demand model. As stated in Dreger and Wolters (2010) most of the studies can not find evidence of stability, as there is no evidence of cointegrating relationships in the model.

Recent empirical studies of money demand usually employ cointegration and error correction analysis to estimate short-run and long-run dynamics. Since the Engle-Granger modelling approach assumes there can only be one cointegrating relation, this may cause misleading results. However, if there are more than two variables, there may be more than one cointegrating relationship. Johansen method enables to find out the number of cointegration vectors and select the optimal one. Therefore, Johansen (1995) method is employed in this study. Johansen (1995) suggests employing unconstrained vector autoregression method by estimating all cointegrating relationships among a set of variables.

Cointegration implies a set of testable restrictions on the coefficients in the model. When the variables are cointegrated, the error correction term has to be included in the VAR model then the model becomes Vector Error Correction Model (VECM). In general representation of n variable VECM:[63]

$$\Delta Y_t = \phi D_t + \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \varepsilon_t \qquad \textbf{(3.16)}$$

[63] See Johansen (1991), pp. 1552; Johansen (1992), pp. 390; Johansen (2000), pp. 362; Johansen and Juselius (1990), pp. 170 for details.

Where $\Pi = \alpha\beta'$, α and β are nxr matrices that $r \leq n$. β is a matrix of cointegrating vector while n is the number of variables and r is the number of cointegrating relations (cointegrating rank), moreover each column of β is a cointegrating vector and α is the adjustment matrix. The deterministic dummies, $D_{t,}$ can be a constant, a linear term, seasonal dummies or other deterministic terms. the ε_t are i.i.d. $N_n(0, \Omega)$. If all elements of Π equal zero, than equation (3.16) is a traditional VAR in first differences. If the variables are nonstationary at I(1) level and cointegrated, CI(1), it gurantees that an error-correction model exists. A cointegrated system can be viewed as a restricted form of a general VAR model. An error correction model can capture short run behaviour while the cointegrating regression describes long-run relationships.

Since the VEC models allow modelling endogenous variables and imposing the restrictions, it is widely used and preferred in economic literature (restrictions within the context of money demand function are discussed in Chapter 4). Because cointegration implies certain restrictions on the VAR representation and enables the researcher to test some economic hypothesis. It can be seen in the review of the money demand studies in Chapter 2 that almost all of the studies prefer VEC model to analyze money demand relationship and other macroeconomic variables. The economic literature posits that, VEC models have a vital role in modelling the demand for money (Examples of the money demand studies can be seen in Hendry, 1995; Yildirim, 2003; Lütkepohl and Wolters, 1999; Calza, Gerdesmeier and Levy, 2001; Berument and Taşçı, 2002; Cassola and Morana, 2002 and many others as given in Table 2.3 in Section 2.5).

Some of the studies employ a single-equation error correction representation of the money demand model (Coenen and Vega, 2001) while the others model the demand for money within a system of equations (Brand and Cassola, 2000; Calza, Gerdesmeier and Levy, 2001; Hendry, 1995). Belke and Robert Czudaj (2010) compare single equation methods (ARDL)[64] with Cointegrated VAR methods. They can find stability in single equation models. The system estimation is more flexible

[64] See for details of Autoregressive distributed lag model (ARDL), Pesaran, Shin and Smith (1999). The model has the advantage thatit does not require all variables to be I(1) as the Johansen framework.

to uncover the long-run relationships among monetary and financial variables. Calza, Gerdesmeier and Levy (2001) argue that the demand for M3 in the Euro Area should be modelled using a system of equations rather than in a single-equation framework. It is therefore that most of the empirical literature prefers system specification in modelling money demand.

3.2.2 Unit Root Test

In order to observe the economic and stability properties of the European money demand, a four equation VAR model is considered. Before applying the framework and carrying out a forecasting procedure, the relevant data is required to be tested for presence of stationarity. Linear stationary can be tested by using the Augmented Dickey-Fuller (ADF) test, Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test and Phillips and Perron test. The Unit Root Test results can be seen in Chapter 4, Table 4.1.

ADF and Phillips-Perron tests assume unit root (nonstationary) under the null hypothesis while the KPSS test assumes stationarity. The ADF test procedure can be outlined as follows:

First, consider following simple long-run regression model:

$$Y_t = \alpha + \beta X_t + \varepsilon_t \qquad \textbf{(3.17)}$$

where ε_t is white noise error term. To test for nonstationary of Y_t, consider the following model:

$$\Delta Y_t = \alpha_0 + \rho_1 Y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta Y_{t-i+1} + u_t \qquad \textbf{(3.18)}$$

where Δ is the difference operator, p is the number of lags of the dependent variable and u_t is the i.i.d. disturbance term with mean zero, $u_t \sim i.i.d.(0, \sigma^2)$. Lag order p in

ADF test can be selected by using Information Criteria such as Schwarz Information Criterion (SIC), Akaike Information Criterion (AIC) and Hannan-Quinn Criterion[65].

In Unit Root Test Results in Table 4.1, lag orders in the ADF tests are selected by SIC. Generally speaking, they can be selected commonly by SIC or AIC in empirical studies. Note that, test results are also hold when the lag orders are chosen by AIC.

The procedure is testing a null hypothesis of unit root against an alternative of stationary.

$H_0 : \rho_1 = 0$, *series contains unit root (nonstationary)*

$H_0 : \rho_1 < 0$, *series is stationary*

The ADF test is the most commonly used unit root test. The models in unit root tests can include both trend and intercept or only intercept. In this study, all results for levels verify significantly nonstationary that only the models with intercept are presented in Table 4.1 in Chapter 4.

To sum up, modelling cycle of Linear VEC Model can be outlined as follows:

I. Select relevant variables for your model, form the system of y_t vector according to the relevant economic framework or theory.

II. Test for unit roots to ensure that all the variables in y_t vector are integrated of order one. This can be mainly checked by ADF test.

III. Determine the order (p) of the VAR model by using model selection criteria, such as Akaike Information Criterion, Schwarz Bayesian Information Criterion, LR tests or Hannan-Quinn Criterion.

IV. Decide the deterministic components, such as dummies of the underlying VAR and check for the diagnostics of test results.

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[65] The formulas of the information criteria are given in Section 3.2.1 briefly.

V. Determine the cointegration rank and estimation. The trace and maximum eigenvalue tests proposed by Johansen (1995) can determine the cointegration rank.

VI. Identify the cointegrating relationships. Impose the identifying restrictions which are determined by economic theory on cointegrating relations in order to have unique cointegrating vectors.

VII. Estimate VEC model to have the long-run relationship of the variables. Than, Parsimonious VAR model is estimated to enhance its interpretability and reduce its sample dependence (Hendry, 1995). The short-run parameters are presented according to Full Information Maximum Likelihood (FIML) estimates. Finally, all model diagnostic statistics are checked.

VIII. Next step, to examine the stability properties of the model, CUSUM and CUSUMSQ tests are applied (Enders, 2010).

IX. Last step of linear modelling cycle is to analyze impulse response functions (IRFs) to examine the dynamic effects. IRFs present short and medium-run effects of a shock on a given variable on all other variables in the cointegrated system.

3.3 Nonlinear Time Series Models

This part of the study presents one of the popular nonlinear time series models,[66] threshold autoregressive (TAR) and threshold cointegration models which are employed in this study.

Brief literature on nonlinear studies can be seen in Chapter 2, which smooth transition (auto)regression (ST(A)R) models[67] are used commonly in empirical money demand studies.

[66] They are all about continuous time series, for modelling discrete, binary time series see Tagore and Sutradhar (2009).

[67] STAR models are developed by Chan and Tong (1986a) as an extended version of TAR models. The details of STAR models can be found in Granger and Terasvirta (1993) and Terasvirta (1994, 1996a, 1996b, 1998). A two-regime STAR model STAR (2; p, p) is given by

3.3.1 Threshold Autoregressive (TAR) Model

TAR models are first introduced by Tong (1977b) and discussed in Tong (1978). The details can be found in Tong (1983, 1990), Tong and Lim (1980), Chan and Tong (1990), Tsay (1989, 1991). Tsay (1989) presents a simple widely applicable procedure for TAR models.

TAR models reveal the asymmetries in linear Autoregressive (AR)[68] and Autoregressive Moving Average (ARMA) Models. Actually if ARMA model contains nonlinearity than it is called TARMA (Threshold Autoregressive Moving Average) model means ARMA model with more than one regime (Tong and Lim, 1980). Unlike linear AR models, TAR models can capture asymmetric dynamics. Tong and Lim (1980) show that the class of TAR models can capture limit cycles in the modelling of business cycle asymmetries.

A two regime Self-Exciting Threshold Autoregressive (SETAR) (2; p, d) model takes the form:

$$y_t = I_t\left[\alpha_0 + \sum_{i=1}^{p}\alpha_i y_{t-i}\right] + (1-I_t)\left[\beta_0 + \sum_{i=1}^{p}\beta_i y_{t-i}\right] + \varepsilon_t \qquad \textbf{(3.19)}$$

where $I_t(.)$ is an indicator function such that:

$$I_t = \begin{cases} 1, y_{t-d} > \tau \\ 0, y_{t-d} \le \tau \end{cases} \qquad \textbf{(3.20)}$$

where p denotes the AR order, d is the threshold lag and positive integer (called the delay parameter by Tong), and τ denotes threshold value that takes the value of

$$y_t = \theta_{10} + \sum_{i=1}^{p}\theta_{1i} y_{t-i} + \left[\theta_{20} + \sum_{i=1}^{p}\theta_{2i} y_{t-i}\right]F(y) + \varepsilon_t$$

where $\varepsilon_t \sim i.i.d.(0,\sigma^2)$ and F(y) is the transition function between regimes 1 and 2. The transition function (F(y)) can be exponential function or logistic function.

[68] See Enders (2010) for linear time series models (AR, ARMA and MA).

$-\infty < \tau < \infty$. The parameters α_i are the autoregressive slope when $y_{t-d} > \tau$, and β_i are the slopes when $y_{t-d} \leq \tau$. I_t is an indicator function or dummy variable that takes the value of 1 if y_{t-d} is above the threshold and takes the value of 0 if y_{t-d} is below the threshold.

y_{t-d} is the transition variable which can be chosen from inside or outside of the model, such as the own lagged values of y_t, another regressor or linear combination of different variables. In eqn. (3.19), transition variable is chosen as own lagged values of y_t, that explains why the model is called Self-Exciting Threshold Autoregressive (SETAR) model.

The equation (3.19) can be extended to k threshold form SETAR (k; p, d) where k is the number of regimes separated by k-1 nontrivial thresholds r_j in equation (3.21) below.

$$y_t = \alpha_{10}^{(j)} + \sum_{i=1}^{p} \alpha_{1i}^{(j)} y_{t-i} + \varepsilon_t^{(j)}, \qquad if \qquad y_{t-d} \in R^j, \qquad j = 1,........,k \qquad \textbf{(3.21)}$$

where $R^{(j)}$ are given thresholds which divide the real line R^j into k regimes. Actually, TAR model allows for a number of different regimes with separate order AR(p) process in each regime. Although Y_t is linear in each regime, the possibility of regime switching implies that the entire sequence is nonlinear and therefore TAR model can be said to be a piecewise linear autoregressive model. Since it follows a linear pattern, an appropriate estimation method is ordinary least squares (OLS).

Three estimation approaches in TAR models are suggested in the literature namely Tsay's (1989) and Chan's (1993) methods and Hansen's (1997) procedure.

The specification of the delay parameter, threshold variable and lag order plays a key role in TAR modelling process.

Chan (1993) and Tsay (1989) methods to test and estimate TAR models are based on the arranged autoregression and can be outlined as follows:

1. Determine the order of autoregression, p, of AR(p) model using AIC, SIC, PACF or LM test.
2. Assume that $1 \leq d \leq p$, in other words each lagged variable can be transition variable. Ascendingly, order the transition variable and other variables with respect to ordered transition variable to keep the original dynamic relationship among variables.
3. Chan (1993) suggests 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.
4. Tsay (1989) proposes recursive estimation method both for testing and modelling TAR model for arranged data. First, estimate a TAR model buy using a small subsample of the data set and compute the predictive residual with its standard error and save estimated coefficients and their t-ratios. Use recursive least square method to update the least square estimates by adding a new observation and re-estimating the model. Again, compute the predictive residual with its standard error and save estimated coefficients and their t-ratios. Apply this procedure until all observations are used up. Than, regress standardized predictive residuals on regressors and use F test to test the null hypothesis that the coefficients of all regressors are equal to zero. Because predictive residuals must have no correlations with regressors if there is no model change in the arranged autoregression. This test avoids nuisance parameter problem that may be encountered in LR test and is suggested to be applied for all possible transition variables. To locate the threshold value, use the scatter plot of standardized predictive residuals versus transition variable Y_{t-d} as the predictive residuals are biased at the threshold, if there is any, and so uncover the location of threshold. Moreover, if a coefficient is significant and show no change then corresponding t-ratio gradually and smoothly converges to a fixed value as the recursion continues, so scatter plot of t-

ratios of recursive estimates of an AR coefficient versus Y_{t-d} could also show the location of the threshold and whether the relevant variable is subject to regime change or not.

5. After determining the transition variable and threshold value, the estimation turn out to be estimation of a switching regression model and OLS can be used.

Hansen (1997) 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. His procedure is as follows,

1. Carry out a grid search for all possible threshold values to find the best TAR and save its variance.
2. Estimate the linear model and keep its variance
3. Use F test to compare the two models by using the F table values derived from bootstrapping process.

Both Chan's and TSAY's approach are used in applying Enders and Granger (1998) model in this thesis.

3.3.2 Threshold Cointegration Models

Threshold cointegration techniques allow modelling cointegrated systems in a multivariate nonlinear framework. Asymmetry in cointegrated models is first introduced by Balke and Fomby (1997) and it is called *threshold cointegration* to combine nonlinearity and cointegration. A two-regime vector error correction model can be written as (Hansen and Seo, 2002):

$$\Delta y_t = \begin{cases} A_1' Y_{t-1}(\beta) + \varepsilon_t & if \quad z_{t-1}(\beta) \le \tau, \\ A_2' Y_{t-1}(\beta) + \varepsilon_t & if \quad z_{t-1}(\beta) > \tau \end{cases} \qquad \textbf{(3.22)}$$

where Y_t be a p-dimensional I(1) time series which is cointegrated with one px1 cointegrating vector β. Let $z_t(\beta) = \beta' x_t$ denote the $I(0)$ error-correction term. τ is the threshold parameter and the threshold effect is in the error correction term, the regressor $Y_{t-1}(\beta)$ is [(p+2)x1] vector such as:

$$Y_{t-1}(\beta) = \begin{bmatrix} 1 \\ z_{t-1}(\beta) \\ \Delta y_{t-1} \\ \Delta y_{t-2} \\ . \\ . \\ \Delta y_{t-p} \end{bmatrix} \qquad \textbf{(3.23)}$$

The equation (3.22) can be also written as

$$\Delta y_t = A_1' Y_{t-1}(\beta) d_{1t}(\beta,\tau) + A_2' Y_{t-1}(\beta) d_{2t}(\beta,\tau) + \varepsilon_t \qquad \textbf{(3.24)}$$

where

$$d_{1t}(\beta,\tau) = \mathrm{I}(z_{t-1}(\beta) \le \tau),$$
$$d_{2t}(\beta,\tau) = \mathrm{I}(z_{t-1}(\beta) > \tau)$$

$I(.)$ denotes the indicator function. Threshold model in (3.24) has two regimes and allows all coefficients (except the cointegrating vector β) to switch between these two regimes, the coefficient matrices A1 and A2 govern the dynamics in these regimes (Hansen and Seo, 2002).

When the cointegrating vector is known, Balke and Fomby (1997) suggest the application of the univariate tests of Hansen (1996) and Tsay (1989) to the error correction term (the cointegrating residual). Balke and Fomby provide a theory for known cointegrating vector. Lo and Zivot (2001) extend Balke and Fomby (1997) approach to a multivariate threshold cointegration model with a known cointegrating vector, using the tests of Tsay (1998) and multivariate extensions of Hansen (1996). Balke and Fomby (1997) focus on univariate estimation and testing methods while Hansen and Seo (2002) test for the complete multivariate threshold model. Hansen and Seo (2002) also extend this literature by examining the case of unknown cointegrating vector.

Hansen and Seo (2002) test the null hypothesis of a linear cointegration against an alternative of a threshold cointegration by using LM statistics. LM statistic is preferred, as it does not require the distribution theory for the parameter estimates of the unrestricted model like the Wald or the likelihood-ratio tests. Their method involves a joint grid search over the threshold and the cointegrating vector.

3.3.2.1 M-TAR Type Threshold Cointegration

Enders and Granger (1998) propose a unit root test against an alternative of stationary with asymmetric adjustment and introduce the momentum threshold autoregressive (M-TAR) model. Following Enders and Granger's (1998) study, Enders and Siklos (2001), Enders and Dibooğlu (2001) and Öcal and Yıldırım (2009) employ this technique and show the evidence of asymmetric long-run relationship in their analysis.

The general M-TAR type threshold cointegration model can be written as:

$$\Delta y_t = \alpha + \sum_{i=1}^{p}\sum_{j=1}^{n}\beta_{ji}\Delta Y_{t-i} + \rho_1 I_t \hat{\varepsilon}_{t-1} + \rho_2(1-I_t)\hat{\varepsilon}_{t-1} + v_t \tag{3.25}$$

where the Heaviside indicator function is as follows:

$$I_t = \begin{cases} 1, \Delta\hat{\varepsilon}_{t-1} \geq \tau \\ 0, \Delta\hat{\varepsilon}_{t-1} < \tau \end{cases} \quad \textbf{(3.26)}$$

τ is the threshold value, $v_t \sim i.i.d.(0, \sigma^2)$, $\hat{\varepsilon}_{t-1}$ denotes the $I(0)$ error correction term, ρ_1 and ρ_2 give the speed of adjustment coefficients for two regimes, p is the lag order of the model and n is the number of regressors, where Y_{t-i} is (1xn) vector of $I(1)$ variables. The threshold value can be estimated by Chan (1993) method, see for details of the method in Section 3.3.1. To be more specific, if threshold variable, $\Delta\hat{\varepsilon}_{t-1}$ is ascendingly ordered and M-TAR models are estimated for each threshold value and sum of squared residuals (SSR) are obtained. The threshold value that gives the minimum SSR presents the consistent estimation of the threshold value.

The threshold specification within the framework of money demand considered in this study can be given as follows:

$$\Delta(m-p)_t = \beta_{01} + \sum_{i=1}^{p} \beta_{1i}\Delta(m-p)_{t-i} + \sum_{i=1}^{p} \vartheta_{1i}\Delta gdp_{t-i} + \sum_{i=1}^{p} \delta_{1i}\Delta^2 p_{t-i} + \sum_{i=1}^{p} \gamma_{1i}\Delta R_{t-i}^{s} + \sum_{t=1}^{k} D_t + \rho_{01} I_t \hat{\varepsilon}_{t-1} + \rho_{02}(1-I_t)\hat{\varepsilon}_{t-1} + v_{0t} \quad \textbf{(3.27)}$$

$$\Delta gdp_t = \beta_{02} + \sum_{i=1}^{p} \beta_{2i}\Delta(m-p)_{t-i} + \sum_{i=1}^{p} \vartheta_{2i}\Delta gdp_{t-i} + \sum_{i=1}^{p} \delta_{2i}\Delta^2 p_{t-i} + \sum_{i=1}^{p} \gamma_{2i}\Delta R_{t-i}^{s} + \sum_{t=1}^{k} D_t + \rho_{11} I_t \hat{\varepsilon}_{t-1} + \rho_{12}(1-I_t)\hat{\varepsilon}_{t-1} + v_{1t}$$

$$\Delta^2 p_t = \beta_{03} + \sum_{i=1}^{p} \beta_{3i}\Delta(m-p)_{t-i} + \sum_{i=1}^{p} \vartheta_{3i}\Delta gdp_{t-i} + \sum_{i=1}^{p} \delta_{3i}\Delta^2 p_{t-i} + \sum_{i=1}^{p} \gamma_{3i}\Delta R_{t-i}^{s} + \sum_{t=1}^{k} D_t + \rho_{21} I_t \hat{\varepsilon}_{t-1} + \rho_{22}(1-I_t)\hat{\varepsilon}_{t-1} + v_{2t}$$

$$\Delta R^{s}{}_t = \beta_{04} + \sum_{i=1}^{p} \beta_{4i}\Delta(m-p)_{t-i} + \sum_{i=1}^{p} \vartheta_{4i}\Delta gdp_{t-i} + \sum_{i=1}^{p} \delta_{4i}\Delta^2 p_{t-i} + \sum_{i=1}^{p} \gamma_{4i}\Delta R_{t-i}^{s} + \sum_{t=1}^{k} D_t + \rho_{31} I_t \hat{\varepsilon}_{t-1} + \rho_{32}(1-I_t)\hat{\varepsilon}_{t-1} + v_{3t}$$

where D_t captures the seasonal and other types of the dummies, k denotes the number of the dummies. The indicator function is as given in eqn. (3.26).

Equation system in (3.27) implies an asymmetric adjustment in the long run in each equation though constant coefficients are presumed in the short run across the distinct regimes.

There are other three types of the Heaviside indicator function in (3.26) that are discussed in Enders and Granger (1998). First one is called TAR models with indicator function such as:

$$I_t = \begin{cases} 1, \hat{\varepsilon}_{t-1} \geq 0 \\ 0, \hat{\varepsilon}_{t-1} < 0 \end{cases} \tag{3.28}$$

The equation (3.27) with indicator function (3.28) assumes the long-run equilibrium point around $\hat{\varepsilon}_{t-1} = 0$. However, the long-run equilibrium may be around a threshold value, and should be estimated using Chan (1993) method to have consistency and model is called consistent TAR model.

$$I_t = \begin{cases} 1, \hat{\varepsilon}_{t-1} \geq \tau \\ 0, \hat{\varepsilon}_{t-1} < \tau \end{cases} \tag{3.29}$$

The model (3.27) with indicator function (3.29) gives the consistent TAR model.

As the economic series usually have unexpected shocks, taking the first difference of threshold variable helps to capture the possibility of asymmetrically “sharp” movements in the series. Then, the indicator function takes the form of:

$$I_t = \begin{cases} 1, \Delta\hat{\varepsilon}_{t-1} \geq 0 \\ 0, \Delta\hat{\varepsilon}_{t-1} < 0 \end{cases} \tag{3.30}$$

The indicator function (3.30) is preferred when the adjustment is asymmetric with the series present more ‘momentum’ in one direction than the other. That is why the model (3.27) with the indicator function (3.30) is called momentum threshold autoregressive (M-TAR) models.

As pointed out in Enders and Granger (1998), Enders and Siklos (2001) and Öcal and Yıldırım (2009), the momentum model can be used to represent Sichel's (1993) notion of 'sharpness'. Sichel (1993) discusses the 'sharp' versus 'deep' cycles called 'steepness asymmetry'. In 'deepness' asymmetry, the troughs are sharp while peaks are relatively rounder. However, in steepness asymmetry, the falls are rapid while the increases are slow (Öcal and Yildirim, 2009).

This momentum property of TAR models enables to characterize the deepness-type asymmetry described in Sichel (1993). For economic data that sharp changes occur with high probability and hence Momentum-TAR model can capture the asymmetric dynamics in the economy. Equation system (3.27) with indicator function eqn. (3.26) delivers Momentum Threshold VEC model. We also consider this model and obtain satisfactory results which are discussed in Chapter 5.

3.3.3 Nonlinear Impulse Response Functions

After having found asymmetry in money demand function, it is important to characterise the dynamics in nonlinear framework. In contrast to the linear models, nonlinear impulse responses are history dependent and magnitude of the shock can change the time profile of the responses. Hence, different shocks hitting the system in expansion or recession do not have symmetric responses. Potter (2000) investigates the univariate case of impulse responses by extending standard linear IRFs to nonlinear case by defining GIRFs.[69] While Koop, Pesaran and Potter (1996) develop multivariate case.

Impulse response functions (IRF) that measure the effect of an exogenous shock (ε_t) on the conditional expectation of Y_{t+k} is as follows:

[69] For example studies; See Beaudry and Koop (1993), Calza and Sousa (2006), Balke (2000) and Becker, Osborn and Yildirim (2010).

$$E\left[Y_{t+k}\middle|\Omega_{t-1},\varepsilon_t]-E[Y_{t+k}\middle|\Omega_{t-1}\right] \quad \textbf{(3.31)}$$

where Ω_{t-1} is the information set (history variables) at time t-1, ε_t denotes the exogenous shocks. As examined in detail in Koop, Pesaran and Potter (1996) and Balke and Chang (1995), the effect of a single exogenous shock is examined at a time that $\varepsilon_t^{'} = (0, \dots 0, \varepsilon_t^i, 0 \dots 0)$ where ε_t^i is a shock to the i^{th} exogenous variable. The model is not linear in the shocks, than the impulse response function for the nonlinear model is not simple depending on the entire past history of the variables and the size and direction of the shock. Then nonlinear impulse responses require the nature of the shock (size and sign) and the initial condition (Ω_{t-1}).

Hence, the expected value of Y_{t+k} for the threshold model is not linear in the ε_t's, the conditional expectations for impulse responses, $E[Y_{t+k}|\Omega_{t-1}, \varepsilon t]$ and $E[Y_{t+k}|\Omega_{t-1}]$must be calculated by simulation methods. For each vector of random shocks, ε_{t+i}, the model is also calculated for shock $-\varepsilon_{t+i}$. This shows any asymmetry in the model. This bases on simulation approach and resulting averages gives the conditional expectation. The response of a variable following a shock must be compared against a baseline 'no shock' scenario.

Modelling cycle of generalized impulse response functions (GIRF) followed by Koop, Pesaran and Potter (1996) and represented in Atanasova (2003) as follows:

m dimensional variable Y is assumed to be known. The shock to the i^{th} variable of Y, occurs in period 0 and responses for l periods after that period. The shock is a one or two standard deviation shock. In nonlinear impulse responses, GIRF must be calculated by simulating the model:

1. Pick a history of r^{th} initial values, Ω_{t-1}^r, where r=1,2,........,R. The history is the actual value of the lagged endogenous variables at a particular date.
2. Pick a sequence of (m- dimensional) shocks, ε_{t+k}^b, k=0,...l and b=1,2,...,B. The shocks are choosen from the estimated residuals. The shocks are assumed to be jointly distributed.
3. Using the parameters, $\Omega_{t-1}^r \, and \, \varepsilon_{t+k}^b$, the model is simulated over l+1 periods. Obtain the model $Y_{t+k}(\Omega_{t-1}^r, \varepsilon_{t+k}^b)$ for k=0,1,....l.

4. Substitute ε_{i0} for the i_0 element of ε_{t+k}^{b} and simulate the model Y_{t+n} over l+1 periods. Denote the resulting model $Y_{t+k}(\varepsilon_{i0}, \Omega_{t-1}^{r}, \varepsilon_{t+k}^{b})$ for k=0,1,...l.
5. Repeat steps 2 to 4 B times.
6. Repeat steps 1 to 5 R times and compute average impulse response function as $Y_{t+k}(\varepsilon_{i0}) = [Y_{t+n}(\varepsilon_{i0}, \Omega_{t-1}^{r}, \varepsilon_{t+k}^{b}) - Y_{t+k}(\Omega_{t-1}^{r}, \varepsilon_{t+k}^{b})]$/BR.

3.4 Conclusion

In this chapter, methodological approaches that are employed in this study are presented. The empirical comparison of two methods is based on linear and nonlinear framework. Firstly, this study analyzes European money demand on linear framework. VAR modelling together with cointegration analysis investigates both short-run and long-run dynamics of the system. A brief modelling cycle for linear estimations is given.

Secondly, empirical analysis investigates European money demand on nonlinear framework. In this context, Threshold Cointegration model is presented. More specifically, MTAR type threshold cointegration model is given. MTAR type threshold cointegration models can capture asymmetric dynamics, such that the series exhibits more momentum in one direction than the other does. As stated in previous nonlinear literature Chapter 2, it is concluded that the Euro Area money demand may have nonlinear relationship. Therefore, Threshold Cointegration model is applied in Chapter 5 and Smooth Transition VECM application is a future research of this thesis.

CHAPTER 4

RESULTS OF VAR and VECM APPLICATIONS: LINEAR MODELS

4.1 Introduction

Time series models are commonly used in analyzing the relationships among economic variables. A popular one is the analysis of money demand function. We employ both linear and nonlinear models to investigate the structure of money demand function for the Euro Area. This chapter provides the empirical results of linear modelling. More specifically, well known VAR and VEC modelling approach have been used to examine the Euro Area money demand function.

Empirical results show that there is a stable relationship among the variables. However, short run estimates of GDP in money demand equation has positive sign but it is insignificant. These conflicting results may be due to nonlinearity which is observed and presented in Chapter 5.

The plan of the chapter is as follows. Section 4.2 considers the variables and the data set. Section 4.3 presents VAR model estimation. Unit root tests and lag selection criteria are given in this section. Cointegration analysis and VEC model estimations are analyzed in Section 4.4 and 4.5. Section 4.6 presents stability tests. Impulse response analysis investigates the dynamic properties of the model in Section 4.7. Conclusion in Section 4.8 completes the chapter. Supplementary tables are provided at the end of the thesis.

4.2 Modelling the Money Demand

Monetary policy and its effect on income, inflation and interest rate is one of the most popular research areas in economics. Monetary aggregates have a significant role in monetary policy strategies of the European Central Bank and for European Monetary Union (EMU) countries.

In the literature, scale and opportunity cost variables, such as real GDP, inflation rate and interest rates (long run and short run), are generally employed as explanatory variables in estimating the demand for money (Brand and Cassola, 2000; Hendry and Ericsson, 1991b; Yıldırım, 1997; Hendry, 1995)[70]. Some of the studies include additional variables like the spreads (the difference between the long run interest rates and short run interest rates and the difference between the interest rates on Treasury bills (RB) and the net interest rates on time deposits (RT^n) and on repos (RR^n)),[71] wealth and exchange rates. This section offers a brief overview of variable selection process and introduces the data.

4.2.1 The Choice of Variables

The most important issue before estimating the model is selection of the variables. Most of the studies in the literature (see Browne, Fagan and Henry, 1997; Goldfeld and Sichel, 1990; Fase, 1993; Filosa, 1995; Sriram, 2001 and Yıldırım, 2003) model money demand by employing interest rates, inflation rate and real GDP.

Lutkepohl and Wolters (1999) state that in the presence of adjustment costs and nominal variables, inflation should enter the long run relation to obtain real balances, even if it is not important for nominal balances.[72] Inflation and long-term interest

[70] See literature review of money demand in Chapter 2.

[71] $ST= RB-RT^n$ and $SR=RB-RR^n$

[72] See Wolters, Terasvirta and Lutkepohl (1998) for detailed discussion.

rates are close substitutes to each other, and therefore some studies[73] do not include inflation rate as a measure of the opportunity cost of holding money as they include long-term interest rates. Because the long-term interest rate and inflation may have similar explanatory content on money demand. Hence, including only one of the variables, inflation rate or long-term interest rate may be enough.

There are various discussions about including inflation rate. According to Coenen and Vega (2001), inflation rate permits a reparametrization of the models in terms of real money holdings and inflation rate. Such reparametrization allows for the theoretically plausible hypothesis of long-run price homogeneity of money demand but does not impose any untested (and frequently empirically rejected) common factor restriction of short-run price homogeneity. Including inflation rate also helps system to be stationary when there are cointegrated variables at higher order. For instance, when the money stock and the price level are cointegrated of order 2, $I(2)$, the real money demand (m-p) is $I(1)$ (Coenen and Vega, 2001). In addition, inflation rate is an important determinant of constant parameter money demand equation system. It represents the opportunity cost of holding money rather than real assets (Ericsson, 1999). Lastly, it is argued by Coenen and Vega (2001) that the inclusion or exclusion of inflation in models of real money demand is an issue of dynamic specification to be settled at the empirical level.

Some studies include an exchange rate variable to capture currency substitution effect[74] between the European currencies and the US dollar. But, since foreign-currency-denominated deposits are included in M3 monetary definition, the effect of pure currency substitution is assimilated (Bruggeman, 2000). Therefore, exchange rate is not included in the analysis in this thesis.

There are some studies that employ additional explanatory variables such as equity and labour markets indicators (Bondt, 2009); equity (Friedman, 1988); real wealth

[73] See Brand and Cassola (2000); Dedola, Gaiotti and Silipo (2001); Golinelli and Pastorello (2002); Calza, Gerdesmeier and Levy (2001).

[74] In Yıldırım (2003), it is defined as “Currency substitution implies that individuals in each country allocate their total holdings of money across several countries’ currencies, including their domestic currency”.

and unemployment rate (Beyer, 2009); wealth effect indicator (Boone and Noord, 2008). Bruggeman, Donati and Warne (2003) include stock prices into money demand model. Fase and Winder (1998) model wealth and demand for money. However, due to the lack of reliable data for wealth for the Euro Area, including wealth variable as a determinant of the money demand is not preferred (Coenen and Vega, 2001). Several studies[75] by ECB staff obtain stable broad money demand function of GDP, inflation and interest rates. Thus, the vector of variables in the joint density can be represented as[76]:

$$(m_t - p_t, gdp_t, \Delta p_t, R_t) \quad \textbf{(4.1)}$$

A standard model is (see Goldfeld, 1973 and Hendry, 1995):

$$M^d = f(I, P, R) \quad \textbf{(4.2)}$$

where M^d denotes money demand, P is the price level[77], I is a scale variable and R is the interest rates, representing the net opportunity costs of holding money against alternative interest-bearing assets.

Referring the most of the studies on money demand namely, Metin (1994, 1995); Yıldırım (1997); Golinelli and Pastorello (2002); Ericsson, Hendry and Prestwich, (1997) our model is formed follows:

$$\frac{M^d}{P} = f(I, \dot{P}, R) \quad \textbf{(4.3)}$$

In equation (4.3), $\frac{M^d}{P}$ is the real money demand, $\dot{P}$ denotes the percentage change in the price level, I denotes the real GDP, R is the interest rates (short-term (R^s)

[75] See for example, Coenen and Vega (2001), Brand and Cassola (2000) and Calza, Gerdesmeier and Levy (2001).

[76] In Hendry (1995).

[77] For price level variable, consumer price index (CPI), producer price index (PPI) or GDP deflator can be used according to the availability of the data.

denotes 3-month interbank rate or long-term (R^l) denotes yields on 10-year government bonds). There are three aggregate interest rates namely interbank overnight rate, 3-month interbank rate and the government bond. Government bonds are widely used as long term interest rates for the analysis as recommended in Poole (1988) and discussed in Yıldırım (1997). Coenen and Vega (2001) and Calza, Gerdesmeier and Levy (2001) use the spread variable (the difference between short and long run interest rates). In fact, Laidler (1971) shows that there is no systematic difference between long and short run interest rates in explaining money demand. The relationship between short run and long run interest rates is studied by Enders and Granger (1998), Enders and Siklos (2001) and Balke and Fomby (1997). Due to the existence of a possible relationship between short run and long run interest rates, only short run interest rates are included in the model in this study to avoid the multicollinearity problem[78].

After determining all variables for money demand model, the equation can be rewritten in logarithms (lowercase variables denote the logarithms), than a log linear specification is adopted for (4.3):

$$m^d{}_t - p_t = \alpha + \beta gdp_t + \gamma' R_t^s + \delta \Delta p_t + u_t \qquad \textbf{(4.4)}$$

Where Δp denotes inflation rate, inflation rate is calculated as annual percentage change in the prices[79], u_t is an error term with $u_t \sim N(0, \sigma^2)$. To show in real terms, $(m-p)_t$ is used which denotes $\ln(\frac{M_t^d}{P_t})$, gdp_t denotes $\ln(RGDP_t)$, The original interest rate series is involved since it is already in percentage form.

Theories differ about the anticipated value of the long-run income elasticity β, which takes the value 0.5 in Baumol and Tobin's transaction demand theory and takes the

[78] In contrast, Holtemöller (2004) uses both short run and long run interest rates in the model.

[79] As defined in the ECB that "the inflation rate is calculated using the change in the latest available 12-month average of the price index over the previous 12-month average." Many studies measure the inflation rate as 'year-on-year changes' in the prices (Vasicek, 2012).

value 1 according to Friedman's quantity theory of money, thus the long-run income elasticity is expected positive in the economic literature.[80] The expected signs of the interest rates depend on the kind of the returns, such that, if the returns are relative to own rates of money, γ is predicted to be positive, $\gamma>0$; but if the returns are relative to financial assets, γ is predicted as negative, $\gamma<0$, in this case short run and long run interest rates are expected to be negatively related with money demand. Finally, for the inflation rate, δ is predicted as negative, $\delta<0$, because goods are alternative to money. If the $\delta=0$, equation (4.4) assumes long run price homogeneity of money (Cushman, 2002; Golinelli and Pastorello, 2002).

As Hendry (1995, p.580) states that the determinants of money demand are essential to modelling observed money holdings, but the 'money supply' is also involved. Also in macroeconomic models, an observed money stock (set by policy makers) is equated to money demand. When the money stock is fixed or the supply M^s is 'exogenous', the equation yields:

$$M^d = M^s = f(I, P, R) \tag{4.5}$$

4.2.2 The Data

To analyze the area-wide studies, aggregated data sets are needed. If the aggregated data does not exist, there are two ways for obtaining the data. One of them is to aggregate variables by using each country's data set. This method has some drawbacks and there is no unique aggregating method in the literature,[81] each method can lead to different results. The other one is extending or using the data sets of other studies. Bosker (2006) shows that aggregation method can have a substantial impact on the parameter estimates for the Euro Area data.

[80] Hendry (1995).

[81] See Chapter 2, Section 2.4.

This study employs quarterly data for Euro Area over the period 1980:Q1 to 2010:Q4. Because of handicaps of aggregation methods[82], some studies[83] use the data set from other reference studies. These reference studies are Coenen and Vega (2001); Brand and Cassola (2000) and Calza, Gerdesmeier and Levy (2001). In this study, the short term interest rate is obtained from the study by Brand and Cassola (2000) till 1994:01; Seasonally adjusted real GDP data is obtained from the study by Brand and Cassola (2000) till 1996:04; ECB and IFS (International Financial Statistics database by IMF) databases are used to extend these data sets till the end of the period, 2010:04. M3 and long-term interest rates are available in IFS database for 1980-2010 periods. For price variables, producer price index (PPI) is preferred[84] and obtained from the ECB database for the 1980-2010 periods.

Because none of the variables is deseasonalized, seasonal dummy variables are included into the model. They are significant and kept in the model. We do not prefer to use seasonally adjusted data set since seasonal adjustment procedures may be particularly problematic for series with structural shifts (Brüggemann and Lutkepohl, 2006).

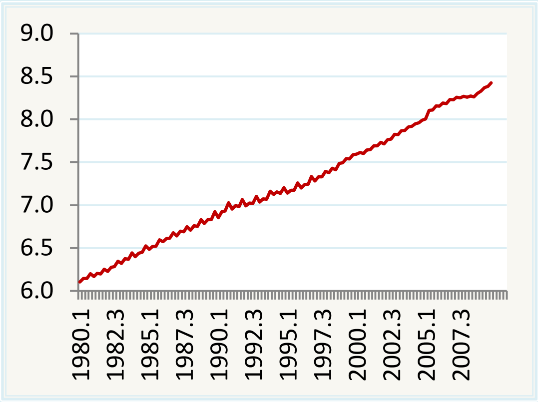
4.2.3 Graphs of the Series

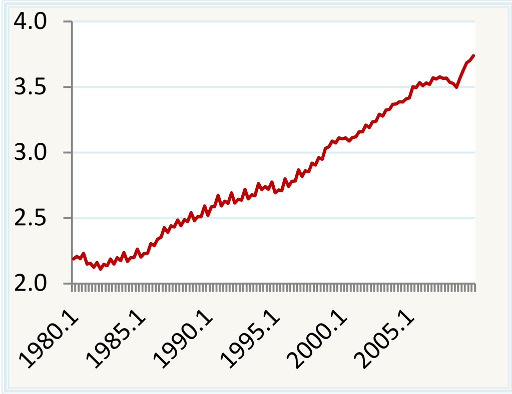
The graphs of the logarithms of monetary aggregates (M1, M2 and M3) and other variables are presented in the Figures 4.1 and 4.2.

[82] Different aggregation methods lead to different results see for example Artis and Beyer (2004) and Dreger and Wolters (2010).

[83] Euro Area data set provided by Brand and Cassola (2000) is used in Holtemöller (2004) and Kontolemis (2002), while Carstensen (2004) uses the data set of Calza, Gerdesmeier and Levy (2001).

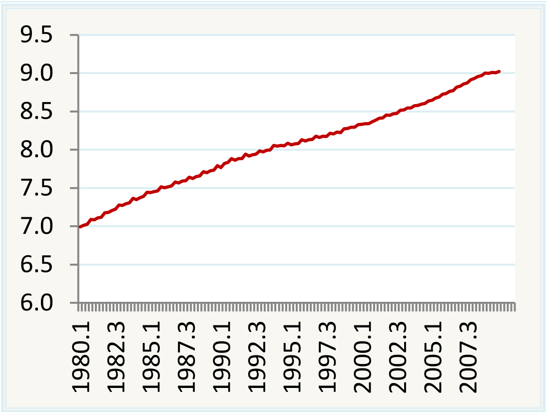
[84] Producer price index (PPI) is chosen because they are nearly similar with consumer price index (CPI) and there is no data availability problem for PPI for the full period 1980-2010.

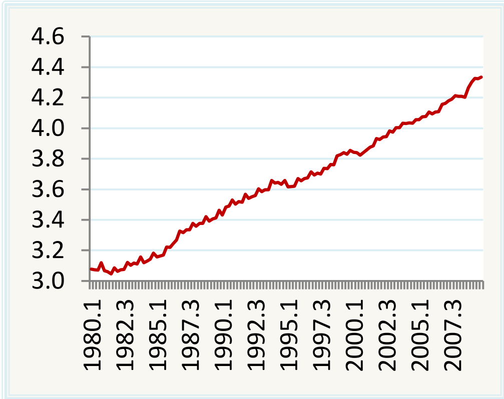




a. Log. of M1

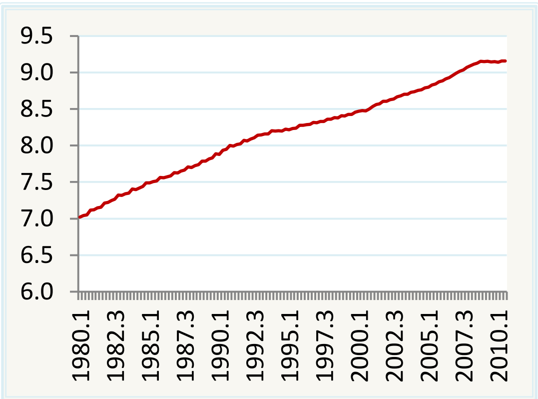
b. Log. of real M1

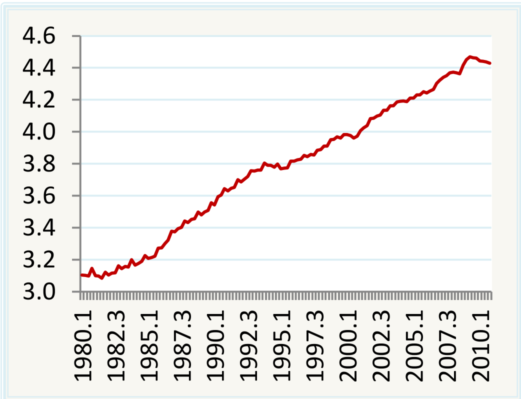




c. Log. of M2

d. Log. of real M2



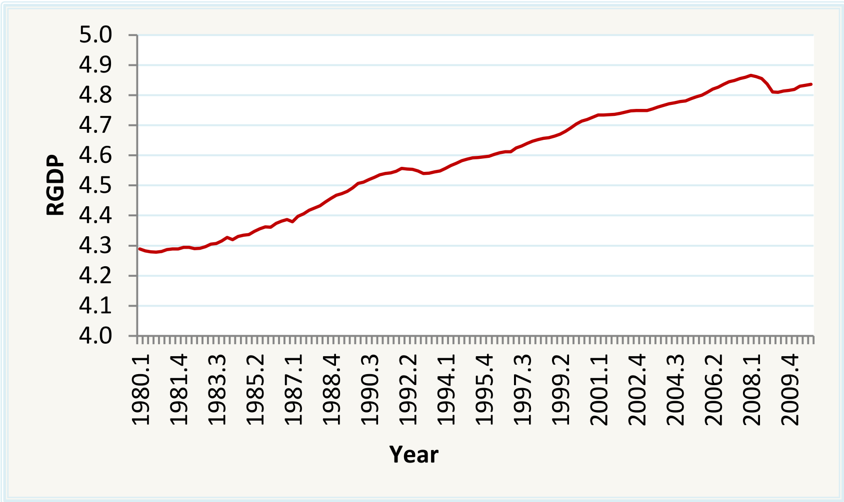


e. Log. of M3

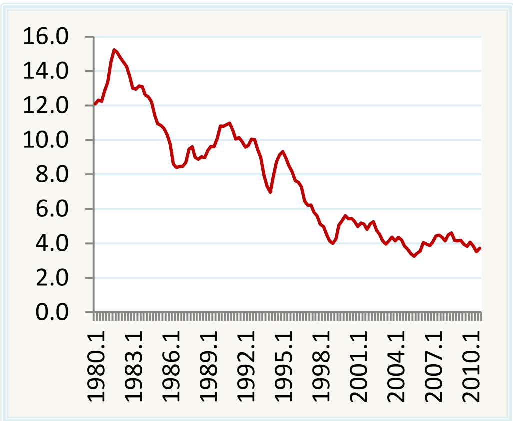
f. Log. of real M3

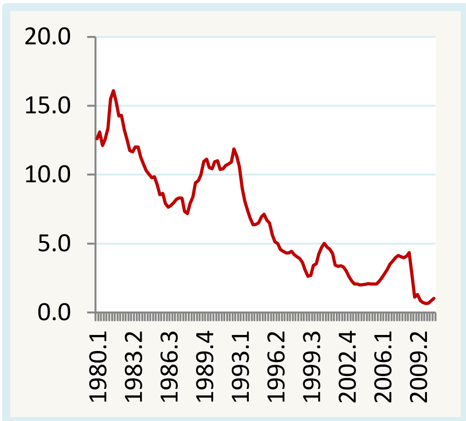
Figure 4.1 Logarithms of Monetary Aggregates

The graphs of the monetary aggregates in Figure 4.1 might provide additional information about the series. Figures show strong upward trend for the whole periods for both levels and real values.

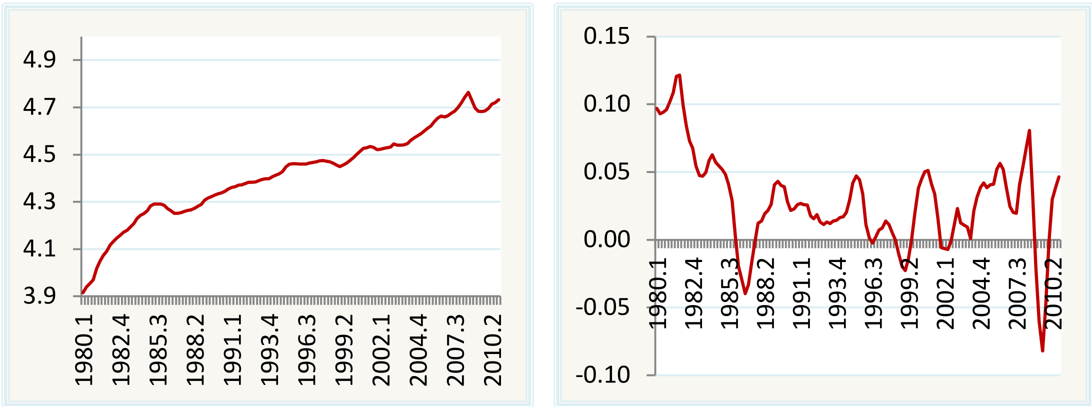


a. Log. of real GDP





b. Long-run Interest Rates (R^l) **c. Short-run Interest Rates (R^s)**



d. Log. of Prices (p) **e. Inflation Rate (Δp)**

Figure 4.2 Graphs of Other Variables

Figure 4.2 presents the graphs of the determinants of the demand for money. The graphs of long run interest rates and short run interest rates show negative trend while the graphs of real GDP and prices show positive trend, with fluctuation during the economic periods.

4.3 VAR Model Estimates

The results of the unit root tests[85] namely Augmented Dickey Fuller (ADF) test, Phillips-Perron test and KPSS test are presented in Table 4.1. The ADF test can not reject the null hypothesis of the presence of a unit root in all series (except inflation rate). According to Phillips-Perron test, nonstationary hypothesis can not be rejected for all variables. For KPSS test, the null hypothesis of stationary can be rejected at 5% level for all variables while the null is rejected at 10% level only for inflation rate. In Table 4.1, the test results conclude that the series are found to be nonstationary, at $I(1)$ level. Although ADF test results for inflation rate do not support nonstationary, the inflation rate is assumed to be stationary at $I(1)$ level, as Phillips-Perron and KPSS tests verify. The mixed results may be due to the time period of this study; with a longer data period it is more likely to have an $I(1)$ series.

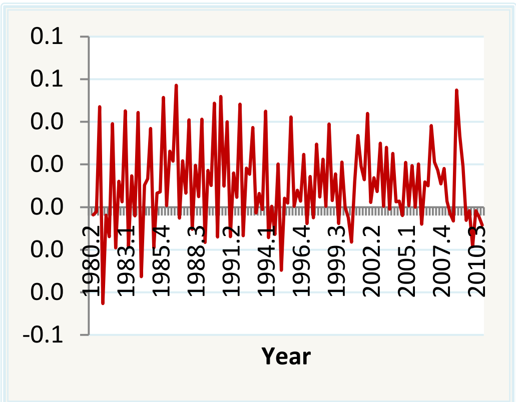
[85] The details of the unit root tests are discussed briefly in Chapter 3, Section 3.2.2.

Table 4.1 Unit Root Test Results

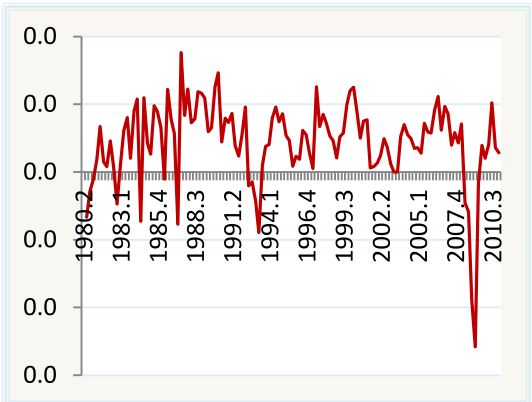
	$I(0)$			$I(1)$		
	Augmented Dickey Fuller Test (ADF)	**Phillips-Perron Test**	**KPSS Test**	**Augmented Dickey Fuller Test (ADF)**	**Phillips-Perron Test**	**KPSS Test**
Variables	p value	p value	test stat	p value	p value	test stat
(m-p)	0.7577*	0.905*	1.324	0.0001	0.000	0.094
GDP	0.665*	0.79*	1.319	0.000	0.000	0.162
$\mathbf{R^s}$	0.577*	0.741*	1.202	0.000	0.000	0.0429
$\mathbf{R^l}$	0.636*	0.773*	1.225	0.000	0.000	0.057
Δp	0.0086	0.0947*	0.433*	0.0037	0.002	0.152

***** denotes nonstationary series.

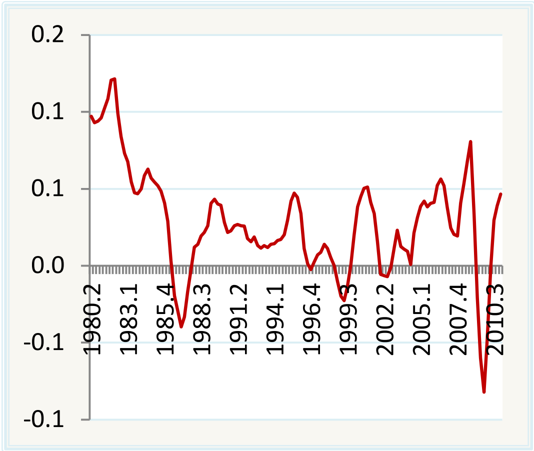
To conclude, the real M3, GDP, inflation, long-term and short-term interest rates are integrated of order 1, $I(1)$, implying that they are all nonstationary, which is a pre-condition for the cointegration analysis. The first differences of all variables are presented in the graphs in Figure 4.3. These graphs do not only show the stationarity of the variables after differencing but are useful to detect the outliers visually. From Figure 4.3, it can be seen that the real monetary balances $\Delta(m-p)$ and interest rates may include outliers.



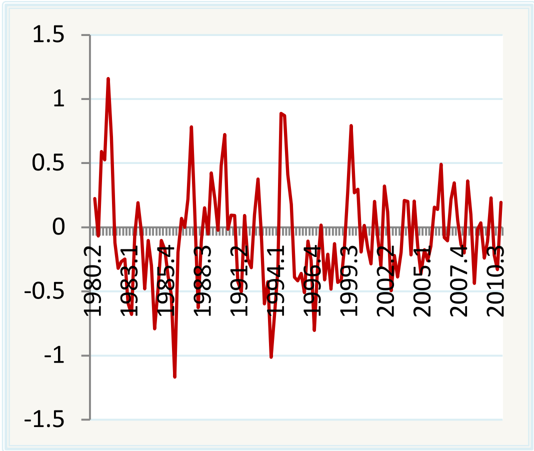
a. Log. of Real M3



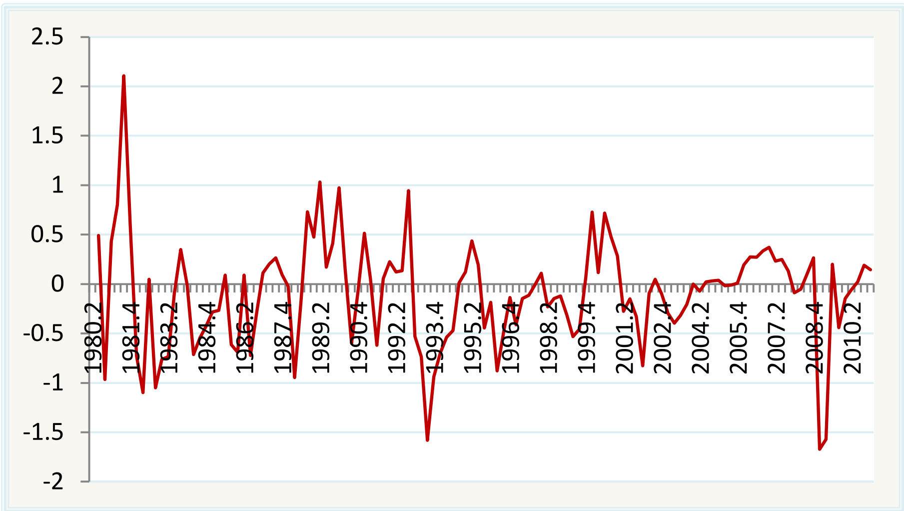
b. Log. of Real GDP



c. Inflation Rate



d. Long-Run Interest Rates



e. Short-Run Interest Rates

Figure 4. 3 First Differences of the Series

Global economic crisis in the last months of 2008 seems to have affected the Euro Area seriously, as can be seen from the graphs of the first differences above in Figure 4.3. For GDP, inflation and interest rates, the fluctuations begin from the last months of 2008 and last for 2 quarters. A dummy variable which takes value of 1 for the periods 2008:4 and 2009:1 is found significant for the model and the diagnostics of the model.

As it is reported by Hendry and Ericsson (1991b) that step dummy can be used for some special events. Step dummy takes value of 0 for all periods before a particular event and value of 1 after that period. Hendry and Ericsson (1989) include also seasonal dummies that takes the value of 1 for first quarter, 0 otherwise and same for other quarters. Because of the data are extended from 1994, it is possible to observe break points. In order to see if there is a structural change in time series data, Chow test is employed. When performing Chow tests, break points are taken as 1994:1 for short-term interest rates and 1996:4 for GDP. Chow test results provide no statistical evidence of structural change in these dates. Therefore, step dummies are not included in to the model.

After establishing the stationarity properties of all variables, the VAR model is estimated. The vector of variables is:

$$((m\text{-}p)_t,\ gdp_t,\ \Delta p_t,\ R_t^s) \qquad \textbf{(4.6)}$$

Estimation is carried over 1980:1-2010:4, yielding 120 observations. The first step of modelling is the determination of lag length. For quarterly variables, in the literature, the modelling begins from lag length 12. Than the lag length, providing the minimum information criteria is chosen.[86]

The results of sequential modified LR test statistic (LR), Schwarz (SC), Akaike (AIC) and Hannan-Quinn (HQ) Information Criteria can be seen in Table 4.2.

[86] The brief description about 'Information Criteria' can be found in Section 3.2.

Table 4.2 Lag Selection					
Model	**Lag**	**LR**	**AIC**	**SIC**	**HQ**
1	0	NA	-18.062	-17.770	-17.944
2	1	116.721	-18.896	-18.213	-18.619
3	2	33.820	-18.946	-17.872	-18.511
4	3	61.941	-19.303	-17.839	-18.709
5	**4**	124.316	-20.366	**-18.511***	**-19.613***
6	5	23.105	-20.341	-18.095	-19.430
7	6	10.376	-20.176	-17.540	-19.106
8	7	12.930	-20.049	-17.022	-18.821
9	8	50.430	-20.424	-17.007	-19.038
10	**9**	**36.457***	**-20.642***	-16.834	-19.098
11	10	16.313	-20.594	-16.396	-18.891
12	11	15.551	-20.549	-15.960	-18.687
13	12	17.808	-20.557	-15.578	-18.537

*denotes the min value

In Table 4.2 Schwarz and Hannan-Quinn criteria have a minimum value for model 5 with lag length 4. LR and Akaike criteria have a minimum for model 10 with lag length 9. A four lag model is chosen for SIC, while nine lag model is chosen according to the AIC. After comparing the models for the diagnostics[87] and the coefficients, four-lag model is preferred. In addition, larger lags are not preferred to avoid data loss and not to decrease degrees of freedom. Lag reduction tests (in Table 4.3) suggest that four lags are significant, so no reduction is needed.

Table 4.3 Lag Length Dynamics					
	(m-p)	**gdp**	**Δp**	**R^s**	**joint**
χ_1^2	9.283	8.814	36.683	22.113	70.233
	[0.054]**	[0.066]**	[2.09e-07]*	[0.0002]*	[9.09e-09]*
χ_2^2	3.976	3.767	7.451	5.724	23.137
	[0.409]	[0.438]	[0.113]	[0.2207]	[0.1101]
χ_3^2	13.599	1.061	16.120	6.132	26.001
	[0.008]*	[0.9004]	[0.002]*	[0.189]	[0.054]**
χ_4^2	103.521	3.492	33.504	2.639	281.786
	[0.000]*	[0.479]	[9.42e-07]**	[0.619]	[0.000]*

Note: Numbers in [] are p-values. * and ** denotes significance at 1% and 10% level.

[87] Model diagnostics denote autocorrelation, normality tests, heteroscedasticity tests.

The residuals are obtained from VAR analysis. By analysing the residual graphs, the outliers can be cleared by including corresponding dummies. Than VAR model is estimated with dummies to improve the diagnostics. The reestimated model with dummies can be seen in Appendix Table A1.1.

Table 4.4 Diagnostic Test Results

	(m-p)	**gdp**	**Δp**	R^s	VAR
$\hat{\sigma}$	0.0095	0.0046	0.0069	0.439	
$\bar{R}^2$	0.764	0.372	0.739	0.304	
F_{ar} (3)					12.62
					(0.70)
χ^2_{het}					404.91
					(0.5615)
χ^{2s}_{nd}					3.43
					(0.49)
χ^{2k}_{nd}					11.89
					(0.018)
χ^{2j}_{nd}	0.028	4.863	2.899	29.88	13.209
	(0.98)	(0.088)	(0.235)	(0.00)	(0.0531)

Note: p-values are given in parenthesis.

Table 4.4 presents diagnostic test results of the unrestricted VAR model, namely, $\hat{\sigma}$ denotes equation residual standard deviation; F_{ar}(.) denotes F test for the hypotheses of no serial correlation against serial autocorrelation up to order 4 (F_{ar}); no heteroscedasticity (F_{het}) and a chi-square test for normality (denoted χ^{2s}_{nd} for skewness, χ^{2k}_{nd} for kurtosis, χ^{2j}_{nd} for Jarque-Bera test).

As can be seen in Table 4.4, for serial correlation LM test, null hypothesis of no serial correlation can not be rejected at 5% significance level (p=0.70). Standard errors of the variables are also included in Table 4.4. According to heteroscedasticity test, the null hypothesis of no heteroscedasticity can not be rejected at 5% significance level (p=0.5615). Following normality test results, skewness and Jarque-Bera tests can not reject the null hypothesis of normality (H_0: Residuals are multivariate normal) at 5% significance level, kurtosis test can not reject the null at 1% significance level. Therefore, normality tests indicate that there is no normality problem and additionally diagnostics show there is no autocorrelation and heteroscedasticity problem.

Table 4.5 Residual Correlation Matrix for VAR (4)

	(m-p)	**gdp**	**Δp**	**R^s**
(m-p)	1.000	-	-	-
gdp	0.025	1.000	-	-
Δp	-0.613	0.055	1.000	-
R^s	-0.082	0.132	0.227	1.000

Referring to Table 4.5, correlation signs of the residual correlation matrix are as expected in the literature that, real money demand and real GDP have positive relationship, real money demand and inflation have negative relationship while real money demand and interest rates have also negative relationship.

4.4 Cointegration Analysis

The concept of cointegration is first proposed in Granger (1981, 1983), Granger and Weiss (1983) and developed in Engle and Granger (1987); Johansen (1995). Cointegration implies the existence of a dynamic error-correction form of the variables in the model. We prefer Johansen's (1995) approach as it allows a selection of cointegrating vector in contrast to Engle and Granger type cointegration analysis which assumes only one cointegrating vector.

After specification of an adequate VAR model, cointegration analysis in the four equation system is carried out. The result of cointegration analysis is presented in Table 4.6. In Table 4.6, λ denotes the eigenvalues, Max and Tr denote the corresponding maximum eigenvalue and trace statistics. The Johansen (1995) cointegration test statistics indicate that there is one cointegrating vector between real money demand, real GDP, inflation rate and short run interest rates.

Table 4.6 Cointegration Analysis				
No. of CE(s)	None	1	2	3
Λ	0.196	0.113	0.068	0.030
Max	25.975**	14.306	8.404	3.625
Tr	52.311*	26.336	12.029	3.625
Unrestricted Adjustment Coefficients (α):				
(m-p)	0.001	-0.002	-0.002	0.000
gdp	-0.002	0.000	0.000	0.000
Δp	-0.001	0.002	0.000	0.000
R^s	-0.085	0.032	0.001	0.060
Unrestricted Cointegrating Coefficients				
(m-p)	**gdp**	**Δp**	**R^s**	
-23.692	63.789	-34.390	0.660	
17.429	-28.835	-4.776	0.278	
18.434	-36.848	54.032	0.118	
-11.225	23.017	35.443	-0.376	

*denotes rejection of the hypothesis at the 5% level, **denotes rejection of the hypothesis at the 10% level.

Trace test shows that there is one cointegrating vector at the 0.05 significance level indicating that there is one stationary relationship between the four non stationary variables of the system.

Overall, the number of cointegrating vectors is specified, our results imply that a VECM analysis can be conducted. Table 4.6 also presents the adjustment coefficients, which can be interpreted as the weights with which the cointegration vectors enter the four equation system. They represent the average speed of adjustment towards the estimated equilibrium state, such that a small coefficient indicates a slow adjustment.

4.5 VECM Estimates

Economic theory and econometric methodology suggest that there are three specific restrictions, which should be applied in the money demand model (Hendry, 1995, p.598). These are weak exogeneity of the variables, unit income elasticity, equal effects from the inflation and the interest rates. In this part of the thesis, VEC model is estimated to model the short run and long run dynamics of the money demand system. In specifying VECMs, the lag order, the cointegration rank and possible restriction should be determined (Lütkepohl, 2005).

The first one of the restrictions is that income, inflation and interest rates should be *weakly exogenous* for the parameters of money demand function.[88] The second restriction is about the *income elasticity* of the demand for money. The last restriction is that *price homogeneity*. Weak exogeneity requires that the cointegrating vector does not appear in short-run equations of (gdp, Δp, R^s) indicating that, income, inflation and interest rates do not react to disequilibriums in real money.

The restrictions are integrated into the model as economic theory suggests and imposed on the adjustment coefficients and cointegrating vector matrices, α and β respectively. There are three restrictions such as:

A.1. First restriction is about the weak exogeneity of interest rates, GDP and inflation rate. The restrictions are applied such that:

$$\alpha = \begin{bmatrix} \alpha_{11} \\ \alpha_{21} \\ \alpha_{31} \\ \alpha_{41} \end{bmatrix}, \qquad H_{01}: \alpha_{21} = \alpha_{31} = \alpha_{41} = 0, \qquad F = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

[88] The concept of weak exogeneity is first developed in seminal paper by Engle, Hendry and Richard (1983).

The resulting test statistic is $\chi^2 = 3.16$ and p value: 0.368. This indicates that the weak exogeneity of GDP, inflation rate and interest rate can not be rejected at 5% level.

The individual weak exogeneity tests are also applied for real GDP, inflation rate and interest rate. Weak exogeneity of real GDP is tested such as:

H_{01}: $\alpha_{21}=0$,

The resulting test statistic is $\chi^2 = 0.501$ and p value: 0.479. This indicates that the individually weak exogeneity of real GDP can not be rejected at 1% level.

For testing the weak exogeneity of inflation rate:

H_{01}: $\alpha_{31}=0$,

The resulting test statistic is $\chi^2 = 2.448$ and p value: 0.118. This indicates that the individually weak exogeneity of inflation rate can not be rejected at 1% level.

For the last individual weak exogeneity test:

H_{01}: $\alpha_{41}=0$,

The resulting test statistic is $\chi^2 = 0.816$ and p value: 0.366. This indicates that the individually weak exogeneity of interest rate can not be rejected at 1% level.

B. Second restriction is that income has unit elasticity in the cointegrating vector. This is a restriction on cointegrating vector (about β) and formulated as

H_{02}: $\beta_{21}=-\beta_{11}$, $\beta' = [\beta_{11} \quad \beta_{21} \quad \beta_{31} \quad \beta_{41}]$

$$D_1 = \begin{bmatrix} 1 \\ -1 \\ 0 \\ 0 \end{bmatrix}$$

The resulting test statistic is $\chi^2 = 5.88$ and p value: 0.015. This indicates that unit elasticity of income can be rejected at 5% level. Income does not have unit elasticity.

C. Third restriction is that inflation rate and interest rate have the same coefficient. To test this restriction, the following restriction is imposed:

H_{03}: $\beta_{13} = \beta_{14}$

The resulting test statistic is $\chi^2 = 5.45$ and p value: 0.020. This hypothesis can be rejected at 5% level. Inflation rate and interest rate do not have the same coefficient.

All three restrictions (A, B and C) are jointly tested under the following null hypothesis.

H_{01}: $\alpha_{21} = \alpha_{31} = \alpha_{41} = 0$, H_{02}: $\beta_{21} = -\beta_{11}$, H_{03}: $\beta_{13} = \beta_{14}$

The resulting test statistic is $\chi^2 = 5.452$ and p value: 0.019. The hypothesis is rejected at 5% level. When the all of the three restrictions are tested jointly, they are not statistically significant.

To summarize, the cointegrating vector is identified by imposing the weak exogeneity of the interest rates, income and inflation over the parameters of the long-run money demand function. As the weak exogeneity of interest rates, inflation and income for the parameters of the long-run demand for money function can not be rejected and that means changes in income, inflation and interest rates do not react to disequilibrium errors but may still react to the lagged changes of money.

The cointegrating vector is estimated as follows:

$$CI = (m-p)_t - 2.07 * gdp_t + 1.41 * \Delta p + 0.005 R_t^s + 5.67 \quad \textbf{(4.7)}$$

Cointegrating vector can be interpreted as the excess demand for the money, with an income elasticity of 2.07. Equation (4.7) shows that the long run demand for money depends negatively on inflation and the interest rate and positively on GDP, in line with the economic theory.

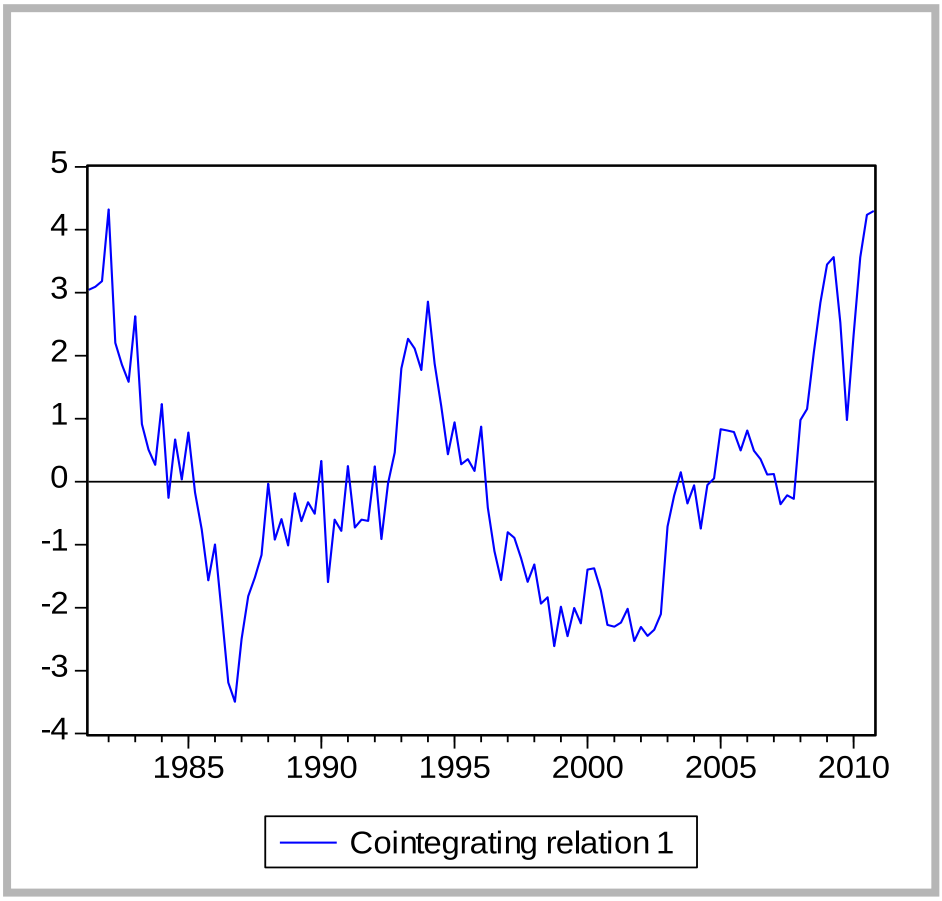


Figure 4.4 Cointegration Vector

Cointegrating vector in equation (4.7) determines the stationary long run relationship between the variables. The long-run demand for money has an income elasticity of 2.07. As Dreger and Wolters (2010) state that due to the increase in the income elasticity of money demand since 2002, the cointegration parameters are unstable. They report higher income elasticity for the Euro Area data, they estimate the income elasticity for the period 1983:1 to 2001:4 that 1.292, while estimating the same system with the data up to 2006:4, they lead to an income elasticity of 2.976, extending the data set may lead higher income elasticity. For instance, Yıldırım (1997) finds income elasticity of long-run demand for money in Germany, 2.21 and 1.77 for Euro Area. Siliverstovs (2008) estimates money demand for Latvia and finds income elasticity of 2.851. There are also other studies that find income elasticity significantly larger than unity. Dregers, Reimers and Roffia (2007) find income elasticity of 1.7; de Santis, Favero and Roffia (2008) observe income elasticity of 1.84 for European money demand; Karla (1999) finds income elasticity of 3.75 using data for Albania. As stated in Laidler (1993, p. 169), “Broader definitions of money produce higher estimates of the income or wealth elasticity of the demand for money than narrower ones”. See Issing and Todter (1995), Scharnagl (1998), Brand and Cassola (2000), Golinelli and Pastorello (2002), Calza, Gerdesmeier and Levy (2001), Bruggeman, Donati and Warne (2003), Lutkepohl and Wolters (2003) for other example studies that estimate the income elasticity greater than unity. In contrast, some studies, before period 2002, find unit income elasticity in the literature (Kremers and Lane (1990), Fase (1996), Hayo (1999) and Vlaar and Schuberth (1999)).

To avoid high income elasticity, different cointegrating relationship approach is employed by Lutkepohl and Wolters (2003) and Dreger and Wolters (2010). They exclude the interest rate from the cointegrating vector, such as new cointegrating vector is (m-p, gdp, Δp). In this study, we also take the interest rate as an exogenous variable and obtain new cointegrating vector including money demand, GDP and inflation rate. Than the unit income elasticity is verified by new long run relationship. The detailed results are not given here, only FIML estimates are given in Table 4.8 and impulse responses functions are given in Figure 4.8 for the model that interest rate is exogenous.

The I(0) system is modelled as a parsimonious VAR where the information set used consists of Δmp_t, ΔR_t, Δgdp_t, $\Delta^2 p_t$ and the cointegrating vector, together with the dummy variables and the constant term. The Full Information Maximum Likelihood Estimation results are presented in Table 4.7. After the exclusion of insignificant variables, overidentifying restriction test is applied that the test does not reject $\chi^2_{or}(77) = 134$), so the marginalization is complete. The resulting equations parsimoniously encompasses the PVAR.

Table 4.7 FIML Model Estimates[89]

$$\Delta(m-p)_t = 0.017 - 0.130CI_{t-1} - 0.199\Delta mp_{t-3} + 0.319\Delta mp_{t-4} + 0.162\Delta gdp_t$$

(0.00) (0.00) (0.0106) (0.000) (0.454)

$$-0.217\,\Delta^2 p_{t-1} - 0.006\Delta R_t^s + 0.028d2008 - 0.019ds1 - 0.011ds2 - 0.010ds3$$

(0.0164) (0.003) (0.0167) (0.000) (0.0002) (0.0372)

$$\Delta gdp_t = 0.0036 + 0.28\Delta gdp_{t-1} - 0.0016\Delta R_{t-2}^s - 0.015d2008$$

(0.00) (0.000) (0.045) (0.000)

$$\Delta^2 p_t = -0.0072 + 0.134\Delta mp_{t-3} + 0.286\Delta mp_{t-4} - 0.240\Delta gdp_{t-4} + 0.533\Delta^2 p_{t-1}$$

(0.0004) (0.017) (0.00) (0.039) (0.00)

$$-0.0031\Delta R_{t-4}^s - 0.040d2008 + 0.0077ds1 + 0.0045ds2 + 0.0028ds3$$

(0.028) (0.000) (0.010) (0.016) (0.42)

$$\Delta R_t^s = 0.396\Delta R_{t-1}^s - 0.6216d2008$$

(0.000) (0.000)

In Table 4.7 it is observed that none of the variables in the system contributes to the explanation of the interest rate equation. Hence, it may be assumed to be exogenous and a three equation system is estimated by FIML method. The estimation results are presented in Table 4.8.

[89] p-values are in parenthesis and mp denotes (m-p).

Table 4.8 FIML Model Estimates[90]

$$\Delta(m-p)_t = 0.017 - 0.131CI_{t-1} - 0.205\Delta mp_{t-3} + 0.313\Delta mp_{t-4} + 0.188\Delta gdp_t$$

(0.00) (0.00) (0.0082) (0.000) (0.383)

$$-0.214\,\Delta^2 p_{t-1} - 0.006\Delta R_t^s + 0.028d2008 - 0.019ds1 - 0.011ds2 - 0.010ds3$$

(0.017) (0.0031) (0.014) (0.000) (0.0001) (0.037)

$$\Delta gdp_t = 0.0037 + 0.25\Delta gdp_{t-1} - 0.0016\Delta R_{t-2}^s - 0.015d2008$$

(0.00) (0.008) (0.079) (0.000)

$$\Delta^2 p_t = -0.0076 + 0.125\Delta mp_{t-3} + 0.291\Delta mp_{t-4} - 0.238\Delta gdp_{t-4} + 0.477\Delta^2 p_{t-1}$$

(0.0049) (0.061) (0.00) (0.031) (0.00)

$$-0.0015\Delta R_{t-4}^s - 0.031d2008 + 0.0082ds1 + 0.0057ds2 + 0.0036ds3$$

(0.025) (0.000) (0.030) (0.021) (0.40)

The short-run estimates of the money demand model in Table 4.7 indicate that the inclusion of the dummy variable for 2008 Euro Area economic crisis improves the estimation results and has significant effect in both money and GDP equation. In GDP equation, the first lag of the income has positive effect though the second lag of the interest rate has relatively smaller negative effect. In the short-run money demand equation the adjustment coefficient is statistically significant and indicates that nearly 13 percent of the disequilibrium is corrected in each quarter. Furthermore, the magnitude of the adjustment coefficient is bigger than the ones found by previous studies estimating the M3 money demand for the Euro Area (Kremers and Lane

[90] p-values are in parenthesis and mp denotes (m-p).

(1990), Fase and Winder (1993), Monticelli and Strauss-Kahn (1993), Coenen and Vega (2001), Golinelli and Pastorello (2002) etc.). Both inflation and interest rate variables have expected signs. GDP has a positive coefficient consistent with economic theory but insignificant effect in money demand equation. In the inflation rate equation, change in inflation is positively correlated with its first lag. The fourth lag of real money demand has positive effect on the inflation while the interest rates have negative effect. In money demand and inflation rate equations, the seasonal dummies have statistically significant effect. The seasonal dummies are found insignificant in income equation, though real GDP is seasonally adjusted. In the last equation, the short-run interest rates are positively correlated with its first lag and negatively affected by crisis dummies. Including the seasonal dummies and all other variables do not have significant effect on the interest rates. Hence, it is assumed to be exogenous and the estimated model is presented in Table 4.8. The sign and the size of the coefficients are close to the model in Table 4.7. GDP is still insignificant but its coefficient increases while p-value of GDP decreases.

Table 4.9 Model Statistics

	(m-p)	**gdp**	**Δp**	**R^s**
$\hat{\sigma}$	0.0087	0.0046	0.0069	0.4417
$\bar{R}^2$	0.799	0.367	0.740	0.298

Model statistics are presented in Table 4.9, where $\hat{\sigma}$ denotes residual standard deviations and $\bar{R}^2$ denotes adjusted R^2. Additionally, model diagnostic statistics, given in Table 4.10, are all insignificant. The presented diagnostics are F test for no serial autocorrelation up to order (F_{ar}), test for no heteroscedasticity (F_{het}: see White, 1980) and a chi-square test for normality (denoted χ^{2s}_{nd} for skewness, χ^{2k}_{nd} for kurtosis, χ^{2j}_{nd} for Jarque-Bera test). All diagnostics are satisfactory that there is no autocorrelation, heteroscedasticity and normality problem.

Table 4.10 Diagnostic Test Results

	VECM
$F_{ar}(3)$	14.28
	(0.57)
χ^{2}_{het}	414.74
	(0.69)
χ^{2s}_{nd}	3.87
	(0.42)
χ^{2k}_{nd}	8.12
	(0.044)
χ^{2j}_{nd}	10.43
	(0.11)

Note: p-values are in parenthesis.

4.6 Stability Tests

Model instability may be caused by some regime shifts. Hansen (1992) discusses various tests for stability. One of the most common tests for stability seems to be Chow's (1960) simple split sample test. In Chow's test, the null hypothesis of parameter constancy versus shift in the parameters at some known time is tested. Therefore, the shortcoming of the test is that we can not always know the shift time. A second method is to calculate the estimates using the subsample of the data and compare this with the estimates using full sample. A third method uses dummy variables for intercept and slope parameters than test the significance of the dummies.[91] About testing stability, See Farley and Hinich (1970), Ashley (1984), Hansen (1992) and Hansen and Johansen (1993).

In order to check the appropriateness of the estimated VAR and VECM specification for stability, the inverse roots of the characteristic AR polynomial is analyzed, see for details Lutkepohl (1991) and Lutkepohl (2005).[92] If all roots have modulus less than one and lie inside the unit circle, the estimated VAR is stable (stationary). There will

[91] See for the power of the stability tests, Hansen (1991).

[92] VAR part in Lutkepohl (2005) is largely same as Lutkepohl (1991).

be *kp* roots, where *k* is the number of endogenous variables and *p* is the largest lag. If VEC model has *r* cointegrating relations, *k*-*r* roots should be equal to unity.[93]

According to Table 4.11 and Figure 4.5, stability condition check results indicate that VECM can be considered as ‘stable’ since VEC specification imposes three unit roots (since four endogenous variables and one cointegrating relationship).

Table 4.11 VEC Stability Condition Check

Root	**Modulus**
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
0.886643	0.886643
0.709397 + 0.501074i	0.868515
0.709397 - 0.501074i	0.868515
-0.002458 + 0.848767i	0.84877
-0.002458 - 0.848767i	0.84877
0.827626 + 0.071123i	0.830677
0.827626 - 0.071123i	0.830677
0.683939 - 0.127809i	0.695778
0.683939 + 0.127809i	0.695778
-0.396355 - 0.540794i	0.670489
-0.396355 + 0.540794i	0.670489
0.205703 - 0.598283i	0.632658
0.205703 + 0.598283i	0.632658
-0.011869 - 0.534092i	0.534224
-0.011869 + 0.534092i	0.534224
-0.523123	0.523123
-0.395935	0.395935

Note: VEC specification imposes 3 unit root(s).

[93] See Eviews 7 User Guide II.

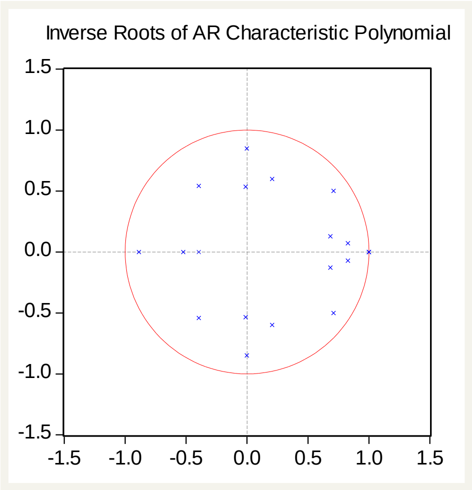


Figure 4.5 Inverse Roots of AR Characteristic Polynomial

Chow test, CUSUM and CUSUMSQ tests are also applied for the stability check (Enders, 2010). The main problem with the Chow test and its variants is that they require a known break point. A method that does not require knowledge of the break point can be more appropriate. The simplest solution to this problem can be recursive estimate. Enders (2010) explains the method with an example such as, consider 150 observations, estimate the model using first, say 10 observations, plot the coefficients, than estimate the model using 11 observations than plot, repeat this estimate until all observations are used up. At each step, calculate the one-step – ahead forecast error. Let $e_t(1)$ is the difference between y_{t+1} and $E_t y_{t+1}$. If the model fits the data well, than the sum of the forecast errors should be near zero. In this case, Brown, Durbin and Evans (1975) calculate whether the cumulated sum of the forecast errors is statistically different from zero. Defined as:

$$CUSUM_N = \sum_{i=n}^{N} e_i\,(1)/\sigma_e \qquad N = n, \ldots \ldots \ldots \ldots, T-1 \qquad \textbf{(4.8)}$$

In equation (4.8), n denotes the first forecast error, while T denotes the last observation. σ_e is the estimated standard deviation of the forecast errors. The original CUSUM test is introduced by Brown, Durbin and Evans (1975) based on cumulative sums of recursive residuals. Ploberger and Kramer (1992) propose a CUSUM test based on cumulated sums of least-squares residuals. CUSUMQ test can be calculated by using squared error that helps to detect changes in the variances.

Figure 4.6 presents the plot of CUSUM and CUSUMSQ at 5% level of significance below. The plot of the CUSUM and CUSUMSQ show stability of the demand for money function during the period 1980:2010.

As the money demand literature emphasizes on the stability properties of Euro Area money demand, the studies after 2001 could not find evidence of stability in main money demand equation. This study shows the stable money demand equation in the Euro Area for 1980-2010 periods. However, short run estimates of GDP in money demand equation has positive sign but it is found insignificant. These conflicting results may be due to nonlinearity which is observed and presented in Chapter 5.

Stability Tests

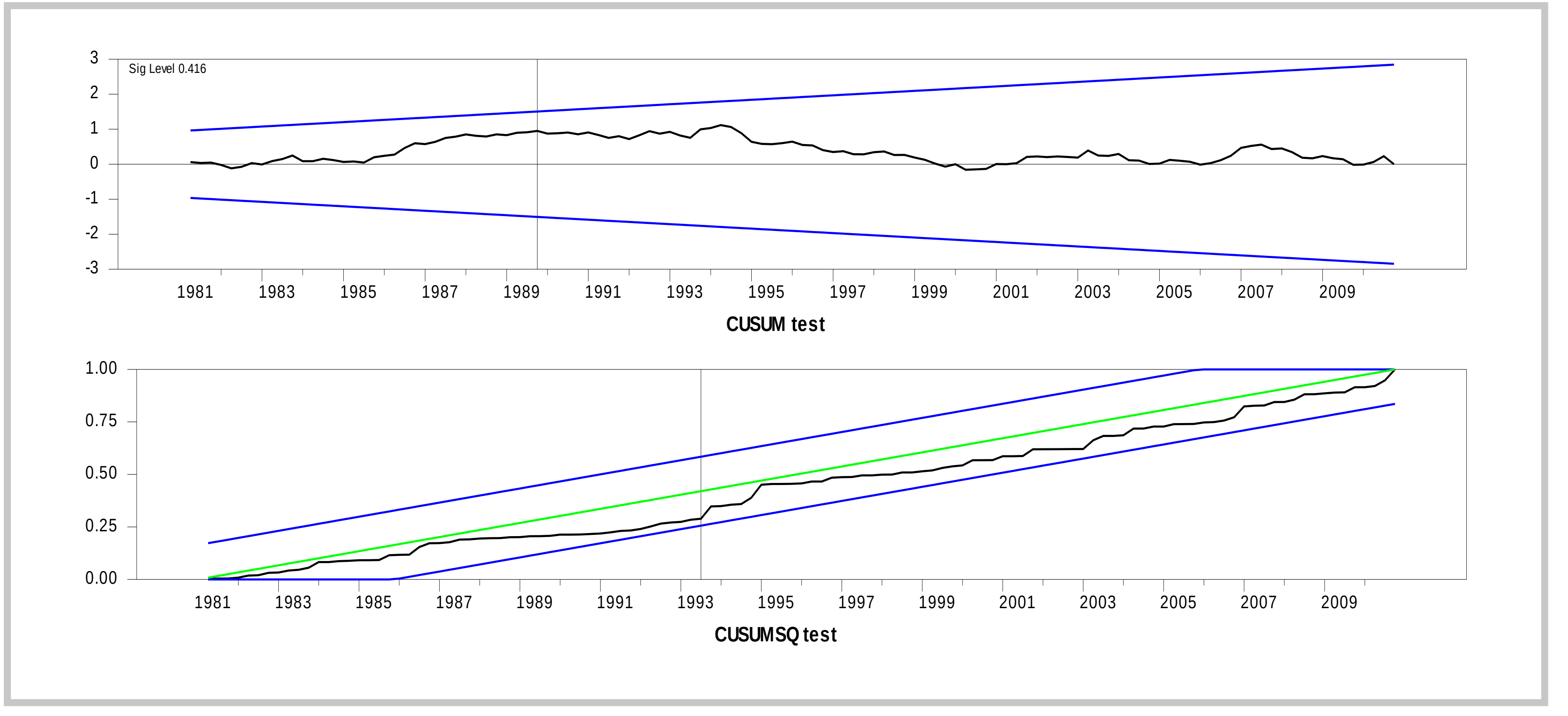


Figure 4.6 CUSUM of squares of the error correction model

4.7 Impulse Response Analysis

Macroeconomic models are used not only for forecasting but also for policy analysis. For policy analysis, it is important to know how sensitive the economic variables to economic shocks. Interpreting the VAR and VEC model estimates is not simple. Impulse response functions measure the persistence and effect of shocks on future values of series. The dynamic properties of the models are investigated by impulse response functions (IRF). The shape of the impulse response functions can indicate whether the dynamic responses of the variables confirm to theory (Enders, 2010).[94] In this section, the IRFs are interpreted for linear VEC models.

In linear IRFs, the dynamic analysis are independent from the sign, size and history of the shocks. Because the IRFs give the response to a one-time impulse in other variable with all other variables dated t or earlier are held constant. The ordering of the variables in y is chosen such as $(m-p)_t, gdp_t, \Delta p_t, R^s)$.

Figure 4.7 examines the dynamic effects of money demand, income, inflation and interest rates to one standard error shock in each variable. The graphs in the first row of Figure 4.7 give the responses of money demand. The responses of money demand to the money demand shock shows a cyclical pattern; its impact response is 1% and declines sharply to -0.2% around 3rd quarter, than rise to around 0.2% and finally gradually tends towards 0 at around 20th quarter. In second graph, the responses of money demand to income shock shows again cyclical pattern; its impact response decline to -0.4% from 0 than goes to positive around 4th quarter and dies out after about 15th quarter. In the third graph, the response of money demand to inflation shock decreases to -0.2% from 0 at 1st quarter. Then rises to 0.15% around 5th quarter and than the effect of shock dies out after about 15th quarter. In the last graph, the response of money demand to interest rate shock declines sharply to -0.15% around 3rd quarter, than rise to 0.1% around 5th quarter and dies out after about 20th quarter.

Second row of the Figure 4.7 gives the responses of income to various shocks. The response of income to money demand shock is positive than dies out fastly. The

[94] See Pesaran and Shin (1998); Akbostancı (2004); Ismihan and Metin-Özcan (2009); Wang and Dunne (2003) for the implications of the impulse response analysis.

response of income to income shock is first positive at 0.5% level than declining but still positive than dies out. The response of income to inflation shock is positive but small and dies out rapidly. The last graph presents the response of income to interest rate shock which is positive at first quarters but small than dies out rapidly.

Third row of the Figure 4.7 gives the responses of inflation. The response of inflation to money demand shock is first -0.5% than increases to 0.4% around 5th quarter, than declines to negative around 10th quarter and dies out after 20th quarter. The response of inflation to income shock rise to 0.15% at 1st quarter than goes to negative around 5th quarter. After 10th quarter the response becomes positive but near 0 than dies out. The response of inflation to inflation shock is first positive around 0.5% but decreasing sharply until 5th quarter, to -0.25%. Than it increases to 0.1% level and finally gradually tends towards 0. In fourth graph, the response of inflation to interest rate shock is first positive around 0.25%, than decreases sharply to -0.30% around 5th quarter. It increases to 0.1% around 10th quarter than decreases again and finally tends towards 0 after 20th quarter.

Last row of the Figure 4.7 presents the responses of interest rate. The response of interest rate to money shock is first negative around -0.014% than increases around zero than dies out after 15th period. The response of interest rate to income shock is first positive around 0.1% than declines slowly to zero. The response of interest rate to inflation shock is positive but small in first quarters. Than dies out rapidly. Finally the response of interest rate to interest rate shock is first rises till 40%, than tends to zero rapidly after 5th quarter and goes around zero until 30rd quarter. The response of interest rate verifies the short-run model for the interest rate equation in Table 4.17 that none of the variables in the system contributes to the explanation of the interest rate equation.

Similar IRFs can be seen in Figure 4.8., which displays the model that takes the interest rate as exogenous. The sign and the size of two impulse responses do not much differ. Comparison of the IRFs for linear VEC model and nonlinear threshold VEC model can be found in Chapter 5, Section 5.2.

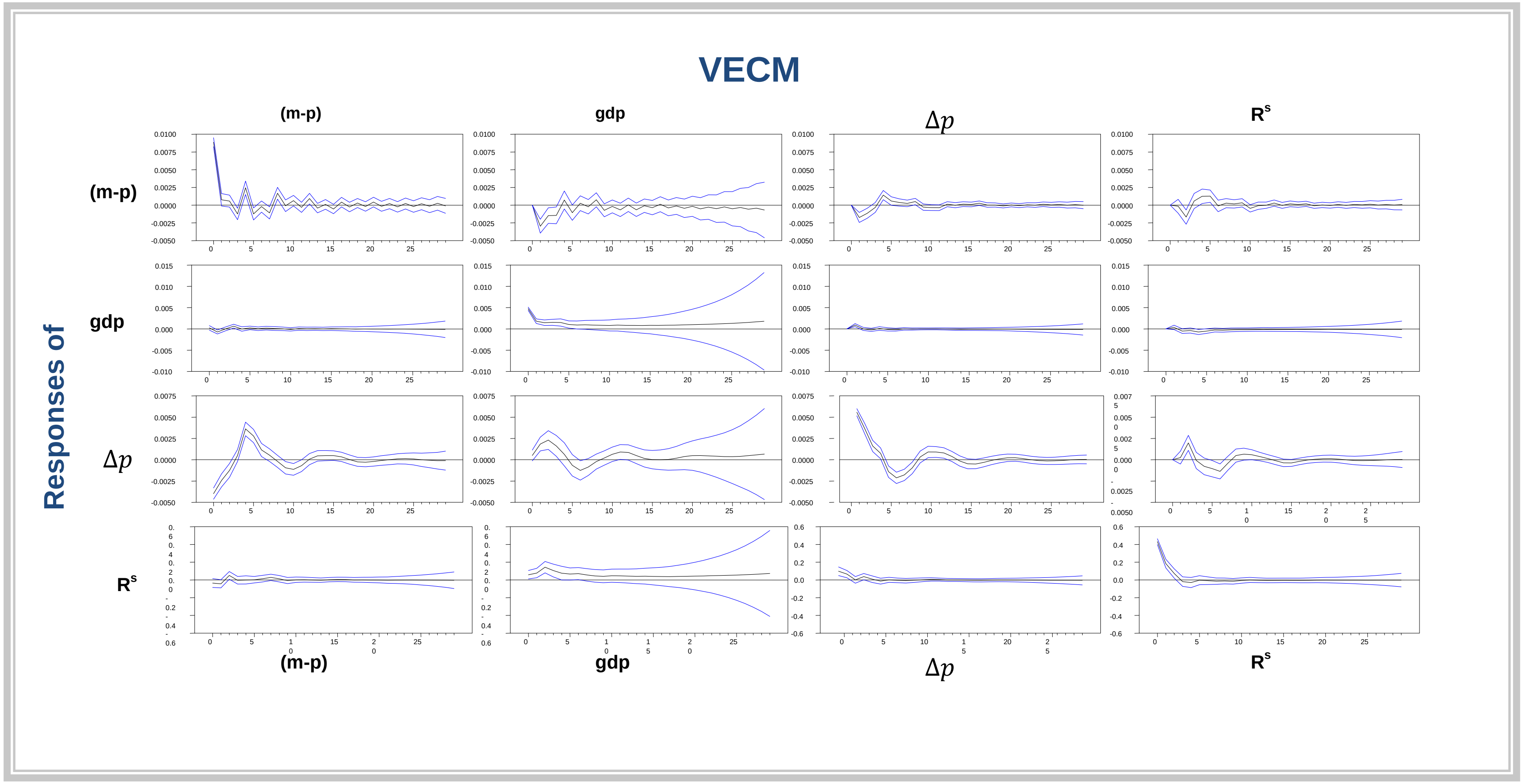


Figure 4.7 Impulse Responses to One S.D. shock (interest rate is endogenous)

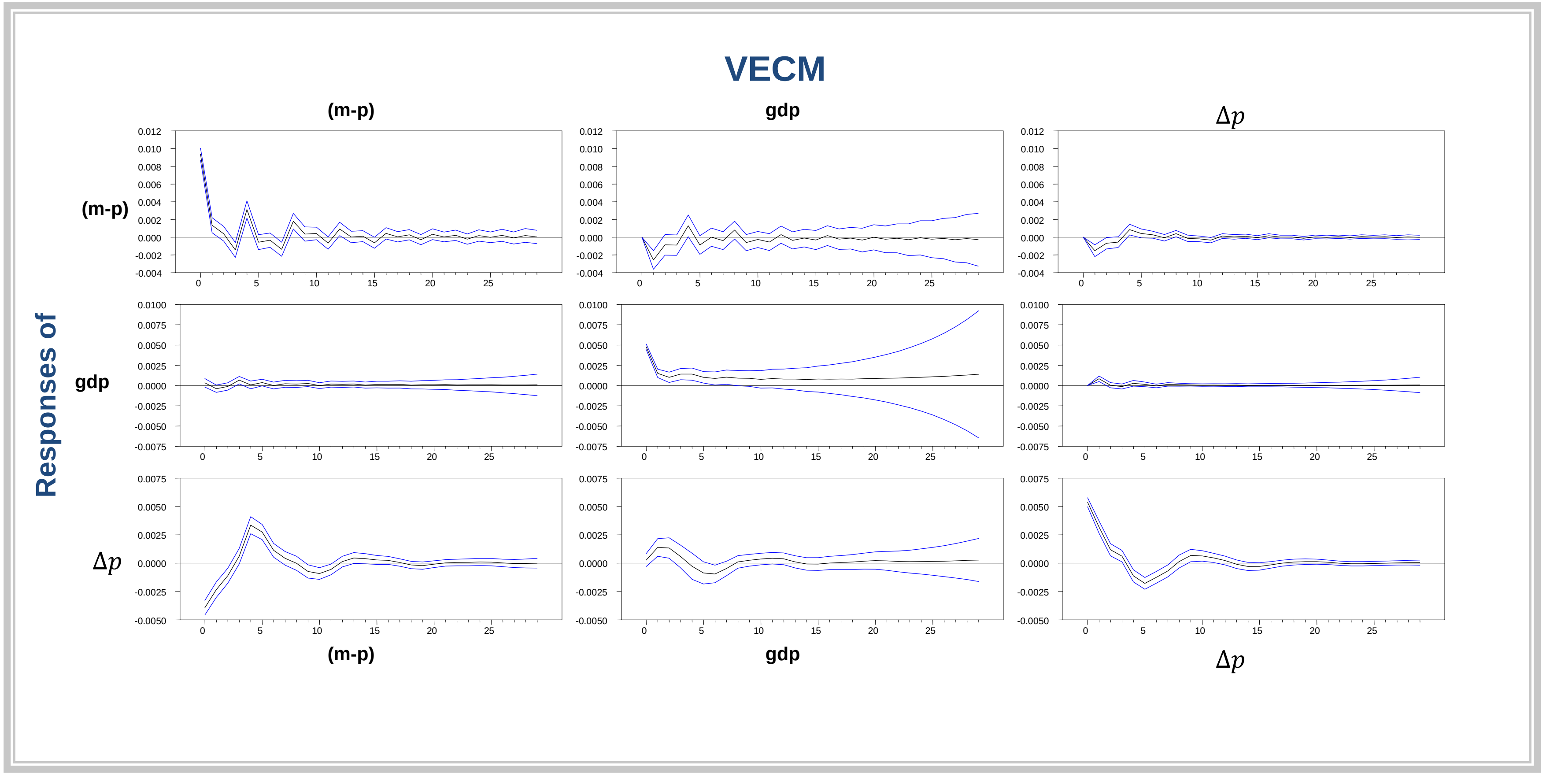


Figure 4.8 Impulse Responses to One S.D. shock (interest rate is exogenous)

4.8 Conclusion

In this chapter, the demand for money in the Euro Area is modelled by employing vector autoregressive and vector error correction modelling approaches which are discussed in Chapter 3. After one cointegrating relationship is found, the money demand is modelled using VECM. Adjustment coefficient is relatively higher than the literature. Afterwards, the dynamic properties of the model is analyzed by using impulse response functions. The life of shocks ranges from approximately 10 to 20 quarters that is between 2.5 to 5 years. As such, the transitory period is rather short. The speed of convergence to the long run equilibrium is slow and in some cases, it takes as long as 5 years for convergence or error correction to be completed.

In contrast to the literature, this study finds stable relationship for European money demand for period 1980-2010. However, the literature suggests after the introduction of the Euro, 2001, the money demand model become unstable. Results of earlier literature may be due to the data set, methodology employed in the analysis.

However, if the functional form is misspecified as it is in the previous literature where mostly linear models are employed, it is not surprising to have mixed results depending on the data set. We therefore investigate the possible nonlinear relationship in money demand in the next chapter.

CHAPTER 5

RESULTS OF VECM APPLICATIONS: NONLINEAR (THRESHOLD) MODELS

5.1 Introduction

This chapter provides the empirical results of Threshold VEC models with all variables being endogenous, and comparison with that of the linear VECM results discussed in Chapter 4. We first assume that only long run adjustment coefficient change across two distinct regimes with no change in short run coefficients. Then, both long and short run coefficients are assumed to be changing between two regimes described by TVEC model. We consider both TAR type and M-TAR type dynamics in TVEC models, and therefore co-integration vector obtained in Chapter 4, all variables used in the estimation of money demand function and their first differences are treated to be possible transition variables. The results show strong nonlinearities in all cases confirming the asymmetries in both short and long run dynamics. The best TVECM is the one which uses first lag of error correction term as transition variable and assumes no change in short run dynamics. Hence only results of this model are presented in this chapter.

The plan of the chapter is as follows. Modelling cycle and threshold co-integration model estimates and nonlinear impulse response analysis are given in Section 5.2. Section 5.3 concludes the chapter.

5.2 Threshold Cointegration Modelling

Modelling cycle of TVECM can be outlined as follows:

I. First, use first lag cointegration vector obtained from linear VAR model in Chapter 4 and all other variables to estimate threshold VEC (TVEC) model as outlined in Section 3.3.2 under the assumption that only long run adjustment coefficients change across regimes.
II. Repeat modelling sequence in Step I. However, this time, allow both short run and long run dynamics to change across two regimes.
III. Repeat step I&II to estimate momentum threshold VEC models with transition variables being first differences of cointegrating vector, money demand, income, inflation and interest rates as alternatives for each other. Estimate corresponding models assuming short run parameters do not change and change while adjustment coefficient changes in both cases. Select the best model using AIC, SIC and SSR.
IV. Use General Impulse Responses Functions (GIRF) analysis to uncover the dynamics exhibited following a shock to the system. Here we follow two different approaches for GIRF's. In the first one, since we have money demand model for each regime, we apply GIRF's for both of them separately. Second we use simulation approach and consider the both system dynamics altogether, as a shock in any of the regime may lead a shift to other regime and vice-versa. This leads to bivariate GIRF's which may cover shocks in both upper and lower regimes.

5.2.1. Empirical Results

Our estimated models are given below in equation (5.1), (5.2), (5.3) and (5.4) with the indicator function of equation (5.5). AIC and SIC values corresponding to estimated models are presented in Table 5.1. These statistics and our own analysis show that Momentum-TVEC model with first lag of error correction term and with only change in long run adjustment coefficient provides the best fit[95]. We therefore present the results of this model and focus on the equation (5.1) whose dependent variable is money demand.

Table 5.1 Akaike (AIC) and Schwarz (SIC) Information Criteria for Model Selection		
(Transition variable is error correction term)		
	AIC	**SIC**
Linear VECM	-21.46	-19.69
TAR Model	-3853.53	-3814.74
M-TAR Model	-3853.53	-3814.74
TAR Consistent Model	-3886.77	-3847.98
M-TAR Consistent Model	**-3910.70**	**-3871.91**

The threshold cointegration model under the assumption of change only in long-run adjustment coefficients:

$$\Delta(m-p)_t = \beta_{01} + \sum_{i=1}^{p}\beta_{1i}\Delta(m-p)_{t-i} + \sum_{i=1}^{p}\vartheta_{1i}\Delta gdp_{t-i} + \sum_{i=1}^{p}\delta_{1i}\Delta^2 p_{t-i} + \sum_{i=1}^{p}\gamma_{1i}\Delta R^s_{t-i} + \sum_{t=1}^{k}D_t + \rho_{01}I_t\hat{\varepsilon}_{t-1} + \rho_{02}(1-I_t)\hat{\varepsilon}_{t-1} + v_{0t} \quad \textbf{(5.1)}$$

$$\Delta gdp_t = \beta_{02} + \sum_{i=1}^{p}\beta_{2i}\Delta(m-p)_{t-i} + \sum_{i=1}^{p}\vartheta_{2i}\Delta gdp_{t-i} + \sum_{i=1}^{p}\delta_{2i}\Delta^2 p_{t-i} + \sum_{i=1}^{p}\gamma_{2i}\Delta R^s_{t-i} + \sum_{t=1}^{k}D_t + \rho_{11}I_t\hat{\varepsilon}_{t-1} + \rho_{12}(1-I_t)\hat{\varepsilon}_{t-1} + v_{1t} \quad \textbf{(5.2)}$$

$$\Delta^2 p_t = \beta_{03} + \sum_{i=1}^{p}\beta_{3i}\Delta(m-p)_{t-i} + \sum_{i=1}^{p}\vartheta_{3i}\Delta gdp_{t-i} + \sum_{i=1}^{p}\delta_{3i}\Delta^2 p_{t-i} + \sum_{i=1}^{p}\gamma_{3i}\Delta R^s_{t-i} + \sum_{t=1}^{k}D_t + \rho_{21}I_t\hat{\varepsilon}_{t-1} + \rho_{22}(1-I_t)\hat{\varepsilon}_{t-1} + v_{2t} \quad \textbf{(5.3)}$$

$$\Delta R^s{}_t = \beta_{04} + \sum_{i=1}^{p}\beta_{4i}\Delta(m-p)_{t-i} + \sum_{i=1}^{p}\vartheta_{4i}\Delta gdp_{t-i} + \sum_{i=1}^{p}\delta_{4i}\Delta^2 p_{t-i} + \sum_{i=1}^{p}\gamma_{4i}\Delta R^s_{t-i} + \sum_{t=1}^{k}D_t + \rho_{31}I_t\hat{\varepsilon}_{t-1} + \rho_{32}(1-I_t)\hat{\varepsilon}_{t-1} + v_{3t} \quad \textbf{(5.4)}$$

$$\boldsymbol{I_t} = \begin{cases} \mathbf{1} & \boldsymbol{if}\ \ \Delta\hat{\boldsymbol{\varepsilon}}_{\boldsymbol{t-1}} \geq \tau \\ \mathbf{0} & \boldsymbol{if}\ \ \Delta\hat{\boldsymbol{\varepsilon}}_{\boldsymbol{t-1}} < \tau \end{cases} \quad \textbf{(5.5)}$$

[95] The details of the models in Table 5.1 are discussed in Chapter 3. Therefore, there is no reason to assume that threshold parameter, τ , is equal to zero in our case. But to follow the modelling sequence in Enders and Granger (1998), we opt for to start with this assumption and compare all models.

Table 5.2 Momentum TAR Consistent Model		
	coefficients	**p-value**
Δmp_{t-1}	-0.020	0.804
Δmp_{t-2}	-0.026	0.749
Δmp_{t-3}	-0.182	0.020
Δmp_{t-4}	0.420	0.000
Δgdp_{t-1}	-0.557	0.004
Δgdp_{t-2}	0.0004	0.999
Δgdp_{t-3}	-0.005	0.980
Δgdp_{t-4}	0.331	0.093
$\Delta^2 p_{t-1}$	-0.299	0.015
$\Delta^2 p_{t-2}$	0.131	0.326
$\Delta^2 p_{t-3}$	-0.101	0.417
$\Delta^2 p_{t-4}$	0.170	0.119
ΔR^s_{t-1}	0.000	0.853
ΔR^s_{t-2}	-0.003	0.231
ΔR^s_{t-3}	0.003	0.172
ΔR^s_{t-4}	0.000	0.812
$I_t\hat{\varepsilon}_{t-1}$	**-0.097**	**0.009**
$(1-I_t)\hat{\varepsilon}_{t-1}$	**-0.107**	**0.004**
C	0.019	0.000
D2008	0.026	0.009
D902	0.037	0.000
D20021	-0.023	0.024
D841	-0.017	0.070
D20003	-0.028	0.005
D20004	-0.027	0.007
S1	-0.014	0.009
S2	-0.011	0.004
S3	-0.009	0.090
threshold value (τ): -0.00224		

The empirical results of M-TAR model with consistent estimation of threshold are presented in Table 5.2. As seen, we have two different and significant adjustment coefficients for two regimes. The negative signs of estimated adjustment coefficients provide evidence of convergence in both regimes. Two distinct adjustment coefficients with transition variable, $\Delta\hat{\varepsilon}_{t-1}$, implies that the series present more 'momentum' in one direction than the other as M-TAR dynamics can mimic the possibility of asymmetrically 'sharp' movements in the series.[96] Test results verify asymmetric structure by strongly rejecting the following null hypothesis:

$$H_0: \rho_1 = \rho_2 = 0 \qquad \textbf{(5.6)}$$

$$H_0: \rho_1 = \rho_2 \qquad \textbf{(5.7)}$$

Hypothesis in equation (5.6) is an F-test which has a nonstandard distribution, and the test statistics are denoted as ϕ_μ^* for M-TAR specification. Second hypothesis entails the detection of the possible asymmetry within the cointegration relationship and is carried out by testing the null hypothesis in (5.7) with a standard F-test.

The value of the F-test, ϕ_μ^*, for testing (5.6) is 12.51. When compared with the values reported in Enders and Granger (1998), these values allow us to reject the null hypothesis of no cointegration at almost 1% significance level. The second hypothesis in (5.7) of symmetric adjustment can be rejected nearly at 1% significance level. It is worth to note that these two hypotheses are rejected very significantly for all models estimated in this study.

The adjustment coefficients of lower and upper regimes are close to the one in linear model. Although the coefficient -0.13 of linear model implies nearly same adjustment, the model has some conflicting results according to the economic theory. Adjustment coefficients is -0.107 in low regime (below threshold, $\Delta\hat{\boldsymbol{\varepsilon}}_{\boldsymbol{t-1}} < -0.00224$) and -0.097 in upper regime (above threshold, $\Delta\hat{\boldsymbol{\varepsilon}}_{\boldsymbol{t-1}} \geq -0.00224$) imply nearly same adjustments. Moreover, in lower regime, equilibrium adjustment is faster compared to upper regime.

[96] As stated in Enders and Dibooglu (2001) "Hansen (1997) present a purely statistical argument for M-TAR adjustment. If $\{\mu_{t-1}\}$ is a near unit root process, setting the Heaviside indicator using $\Delta\mu_{t-1}$ can perform better than the specification using pure TAR adjustment."

Table 5.3 Momentum TAR Consistent Model		
	coefficients	**p-value**
Δmp_{t-3}	-0.232	0.000
Δmp_{t-4}	0.326	0.000
Δgdp_{t-4}	0.427	0.013
$\Delta^2 p_{t-1}$	-0.330	0.000
ΔR_t^s	-0.003	0.08
$I_t\hat{\varepsilon}_{t-1}$	**-0.05**	**0.092**
$(1-I_t)\hat{\varepsilon}_{t-1}$	**-0.109**	**0.000**
C	0.018	0.000
D2008	0.031	0.002
D902	0.029	0.001
D20021	-0.017	0.085
D841	-0.025	0.006
D20003	-0.026	0.005
D20004	-0.025	0.007
S1	-0.018	0.000
S2	-0.012	0.000
S3	-0.009	0.068
threshold value (τ): -0.00224		

It is important to note that although the speed of adjustment towards long run equilibrium in linear and nonlinear models discussed above do not show high differences, the reduced form of nonlinear specification show important differences. Table 5.3 provides the estimation results of reduced form Momentum TAR model. As seen, both coefficients are significant and negative implying convergence. Moreover, adjustment coefficient corresponding to upper regime is -0.05 implying quite slow adjustment process compared with both linear and lower regime of the nonlinear model. It seems that the adjustment speed in the lower regime is close to the one observed in the linear model. Generally speaking, when in the lower regime the effectiveness of economic policies to establish the equilibrium is quite strong though its effects are higher than upper regime suggesting the strong asymmetries in money demand function and therefore effects of the economic policies.

The comparison of diagnostic test results for Momentum TAR and reduced form of Momentum TAR models are presented in Table 5.4 below. Q(4) is the Ljung-Box Q test for serial correlation in order 4, JB is Jarque-Bera Normality test, Sk is skewness, Ku is kurtosis, AIC gives Akaike Information Criterion, SIC is Schwarz Information

Criterion and p values of the test statistics are given in Table 5.4. Diagnostic test results show there is no normality and autocorrelation problem in the models.

Table 5.4 Threshold Cointegration Diagnostic Test Results

	Momentum TAR Model	**Reduced Momentum TAR Model**
Q(4)	0.176	0.672
JB	0.913	0.610
Sk	0.854	0.608
Ku	0.709	0.410
AIC	-3910.70	-4077.59
SBC	-3871.91	-4038.22

The next step is GIRF. As detailed in Step IV, we follow two different approaches for GIRFs. First one is two separate functions for lower and upper regimes. Corresponding IRFS graphs are given in Figures 5.1 and 5.2.

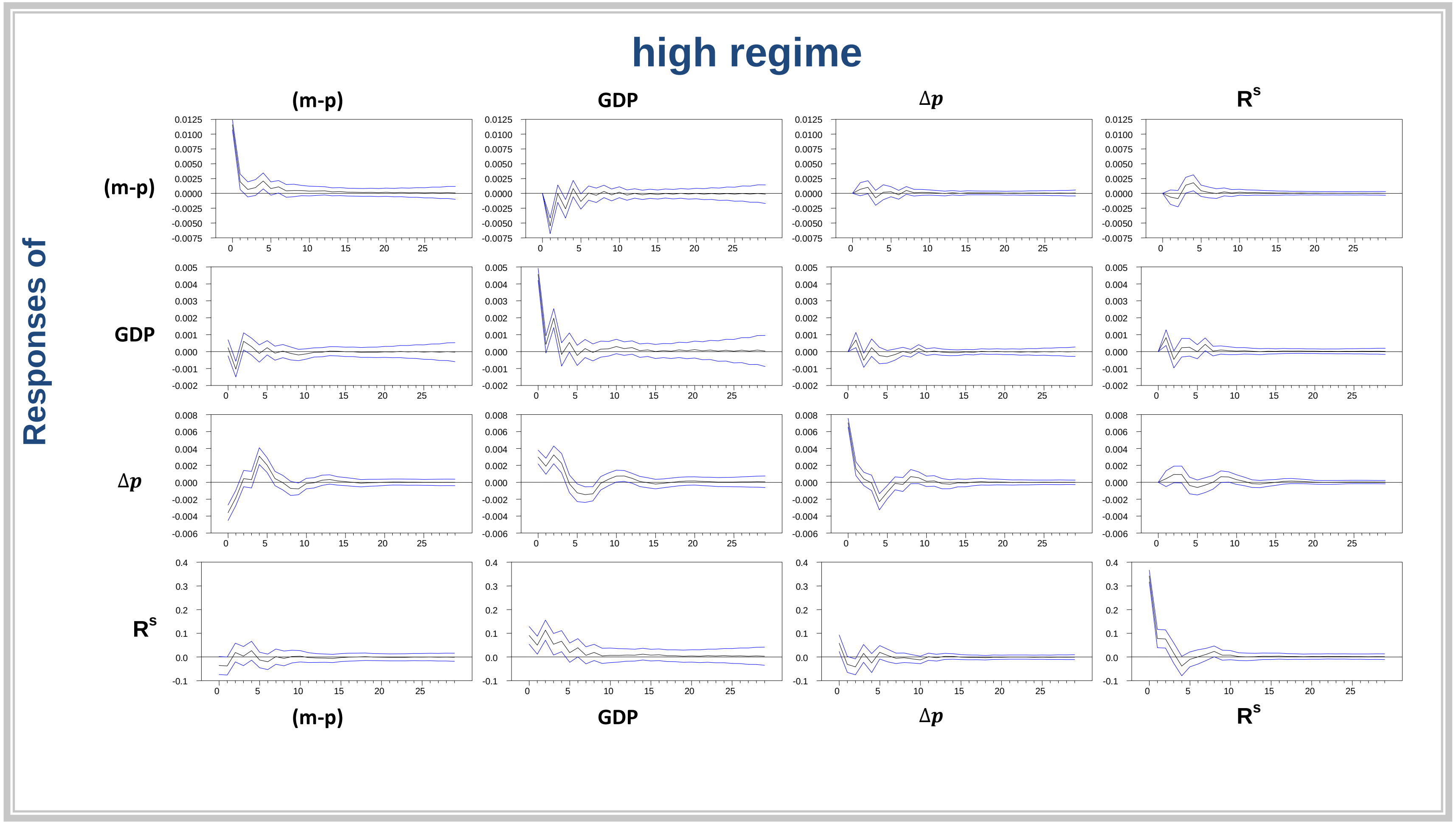


Figure 5.1 Impulse Responses (for high regime)

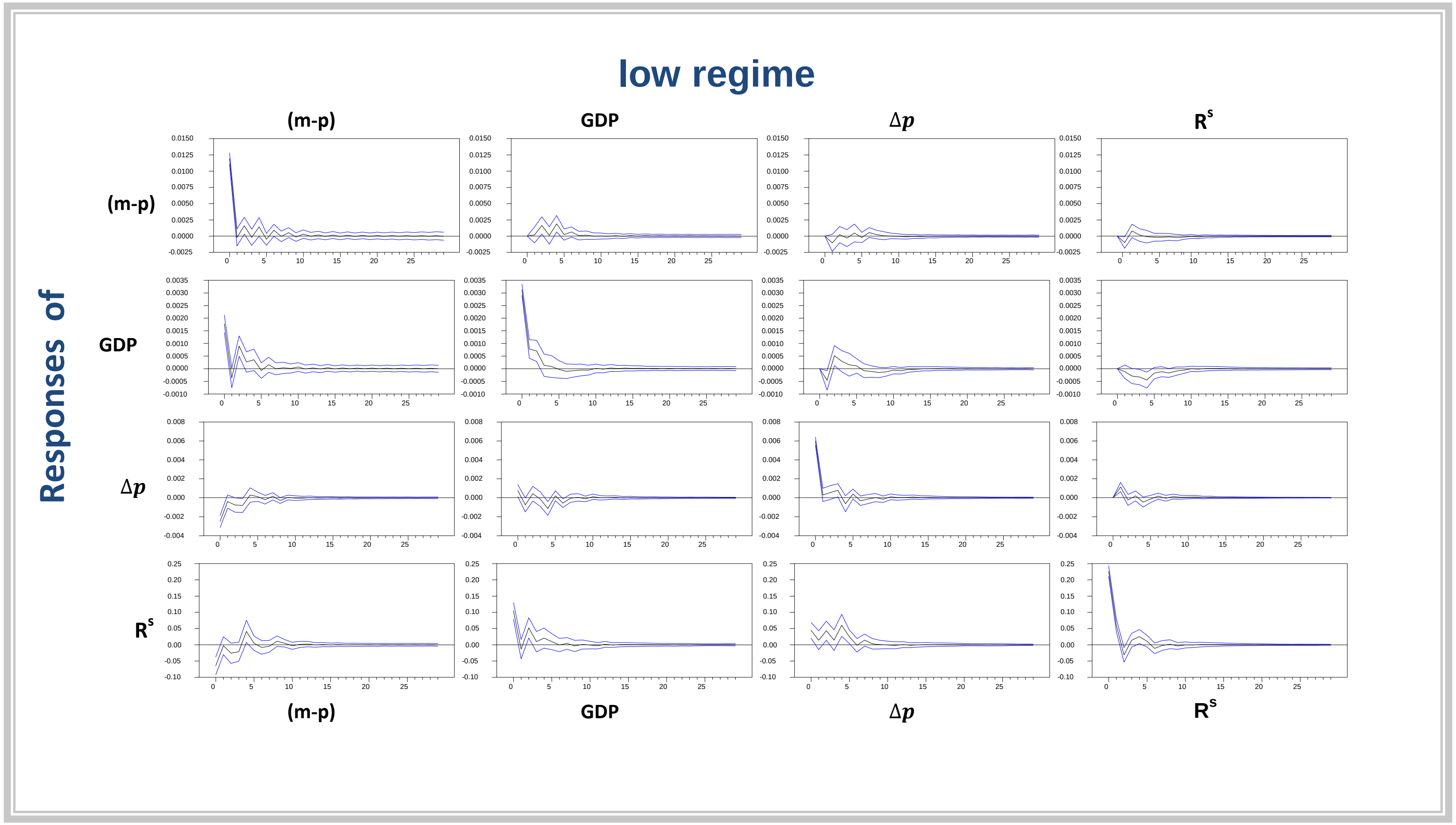


Figure 5.2 Impulse Responses (for low regime)

Figure 5.2 shows asymmetries following one standard deviation shock which die out in a shorter period in lower regime compared to upper regime model. It is also worth to note that, the response of money demand to one standard deviation shock in GDP is negative in upper regime conflicting with economic theory. The path of the dynamics after the shocks is summarized in Tables 5.5, 5.6, 5.7 and 5.8. As also seen in these tables, although there is some differences in the path as far as the sign is concerned, in all cases shocks die out faster in low regime.

Table 5.5 Responses to Shock in (m-p)

	High Regime				Low Regime			
Period	**(m-p)**	**gdp**	**Δp**	**R^s**	**(m-p)**	**gdp**	**Δp**	**R^s**
1st	0.010	0.0002	-0.0032	-0.0326	0.010	0.0015	-0.0022	-0.057
5th	0.0017	-0.0001	0.0027	0.0219	0.0001	0.0003	-0.0007	-0.018
10th	0.0003	-0.0001	-0.0006	0.0018	-0.0001	0.00008	0.00003	0.0038
15th	0.0001	0.0001	0.0001	-0.0053	0.000004	-0.0000008	0.00001	0.000006
20th	0.00002	-0.00001	-0.00004	0.00027	-0.000005	0.0000	0.00000	0.00007
25th	0.000001	0.000003	0.00002	-0.0002	0.000002	0.000000	0.00000	0.00000
30rd	0.000001	-0.000002	-0.000007	0.000004	-0.00000	-0.00000	0.00000	0.00000

Table 5.6 Responses to Shock in (GDP)

	High Regime				Low Regime			
Period	**(m-p)**	**gdp**	**Δp**	**R^s**	**(m-p)**	**gdp**	**Δp**	**R^s**
1st	0.0000	0.0040	0.0026	0.0791	0.000	0.002	0.000	0.092
3rd	-0.00250	0.001	0.002	0.05	0.0020	0.00025	0.0001	0.05
5th	0.00069	0.00037	-0.0002	0.05641	0.0016	0.00002	-0.0010	0.016
10th	-0.000017	0.000128	0.00025	0.000188	-0.00003	-0.00008	-0.00008	0.0004
15th	-0.000063	-0.000018	-0.0001	0.003419	-0.000009	0.000006	-0.000003	0.00006
20th	0.0000381	0.000014	0.00006	-0.00078	0.000006	0.00001	-0.000006	0.00013
25th	-0.000007	-0.000005	-0.00002	0.000454	0.00000	-0.0000	-0.00000	-0.000
30rd	0.000004	0.000002	0.000007	-0.00019	-0.0000001	0.0000	-0.00000	0.000001

Table 5.7 Responses to Shock in Δp

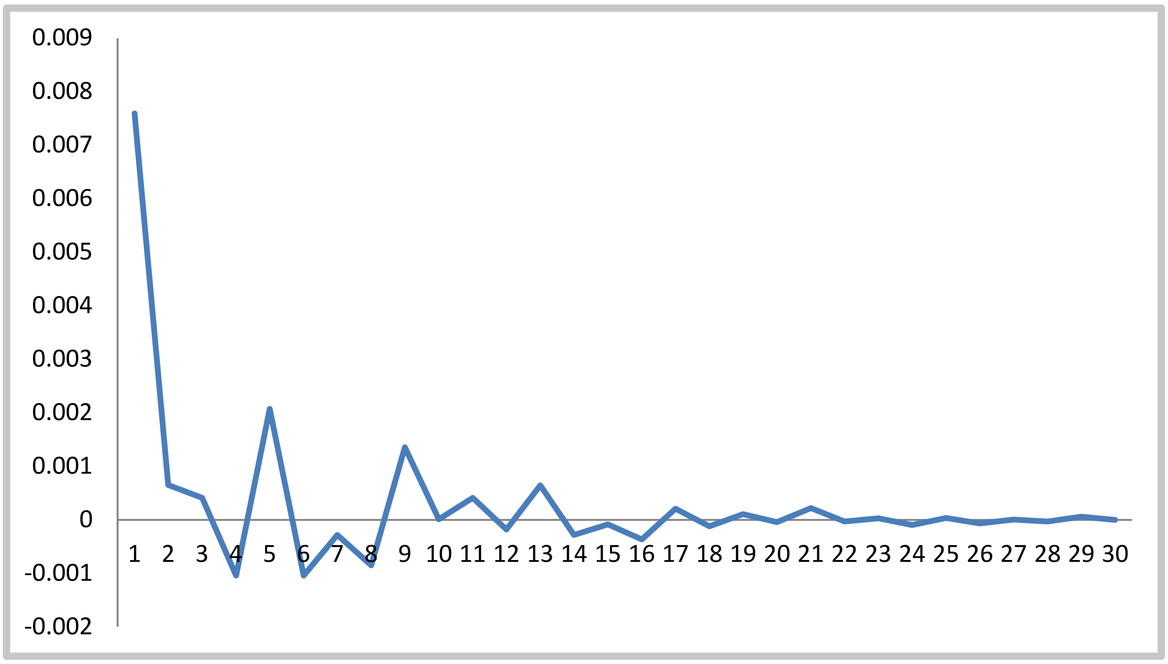
	High Regime				Low Regime			
Period	**(m-p)**	**gdp**	**Δp**	**Rs**	**(m-p)**	**gdp**	**Δp**	**Rs**
1st	0.0000	0.0000	0.0063	0.0524	0.0000	0.0000	0.0053	0.0395
5th	0.000145	-0.00018	-0.0021	-0.02292	0.00041	0.000135	-0.00062	0.052283
10th	0.00009	0.00017	0.000529	-0.00581	0.00005	-0.00011	-0.00016	-0.00027
15th	-0.00005	-0.000036	-0.000072	0.003065	-0.00004	-0.000005	0.000008	-0.00057
20th	0.000007	0.000007	0.000042	-0.00052	0.000005	0.00000	-0.000004	0.000156
25th	0.0000023	-0.000004	-0.000018	0.000086	0.000002	0.00000	-0.0000016	0.000012
30rd	0.00000	0.0000014	0.000006	-0.000066	-0.0000	0.00000	0.0000	-0.000002

Table 5.8 Responses to Shock in (R^s)

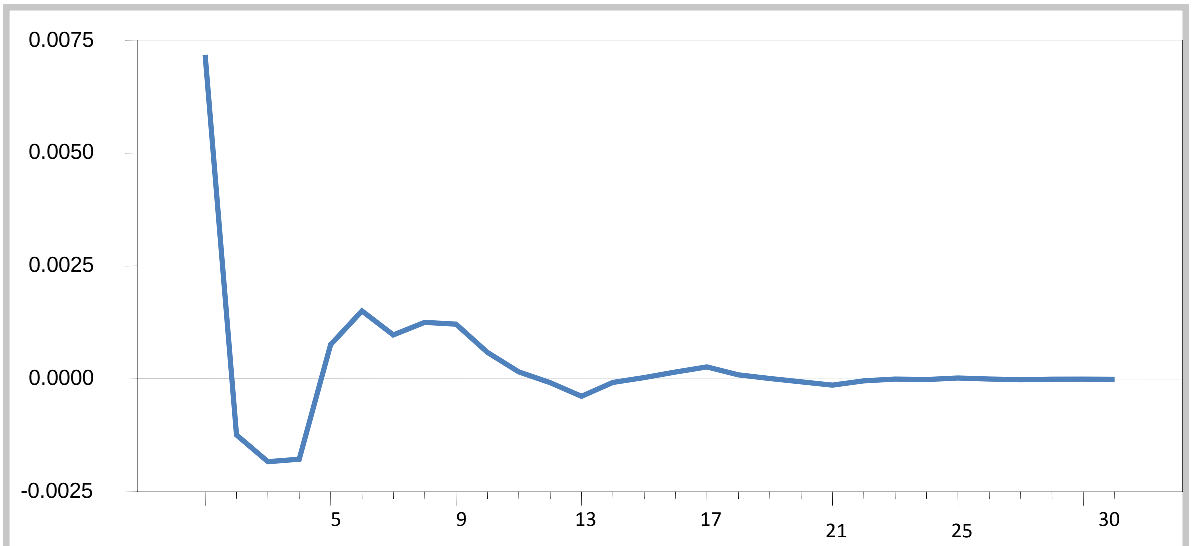
	High Regime				Low Regime			
Period	**(m-p)**	**gdp**	**Δp**	**R^s**	**(m-p)**	**gdp**	**Δp**	**R^s**
1st	0.0000	0.0000	0.0000	0.3042	0.0000	0.0000	0.0000	0.2013
5th	0.001593	0.000223	-0.00034	-0.0377	-0.00011	-0.0004	-0.00041	0.021663
10th	0.00004	0.00001	0.000523	0.004156	-0.00013	-0.00005	0.00002	-0.00415
15th	0.000045	-0.00002	-0.00012	0.000439	-0.000004	0.000008	0.000002	-0.00018
20th	0.000012	0.0000061	0.000036	-0.00053	0.000005	0.0000002	-0.000004	0.000005
25th	0.000007	-0.0000036	-0.000006	-0.000004	-0.0000001	-0.000000	-0.00000	-0.00002
30rd	-0.0000005	0.0000005	0.0000018	-0.000001	-0.00000	0.0000	0.0000	-0.000001

GIRFs presented above are valid under the assumption that when a shock hits the system it does not cause movement from one regime to another. This is a very strict assumption and when it does not hold the dynamics implied by these GIRFs are not valid. To solve this issue we adopt simulation approach which considers possible regime shifts following a shock. This leads to bivariate GIRF's as shown in Figure

5.3, 5.4 and 5.5. These GIRFs do not have confidence bands because, as argued in Rahman and Serletis (2010), since nonlinear generalized impulse responses are expected values which are not random and include conditional expectations, they do not have error bands. In the literature, this is the only study utilizing bivariate GIRFs for threshold VEC models. For ease of comparison, we present GIRFs of linear model without confidence bands and nonlinear models sequentially in Figures 5.3-5.11. We do not give GIRFs corresponding to interest rates because as stated in Chapter 4 Section 4.5 that none of the variables contributes to the explanation of the interest rate equation.

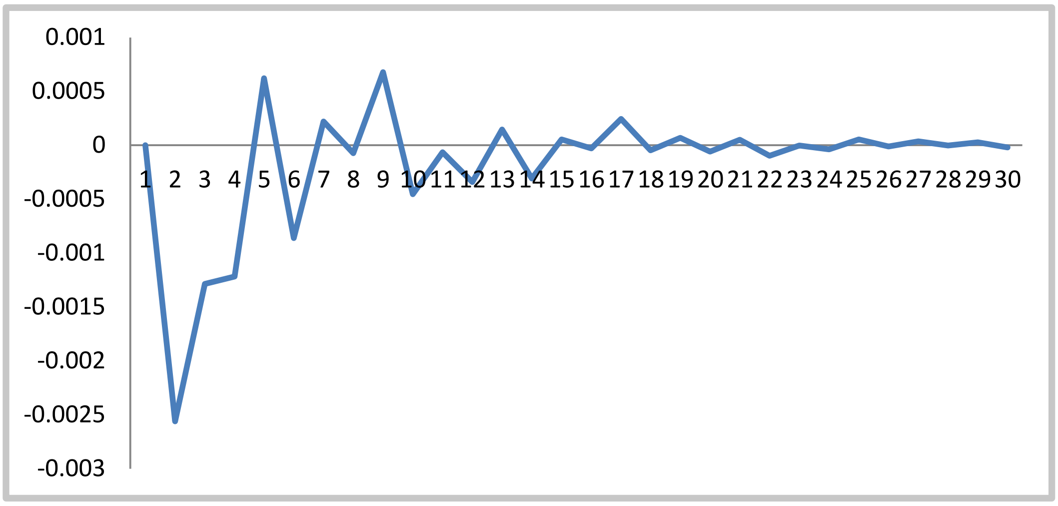


a. Linear IRF for (m-p) to One S.D. Shock in (m-p)

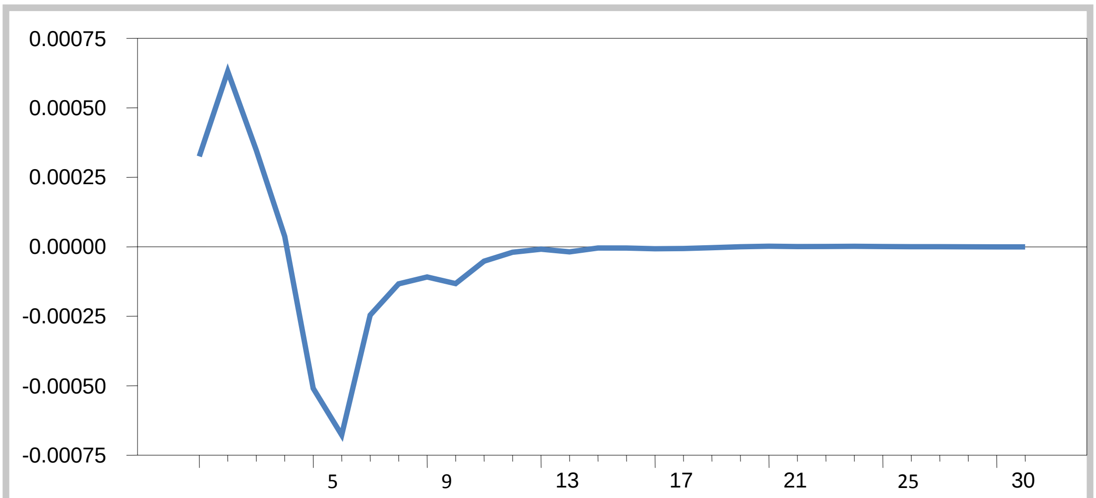


b. GIRF for (m-p) to One S.D. Shock in (m-p)

Figure 5.3 Impulse Responses of (m-p) for One S.D. Shock in (m-p)

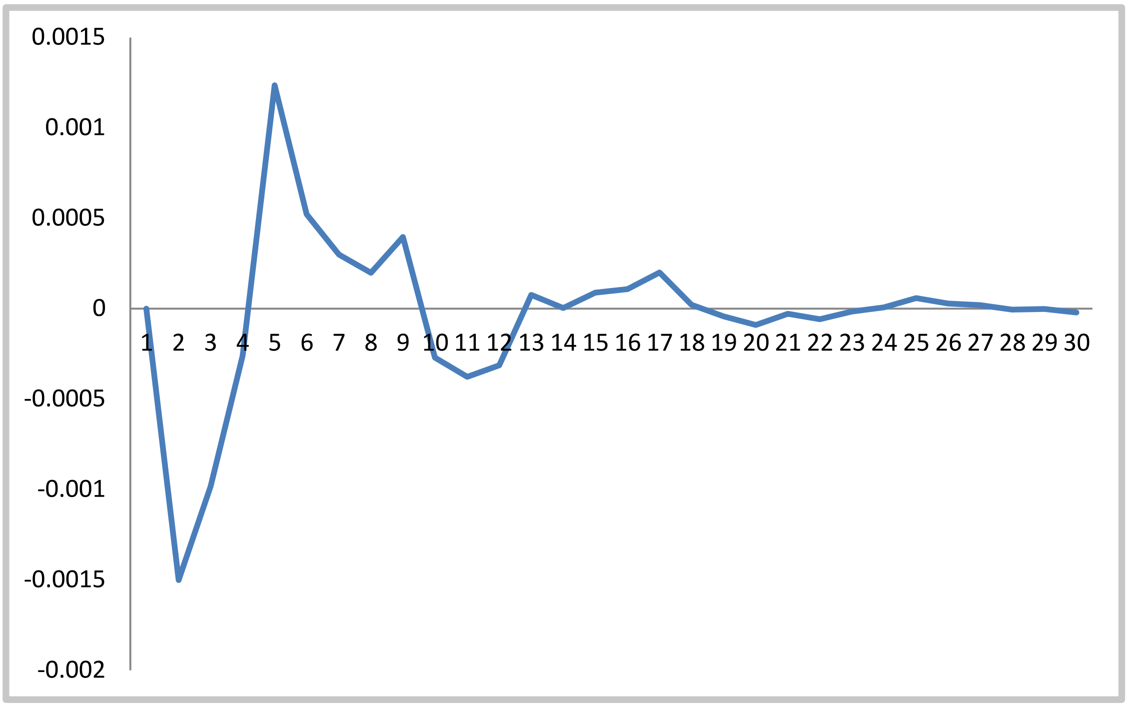


a. Linear IRF for (m-p) to One S.D. Shock in GDP

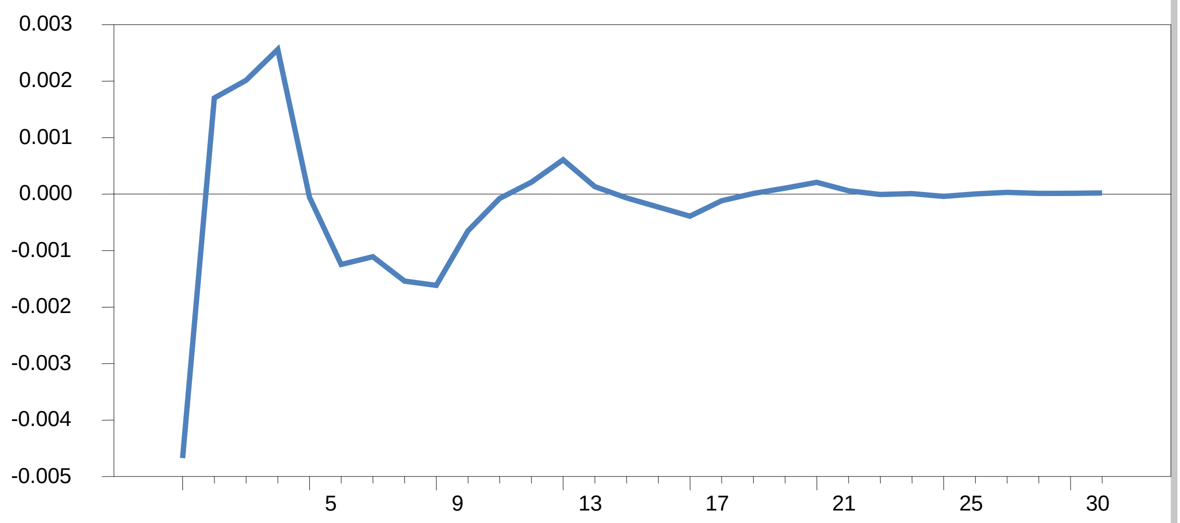


b. Nonlinear GIRF for (m-p) to One S.D. Shock in GDP

Figure 5.4 Impulse Responses of (m-p) for One S.D. Shock in GDP

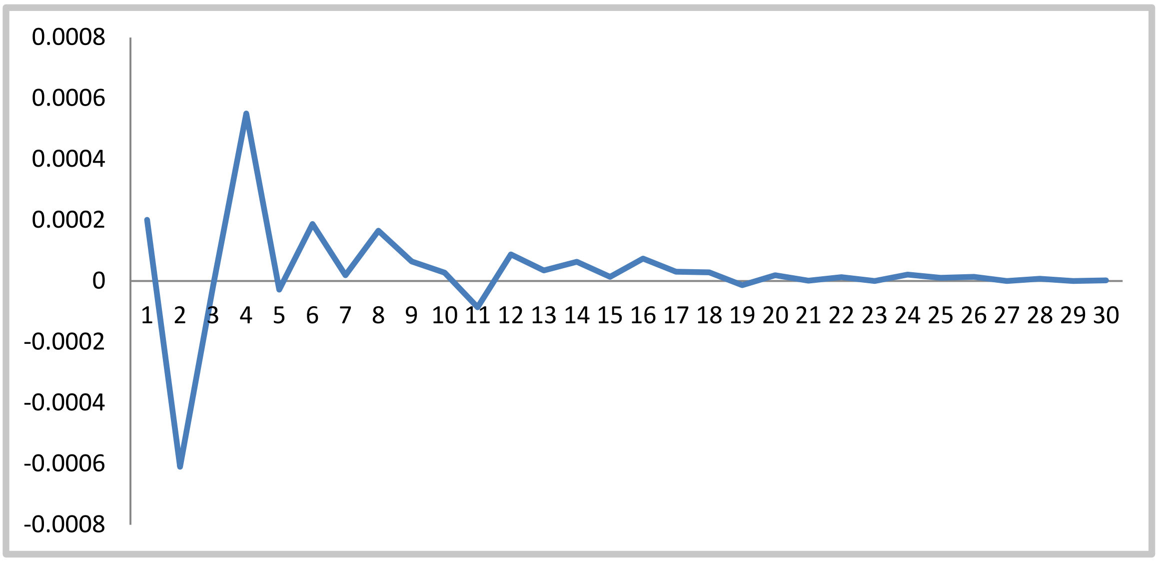


a. Linear IRF for (m-p) to One S.D. Shock in inflation

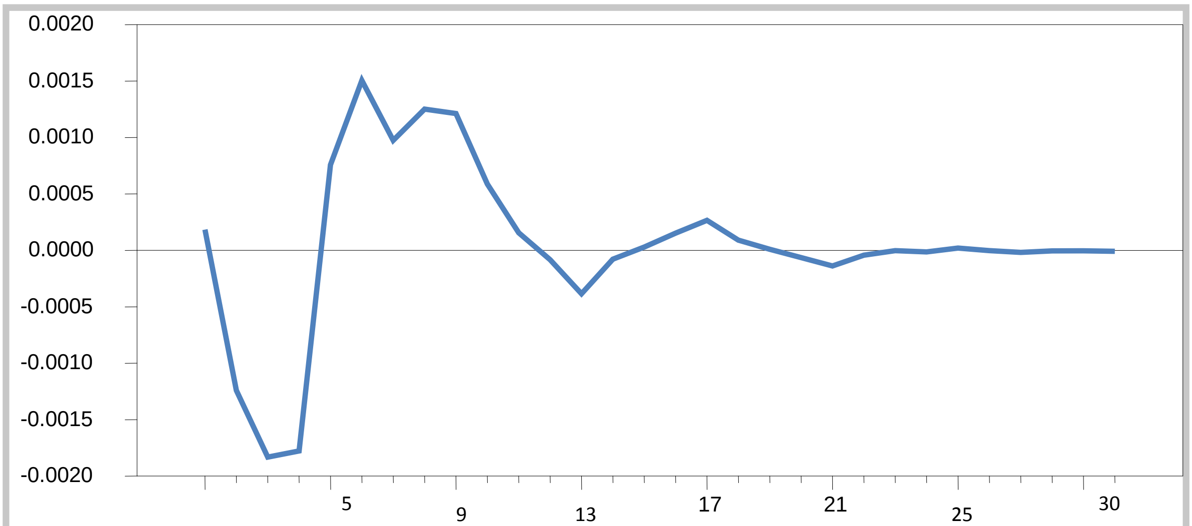


b. Nonlinear GIRF for (m-p) to One S.D. Shock in inflation

Figure 5.5 Impulse Responses of (m-p) for One S.D. Shock in Inflation

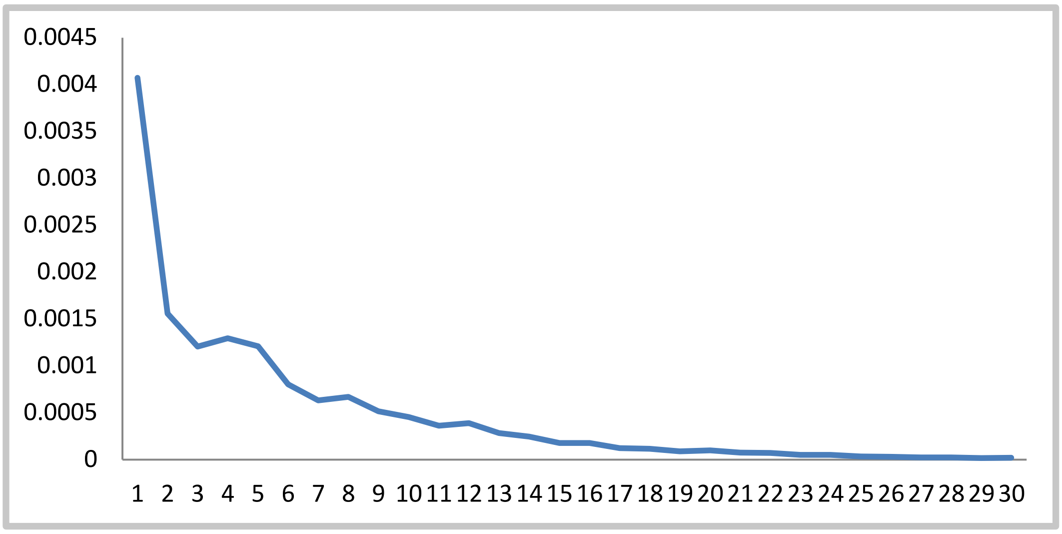


a.Linear IRF for GDP to One S.D. Shock in (m-p)

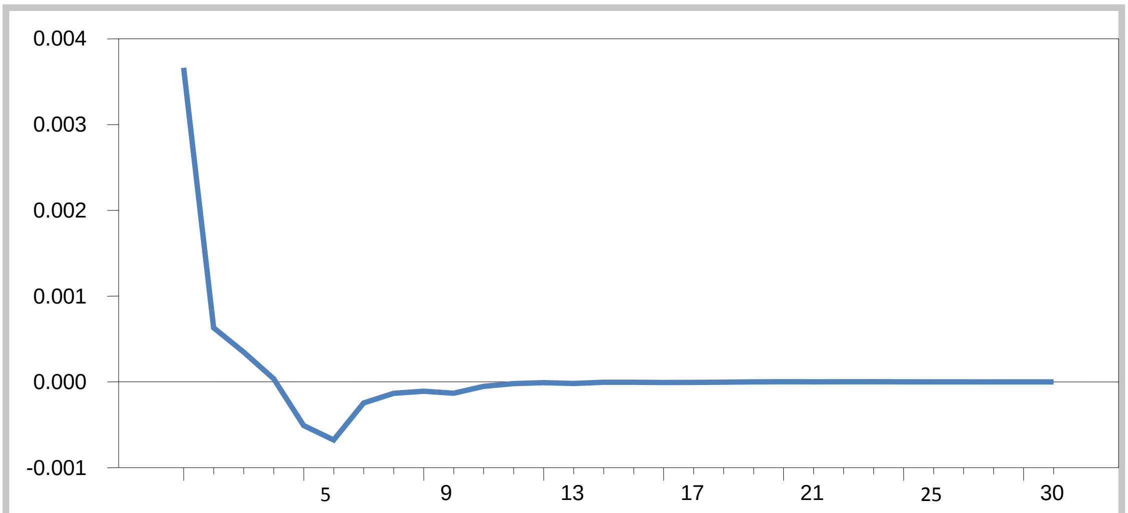


b. Nonlinear GIRF for GDP to One S.D. Shock in (m-p)

Figure 5.6 Impulse Responses of GDP for One S.D. Shock in (m-p)

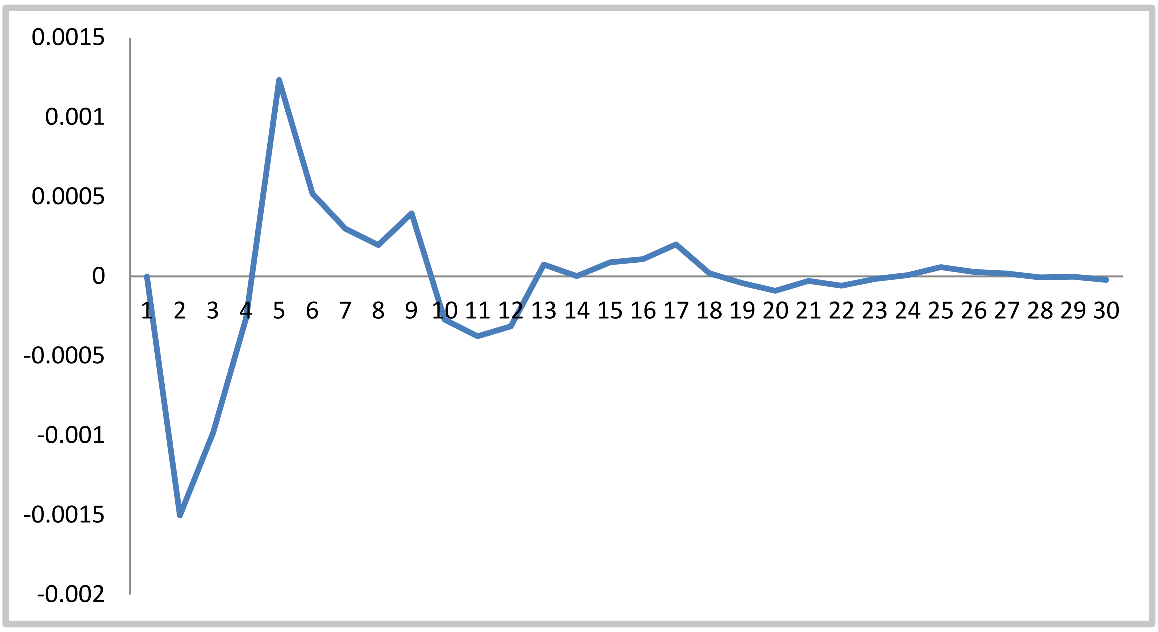


a. Linear IRF for GDP to One S.D. Shock in GDP

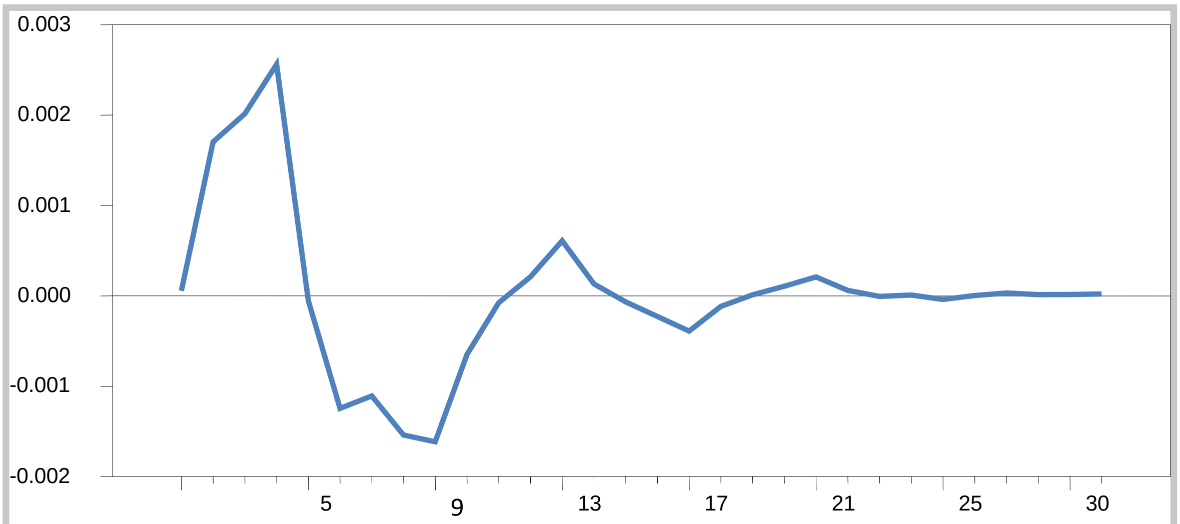


b. Nonlinear GIRF for GDP to One S.D. Shock in GDP

Figure 5.7 Impulse Responses of GDP for One S.D. Shock in GDP

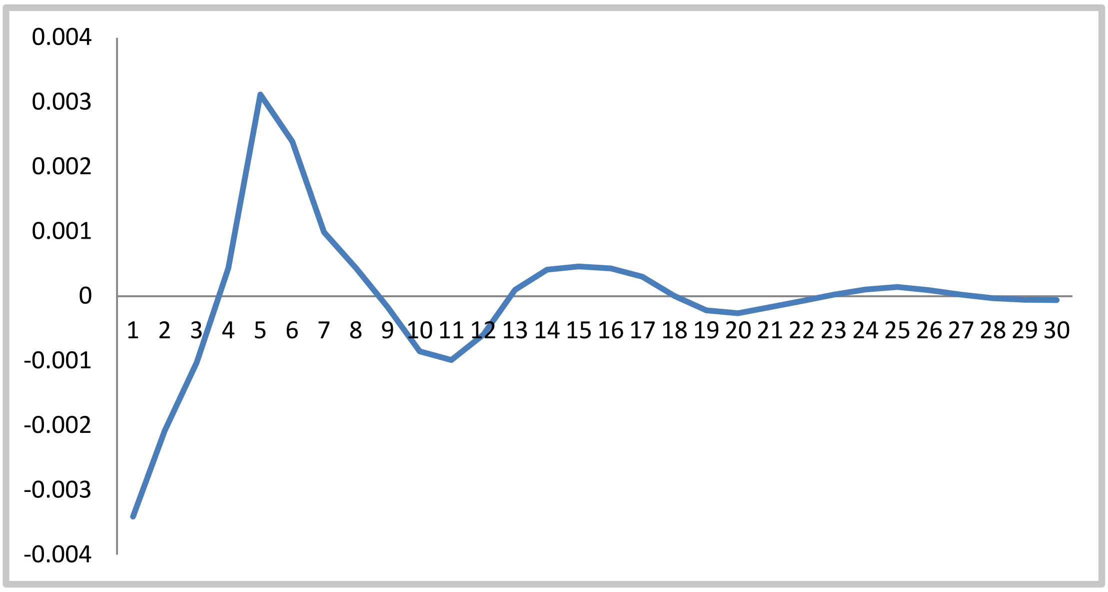


a. Linear IRF for GDP to One S.D. Shock in Inflation

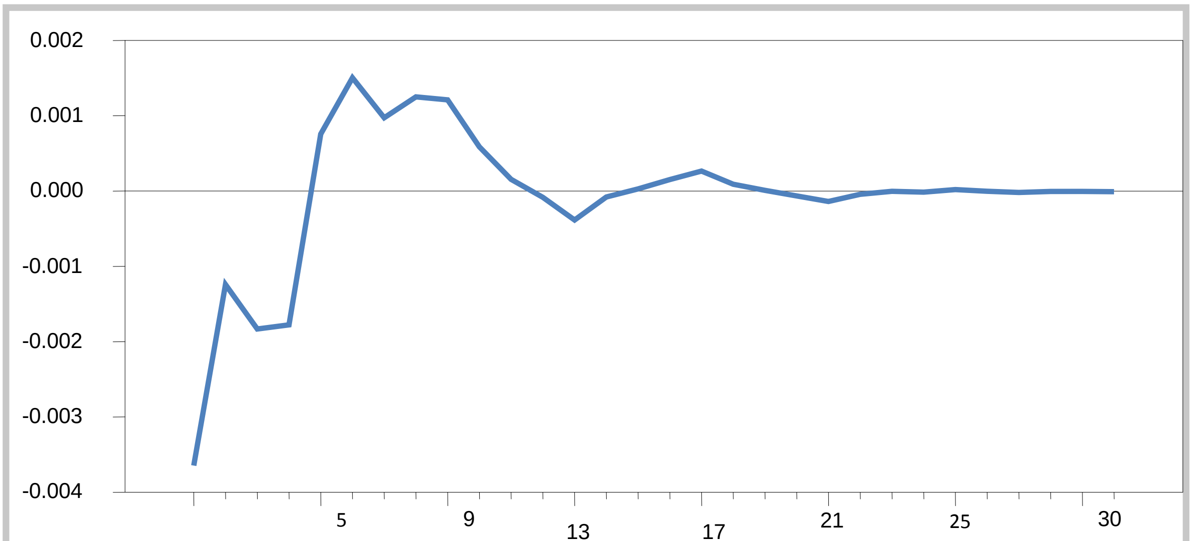


b. Nonlinear GIRF for GDP to One S.D. Shock in inflation

Figure 5.8 Impulse Responses of GDP for One S.D. Shock in Inflation

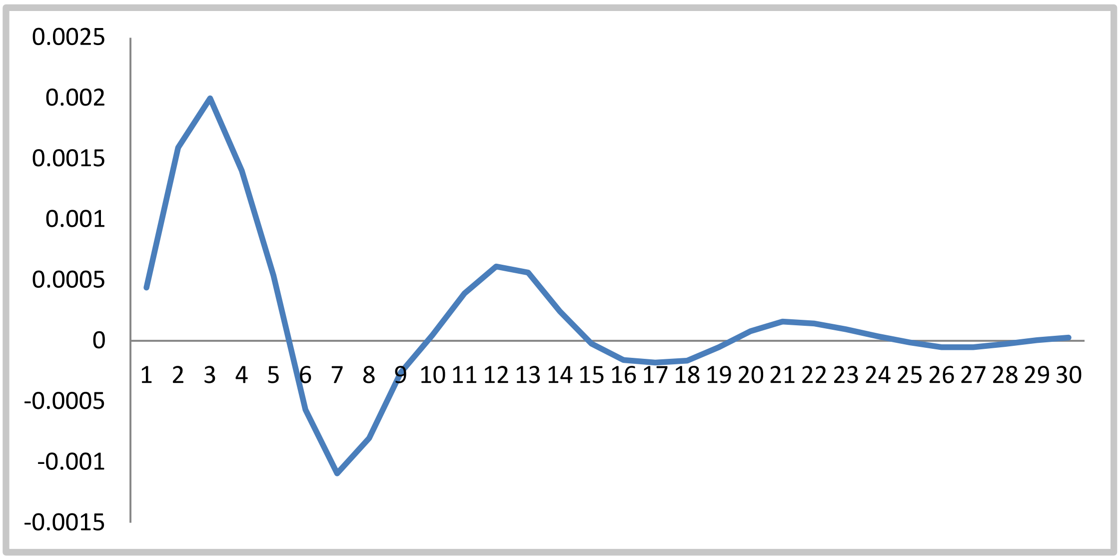


a. Linear IRF for Inf to One S.D. Shock in (m-p)

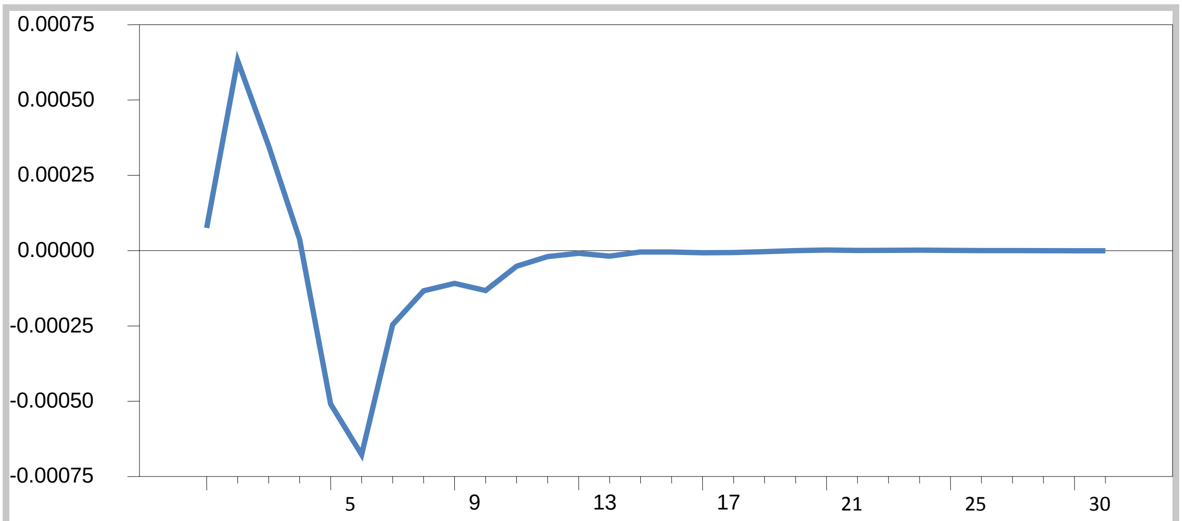


b. Nonlinear GIRF for Inf to One S.D. Shock in in (m-p)

Figure 5.9 Impulse Responses of Inflation for One S.D. Shock in (m-p)

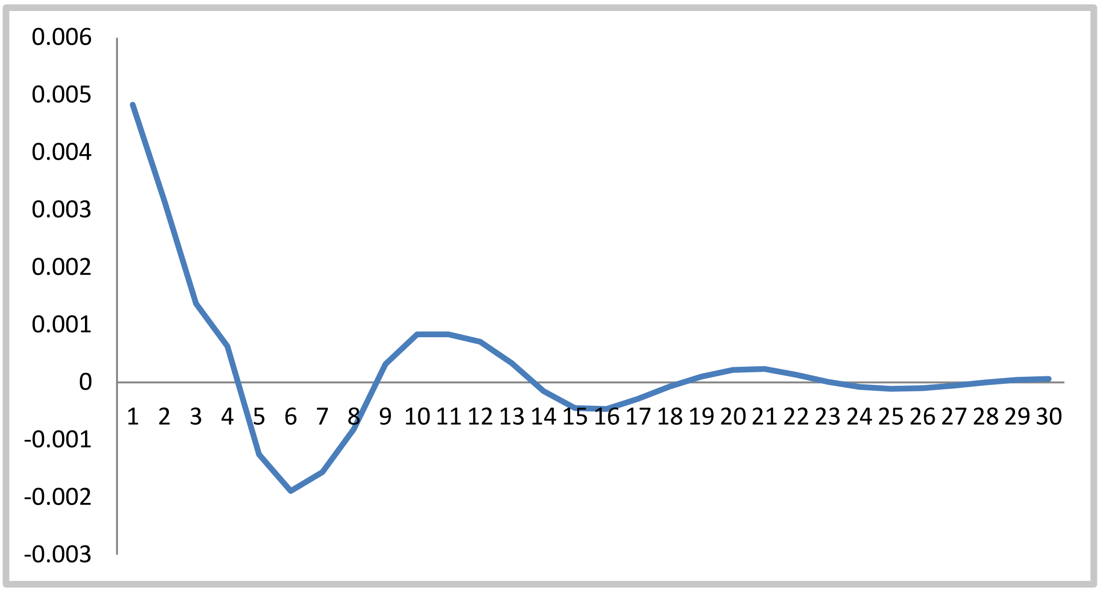


a. Linear IRF for Inf to One S.D. Shock in GDP

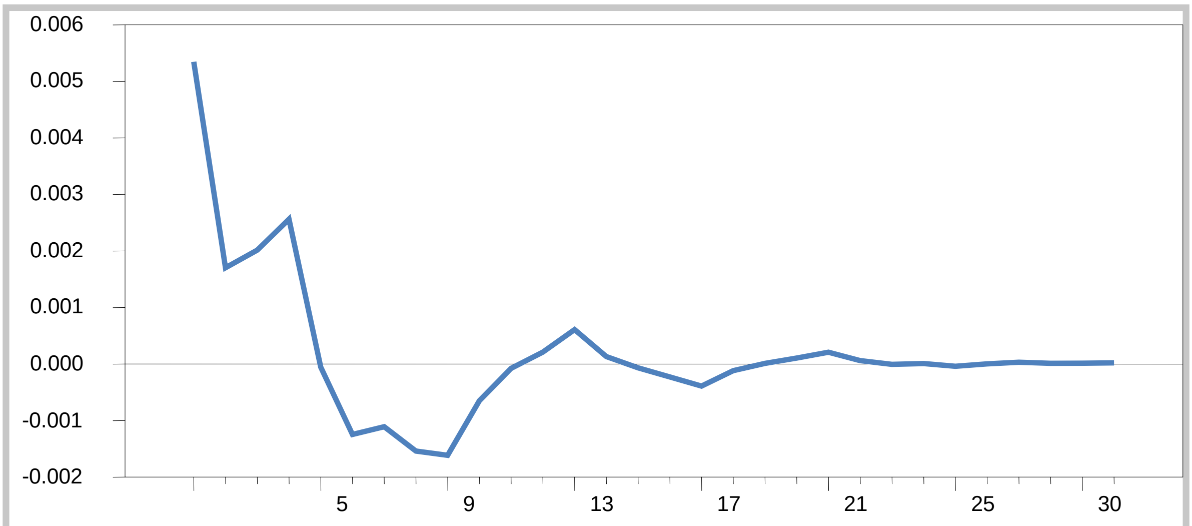


d. Nonlinear GIRF for Inf to One S.D. Shock in in GDP

Figure 5.10 Impulse Responses of Inflation for One S.D. Shock in GDP



a. Linear IRF for Inf to One S.D. Shock in Inf



b. Nonlinear GIRF for Inf to One S.D. Shock in Inf

Figure 5.11 Impulse Responses of Inflation for One S.D. Shock in Inflation

Table 5.9 Responses of (m-p) to Shocks in						
	Linear VECM			Threshold VECM		
Period	**(m-p)**	**gdp**	**Δp**	**(m-p)**	**gdp**	**Δp**
1st	0.0078	0.0000	0.0000	0.0075	0.0006	-0.0048
3rd	0.0005	-0.0013	-0.0008	-0.002	0.0025	0.0018
5th	0.002	0.0006	0.0007	0.001	-0.00065	-0.0002
10th	0.0002	-0.00045	-0.000013	0.001	-0.0001	-0.0013
15th	-0.00001	-0.00001	0.00007	0.0000	-0.000004	-0.00001
20th	-0.00002	-0.00015	-0.00002	-0.000005	0.0000	0.00001
25th	0.000003	0.000047	0.00009	0.00000	0.0000	0.0000
30rd	0.0000005	-0.000016	-0.000007	0.00000	0.0000	0.0000

Table 5.10 Responses of GDP to Shocks in						
	Linear VECM			Threshold VECM		
Period	**(m-p)**	**gdp**	**Δp**	**(m-p)**	**gdp**	**Δp**
1st	0.0002	0.004	0.0000	0.00015	0.0038	0.0000
5th	-0.0001	0.0013	0.0013	0.0010	-0.0006	-0.00013
10th	0.00001	0.0006	-0.0002	0.0005	-0.0002	-0.0006
15th	0.0000	0.0003	0.000009	0.0000	0.000	-0.00005
20th	0.00003	0.0002	-0.000024	-0.00001	0.000	0.000001
25th	0.0000	0.0001	0.000008	0.000	0.000	0.00000
30rd	0.00001	0.00006	0.000007	0.000	0.000	0.00000

Table 5.11 Responses of Inflation to Shocks in						
	Linear VECM			Threshold VECM		
Period	**(m-p)**	**gdp**	**Δp**	**(m-p)**	**gdp**	**Δp**
1st	-0.0034	0.00045	0.0047	-0.0038	0.0001	0.0055
5th	0.003	0.0005	-0.001	-0.0016	-0.00065	-0.0005
10th	-0.0006	0.00004	0.0008	0.0003	-0.00015	-0.0005
15th	0.0004	-0.00002	-0.00045	0.000001	0.0000	-0.0002
20th	-0.0002	0.00008	0.0002	-0.00001	0.0000	0.00002
25th	0.00002	-0.000012	-0.0001	0.00000	0.00000	0.00000
30rd	-0.00001	0.000027	0.00006	0.00000	0.00000	0.000000

The comparison of responses for linear VECM and Threshold VEC models are given in Table 5.9, 5.10 and 5.11 As can be seen from these Tables, generally speaking, the size and sign of responses are close to each other. However, a shock dies out faster in Threshold VEC model compared to linear VEC model, implying that the effect of monetary policy is absorbed in a shorter period of time in the former model. Moreover, as shown in Figures 5.4 and 5.5, the response of money demand to a one standard deviation shock in GDP and inflation seems more reasonable in nonlinear model since the respond of GDP is positive in the first four quarters though it is negative during the same period in linear model.

5.3 Conclusion

This chapter estimates a threshold cointegration model over the period 1980-2010 for European money demand and analyses the dynamic responses of the model to money demand shocks by means of impulse responses.

In the literature ECM terms from linear VAR is preferred as transition variable since it is a linear combination of all variables in the system carrying information provided by all of them. Therefore, we also focus on the models which use this variable as transition variable. However, we also estimate TVECM using money demand, GDP, inflation and interest rate as transition variables to see whether nonlinearity appeared itself because of estimation procedure of linear VAR model or due to an inherent nonlinear structure showing itself for all variables.

Empirical results show that irrespective of the transition variable used in TVECM model, there is strong evidence of nonlinearites in money demand function. The best one is an M-TAR type dynamics delivered by the one using the first lag of error correction term as transition variable. It seems that long run adjustment is faster in lower regimes of the nonlinear model compared to upper one. Furthermore, the response to shocks obtained from nonlinear model seems more plausible and consistent with economic theory.

CHAPTER 6

CONCLUSION

The money demand function has been regarded as a fundamental building block in macroeconomic modelling, as it represents the link between the monetary policy and rest of the economy. This thesis aims to model European money demand by using linear VEC model and its nonlinear version namely threshold VECM specification. We use the error correction term, obtained from a linear VAR analysis as transition variable in our nonlinear modelling. Therefore, there are many empirical studies investigating relationships among the monetary variables. The most popular one is the stability of the money demand function both at the country level and regional level as for example Euro Area.

A shortcoming of most of the empirical studies is the use of linear specifications in analyzing the money demand function. We therefore not only use linear models but also a class of nonlinear models called Threshold models to analyze the Euro Area money demand function. More specifically, we estimate a linear VAR and VECM model and then use the error correction term as a transition variable under TVECM specification. Empirical results are consistent with our expectations as we find strong nonlinearity in the money demand function of Euro Area. Moreover, nonlinear specification provides more reasonable results as far as both the size and sign of the coefficients are concerned.

Chapter 2 reviews literature in linear and nonlinear framework. The review shows that there is no study that investigates the nonlinearity of European money demand for long span data. The recent time series literature shows an important development in nonlinear adjustment mechanism. Much of the impetus for this interest may come from a large number of studies showing that key macroeconomic variables such as real GDP, unemployment, interest rates and exchange rates display asymmetries. From the review of the nonlinear literature, the findings support the hypothesis that the Euro Area money demand may have nonlinear relationship. Next, we describe the definition of monetary aggregates and theories of money demand. The advantages and disadvantages of monetary aggregation are summarized. Based on these we prefer to model M3 definition of monetary aggregate with GDP, inflation and interest rates.

Chapter 3 gives an account of vector autoregressive (VAR) and threshold autoregressive (TAR) modelling which are employed in this thesis. Vector autoregressive modelling with cointegration analysis enables us to test a number of economic hypotheses about the behaviour of variables. We employ Momentum type TAR model for nonlinear modelling. Momentum TAR model can capture the asymmetric dynamics, such that the series exhibits more momentum in one direction than the other. The brief description of nonlinear impulse responses are given at the end of the chapter. Nonlinear impulse responses are dependent to history. Magnitude of the shock can change the time profile of responses in nonlinear GIRFs. Sign and size of the shock does matter for nonlinear impulses in contrast the linear ones.

In Chapter 4, the demand for money is estimated for Euro Area. The variables used for the model is M3 monetary aggregate, GDP, inflation and interest rates. To avoid data aggregation problem, we use an existing data set until 1999 than extend it according to ECB and IFS databases up to 2010. In addition to four explanatory variables mentioned above, some dummy variables are included into the model to account for economic crisis and/or unusual events. A dummy variable for 2008 economic crisis which takes the value of 1 for 2008:4 and 2009:1 period is found significant. This implies 2008 economic crisis would have significant effect on the demand for money function. The dummy for 1990:2 presents German unification, the dummy for 2002:1 shows the period that the Euro banknotes and coins are presented into the market. Lastly, the dummies for 2000:3 and 2000:4 represent stock market turbulences after the new economy bubble. Furthermore, seasonal dummies are included to avoid seasonality in the model. The restrictions according to the economic theory are tested and GDP, inflation and interest rates are found weakly exogenous. A long run and short run estimates of money demand model is presented. In the long run model, all coefficients are consistent with economic theory. However, the income elasticity is relatively higher than unity but lower than the ones found in some empirical studies in the literature. This is attributed to use the data after 2002 period for European money demand in the empirical literature. The adjustment coefficients (ECM) of the short run money demand function is 0.13 which reflects the speed of adjustment to any long run equilibrium. The life of shock is approximately 2 years in linear model. This ECM is comparatively higher than the ones found in empirical literature that includes long span data. A higher adjustment coefficient for the demand for money indicates that deviation of the demand for money from its long-run equilibrium are eliminated faster compared to other studies. This could make monetary policy implementation easier, because it implies that impulses coming from monetary policy instruments are quickly transmitted to economic activity. The short run estimates of money demand model show that although GDP has a positive coefficient consistent with economic theory, but insignificant effect on money demand. This poor result of linear model can be attributed to data, modelling approach but also adherence to linear specifications which are not as flexible as nonlinear specifications. Moreover, stability tests are presented and European money demand is found stable over the period 1980-2010. Recently, previous empirical studies in the Euro Area generally report instability in traditional money demand function. Stable money demand supports and increases the effectiveness of the monetary policy implications in the Euro Area. Finally, the impulse responses are presented to analyze the dynamics of the short-run and medium-run of European money demand. The response of money demand in one standard deviation shock in GDP seems negative in first quarters that conflicts with economic theory. More plausible responses are delivered by nonlinear impulse responses.

Finally, in Chapter 5 we examine for evidence of nonlinearity in European money demand function. For this, we obtain cointegrating vector from linear VAR model. Thereafter, we apply nonlinearity tests and obtain strong evidence of nonlinearity in error correction term. We investigate whether the relationship between the European money demand, GDP, inflation and interest rates can be characterized by Momentum type TVEC model. We opt for the model which uses first lag of error correction term as transition variable and assumes no change in short run dynamics. The tests of the asymmetric regimes are also found significant. The coefficient of ECM in low regime is 0.11 which is comparatively lower than linear model meaning the life of shock dies out approximately 2.5 years. The results of the reduced form of nonlinear model is very consistent with the economic theory compared to its linear counterparts. Moreover, the response of money demand in one standard deviation shock in GDP seems positive in first quarters as expected in empirical economic literature.

Although, research in nonlinear time series econometrics seems to be growing exponentially, there are few studies that analyze money demand in nonlinear framework. This study makes several contributions to the empirical literature of money demand relationship. Though researchers show evidence of nonlinearity in most of the macroeconomic variables, most of the applied work to date assumes linearity for money demand model. The nonlinearity of the macroeconomic variables should not be neglected in empirical economic studies. Chapter 5 presents, for the first time, how a Momentum TVEC model can capture the asymmetries in the European money demand function. We then provide the first empirical examples of Momentum TVEC model and its impulses for European money demand equation.

Our conclusions may now be summarized. We have provided the first study which investigates stability of the demand for money for Euro Area over the period 1980-2010 for traditional money demand function. Our findings would suggest that the demand for money in the Euro Area can be explained by nonlinear models more plausibly and consistently with economic theory.

Secondly, this study is the first study which compares European money demand for linear and nonlinear framework over the period 1980-2010. The dynamics of the European money demand model can be explained better by nonlinear methods compared to their linear counterparts.

The empirical findings presented here are very compelling and encourage further research in a number of directions. Some extensions that could build on this study are given below.

Although we have used MTAR vector error correction models on the basis of our test results, it would be very interesting to examine how other types nonlinear models, such as Smooth transition VEC model perform in describing these series. Since Smooth transition models allow the parameters to change slowly in contrast to sharp change in TAR models.

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APPENDICES

APPENDIX A

ADDITIONAL TABLES

A1.1 VAR Estimates

Table A1. 1 Unrestricted VAR Estimates (with dummy)

	(m-p)	**gdp**	**Δp**	**R^s**
mp_{t-1}	-0.058	-0.020	0.018	-1.559
	[-0.621]	[-0.426]	[0.262]	[-0.360]
mp_{t-2}	-0.030	0.001	-0.032	4.991
	[-0.341]	[0.029]	[-0.482]	[1.207]
mp_{t-3}	-0.189	0.047	0.155	0.685
	[-2.249]	[1.132]	[2.507]	[0.176]
mp_{t-4}	0.506	-0.027	0.149	-1.948
	[5.880]	[-0.641]	[2.368]	[-0.489]
gdp_{t-1}	-0.379	0.317	0.237	8.844
	[-1.894]	[3.227]	[1.611]	[0.954]
gdp_{t-2}	0.284	0.048	0.024	15.284
	[1.373]	[0.477]	[0.157]	[1.598]
gdp_{t-3}	0.225	0.102	-0.152	1.832
	[1.082]	[1.004]	[-0.995]	[0.190]
gdp_{t-4}	0.634	0.127	-0.213	-3.873
	[3.141]	[1.283]	[-1.439]	[-0.415]
Δp_{t-1}	-0.385	0.157	0.676	4.705
	[-2.939]	[2.441]	[7.031]	[0.776]
Δp_{t-2}	0.062	-0.122	-0.225	-8.853
	[0.425]	[-1.706]	[-2.110]	[-1.315]
Δp_{t-3}	-0.198	0.020	0.178	12.549
	[-1.456]	[0.301]	[1.790]	[1.999]
Δp_{t-4}	0.180	0.022	-0.248	-6.748
	[1.520]	[0.384]	[-2.851]	[-1.231]

Table A1.1. (Continued)				
	(m-p)	**gdp**	**Δp**	**R^S**
R^S_{t-1}	0.000	0.001	0.001	0.427
	[-0.181]	[0.694]	[0.375]	[4.010]
R^S_{t-2}	-0.003	-0.002	0.004	-0.043
	[-1.110]	[-1.713]	[2.025]	[-0.378]
R^S_{t-3}	0.004	-0.001	-0.005	-0.122
	[1.561]	[-0.519]	[-2.611]	[-1.072]
R^S_{t-4}	0.002	0.000	0.001	0.083
	[0.725]	[-0.059]	[0.431]	[0.812]
C	0.012	0.004	-0.003	-0.172
	[2.934]	[1.927]	[-0.902]	[-0.943]
d2008	0.032	-0.022	-0.047	-1.386
	[2.977]	[-4.240]	[-5.982]	[-2.768]
d841	-0.002	-0.016	-0.001	-0.493
	[-0.206]	[-3.135]	[-0.118]	[-1.020]
d20021	-0.021	0.002	0.006	0.549
	[-1.972]	[0.368]	[0.761]	[1.129]
d902	0.035	-0.002	-0.004	-0.837
	[3.360]	[-0.448]	[-0.475]	[-1.718]
d20003	-0.024	-0.002	0.014	0.041
	[-2.272]	[-0.308]	[1.789]	[0.084]
d20004	-0.020	0.000	0.000	0.048
	[-1.884]	[-0.075]	[0.012]	[0.097]
DS1	-0.011	-0.002	-0.001	-0.104
	[-1.889]	[-0.882]	[-0.146]	[-0.396]
DS2	-0.009	0.000	0.003	-0.026
	[-2.213]	[-0.100]	[0.913]	[-0.140]
DS3	-0.006	-0.004	-0.004	0.090
	[-0.982]	[-1.344]	[-0.912]	[0.339]

Note: t statistics are given in square brackets.

APPENDIX B

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Korucu Gümüşoğlu, Nebile
Nationality: Turkish (TC)
Date and Place of Birth: June 12, 1981; Ankara
Marital Status: Married
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EDUCATION

Degree	**Institution**	**Year of Graduation**
MSc	Baskent University, Economics	2005
BSc	Baskent University, Statistics and Computer Sciences	2003
High School	Ayrancı Anadolu High School, Ankara	1999

WORK EXPERIENCE

Year	**Place**	**Enrollment**
2008- Present	Istanbul Kultur University, Dept. of Economics	Research/Teaching Assistant
2003-2007	Baskent University, Dept. of Economics	Research/Teaching Assistant
August 2002	Turkish Treasury	Trainee
July 2002	Turkish Statistical Institute	Trainee
July 2002	Central Bank of the Republic of Turkey	Trainee
February 2002	Prime Ministry State Planning Organization	Trainee

FOREIGN LANGUAGES

Advanced English

PUBLICATIONS

SSCI Journal Articles

1. Yildirim, J., Korucu, N. and Karasu, S., 2010, Further Education or Reenlistment Decision in Turkish Armed Forces: A Seemingly Unrelated Probit Analysis, *Defence and Peace Economics*, 21: 1, 89-103.

2. Yildirim, J., Yilmaz, E. and Korucu, N., 2011, The Determinants of Out-of Pocket Payments: Evidence from Selected Hospitals in Ankara, Turkey, *Applied Economics Letters*, 18, 1159-1162.

Projects

1. "Science, Engineering and Technology Network of Women Academic in Turkey", Analyst, supported by Istanbul Technical University, 2012-2013.

2. "Survey of the University Career of Female Scientists at Life Sciences versus Technical Universities", Analyst for Istanbul Technical University, supported by European Commission's 6th Framework Programme, 2008.

3. "The Impacts of Internal Migration on Natives' Educational and Labor Market Outcomes: Evidence from Turkish Provinces", Project by TUBITAK (No: 106K134), 2006-2008.

International Conference Presentations

1. Korucu, N., Öcal, N, and Yıldırım, J, "The Stability of the Demand for Money in the Euro Area", Ecomod, International Conference on Policy Modeling, July 2011, Ponta Delgada, the Azores.

2. Korucu, N., Öcal, N, and Yıldırım, J, "The Stability of the Demand for Money in the Euro Area", EconAnadolu, Haziran 2011, Eskişehir, Türkiye.

3. Korucu, N., Öcal, N, and Yıldırım, J, "The Stability of the Demand for Money in the Euro Area", 12th International Symposium on Econometrics, Operations Research and Statistics, Mayıs 2011, Denizli, Turkiye.

4. Berksoy Oğuz, B. and Korucu, N., "Importance of Innovative Modes in EU Perspective about Policy of Fight Against Social Exclusion Young People in Turkey", International Symposium on Poverty Alleviation Strategies, October 2010, Istanbul.

5. Yildirim, J., Korucu, N. and Karasu, S., “The Effect of Civilian Unemployment on Reenlistment Decision in Turkish Armed Forces”, 14th Annual International Conference on Economics&Security, İzmir, Turkey, June 17-18, 2010.

6. Yildirim, J., Korucu, N. and Karasu, S., “The Effect of Civilian Unemployment on Reenlistment Decision in Turkish Armed Forces”, Ecomod 2010, International Conference on Policy Modeling, İstanbul, Turkey, July 7-10, 2010.

7. Yıldırım, J., Ocal, N. and Korucu, N., “Analysing the Determinants of Terrorism in Turkey Using Geographically Weighted Regression”, 3rd World Conference of Spatial Econometrics, Barcelona, 8-10th July, 2009.

8. Yıldırım, J., Yilmaz, E. and Korucu, N., “The Determinants of Out-of-Pocket Payments: Evidence from Selected Hospitals in Ankara, Turkey”, Ecomod 2009, International Conference on Policy Modeling, Ottawa, Canada, June 24-26, 2009.

9. Kiracı, A. and Korucu, N. “Examples of Outliers in Turkish Economic Data and Their Effects on Scientific Inference”, International Conference on Robust Statistics-ICORS 2008, Antalya, Turkey. September 2008.

10. Yildirim, J., Korucu, N. and Karasu, S., “Further Education or Reenlistment Decision in Turkish Armed Forces: A Seemingly Unrelated Probit Analysis”, International Conference on Policy Modeling-ECOMOD-2008, Berlin, 2-4 July 2008.

11. Yildirim, J., Korucu, N. and Karasu, S., “Further Education or Reenlistment Decision in Turkish Armed Forces: A Seemingly Unrelated Probit Analysis”, Jan Tinbergen European Peace Science Conference 2008, Amsterdam, 30rd of June-2nd of July, 2008.

National Conference Presentations

1. Yıldırım, J., Yılmaz, E. and Korucu, N., “Sağlık Harcamalarında Cepten Yapılan Ödemeler, Ankara Üzerine Bir Uygulama”, 10.Ekonometri ve İstatistik Sempozyumu, Atatürk Üniversitesi, Erzurum, Mayıs 2009.

2. Kiracı, A. and Korucu, N. “Türk Ekonomik Verilerinde Uç Değerlerin Varlığı ve Bilimsel Çıkarsama Üzerindeki Etkileri”, 14. İstatistik Araştırma Sempozyumu, T.C. Başbakanlık Devlet İstatistik Enstitüsü, Mayıs 2005.

3. Korucu, N. and Kiracı, A. “Güncel Uç Değer Tespit Yöntemleri”, VII. Ulusal Ekonometri ve İstatistik Sempozyumu, İstanbul Üniversitesi İktisat Fakültesi Ekonometri Bölümü, Mayıs 2005.

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APPENDIX C

TURKISH SUMMARY

Para talebi fonksiyonu, para politikaları ile ekonominin geri kalan kısmı arasındaki bağlantıyı temsil etmesinden dolayı, makroekonomik modellemede önemli bir yapı taşı olarak kabul edilmektedir. Para talebi literatürünün önemli bir kısmı para arzına gelen bir şokun, enflasyon, faiz oranları, milli gelir, özel yatırımlar ve diğer politika değişkenlerine olan beklenen etkisini ölçmeyi sağlayan istikrarlı para fonksiyonu ile ilgilenmektedir. Para ve fiyatlar arasındaki istikrarlı bir ilişki parasal bileşenlerin para politikalarında kullanılabilmesi için bir ön koşul olarak kabul edilmiştir. Bu nedenledir ki, para talebi literatürünü oluşturan çalışmaların ilk amacı istikrarlı bir para talebi fonksiyonuna ulaşmak olmuştur. Parasal fonksiyonlar yüzyıllardır, ülkeler ve bölgeler bazında popular çalışma alanlarından biri olmuş ve literatürde önemli bir yer edinmiştir.

Bu bağlamda, bu tez çalışmasında, 1980-2010 dönemi için, Avrupa Bölgesi para talebi fonksiyonunun doğrusal ve doğrusal olmayan çerçevede modellenerek karşılaştırılması amaçlanmıştır. Avrupa Bölgesi para talebi fonksiyonu da, her ekonomide olduğu gibi beklenmedik olaylar/şoklara açık bir fonksiyondur. Bu ekonomik kriz ve şoklar modelde çeşitli asimetrik etkiler oluşturabilir. Doğrusal zaman serisi tahmin yöntemleri bu asimetrik etkileri tahmin etmede yetersiz kalmaktadır. Bu asimetrileri modellemek için doğrusal olmayan tahmin yöntemlerine ihtiyaç duyulmaktadır. Bu nedenledir ki, son zamanlarda doğrusal olmayan modellemeler, ampirik ekonomik çalışmalarda daha fazla yer bulmaya başlamıştır. Fakat para talebi kadar ekonominin temel taşlarını oluşturan bir konuda, yeteri kadar doğrusal olmayan yöntemleri kullanan çalışmaya rastlanamamıştır. Bunun en önemli sebeplerinden bir tanesi, doğrusal olmayan metodların, doğrusal metodlar kadar basit hesaplama tekniklerine sahip olmamasıdır. Mevcut modelleme teknikleri de genellikle doğrusal yöntemler üzerine kuruludur.

Bu çerçevede, tezin ana içeriği 2.-5. bölümlerde sunulmuştur. Öncelikle, Fisher (1911) ‘Klasik Para Miktar Teorisi’nden başlayarak Friedman (1956) ‘Modern Para Teorisi’ne kadar para teorileri incelenmiştir. Para talebinin bileşenleri incelenmiş ve bu çalışmada, para talebinin, GSYIH, enflasyon ve faiz oranları değişkenleri ile modellenmesine karar verilmiştir. Genel olarak toplulaştırma (aggregation) yöntemlerinin avantaj ve dezavantajları özetlenmiş ve bu çalışmada kullanılacak veri toplama yöntemine karar verilmiştir. Avrupa Birliği’nin yapısı üzerinde durulmuştur. Literatür taraması doğrusal yöntemleri kullanan çalışmalar ve doğrusal olmayan yöntemleri kullanan çalışmalar olmak üzere iki bölümde gerçekleştirilmiştir. Literatür taramasından Avrupa Bölgesi için para talebi çalışmalarının ortak özellikleri, doğrusalsızlığı temel alan çalışmaların azlığı ve para talebi fonksiyonunun bileşenlerinin uygulamalı literatürde doğrusalsızlık gösterdiği bu nedenle para talebi fonksiyonunda doğrusalsızlık gösterebilmesinin yüksek ihtimal olduğu gibi sonuçlara ulaşılabilir.

Üçüncü bölüm tezin metodoloji kısmını kapsamaktadır. Şöyle ki, Avrupa Bölgesi para talebi modellemesinde kullanılacak, doğrusal çerçevede VAR (Vector Autoregression/Yöney Ardışık Bağımlı Regresyon) ve VEC (Vector Error Correction/Yöney hata düzeltme) modelleri ve doğrusal olmayan çerçevede ise TAR (Threshold autoregressive/Eşik ardışık bağımlı) modelleri sunulacaktır. Eşbütünleşik (Cointegrated) VAR modelleri verileri uzun ve kısa vadede açıklamakla birlikte, belirli ekonomik kısıtlarında uygulanabilmesine olanak verir. TAR modellerinden özellikle M-TAR eşik eşbütünleşim yöntemine yer verilmiştir. M-TAR tipi eşik eşbütünleşim yöntemi, inişlerin ve çıkışlarının simetrik olmadığı ekonomik değişkenlerde ve durumlardaki asimetrileri açıklamada daha başarılı sonuçlar verebilmektedir. Sichel (1993)’de de belirtildiği gibi M-TAR modelleri serinin bir yöne sergilediği asimetrik ivmeyi yakalamakta daha başarılı olmaktadır. Ekonomide sıklıkla çıkışların daha yavaş inişlerin ise daha keskin olduğu durumlara rastlanmaktadır. Son olarak etki tepki analizlerinin doğrusal olmayan modellerdeki uygulaması özetlenmiştir.

Diğer bölümde, doğrusal modelleme sonuçlarına yer verilmiştir. Bu kapsamda Avrupa para talebi, GSYIH, enflasyon ve faiz oranları değişkenleri VAR tekniği kullanılarak modellenmiştir. Eğer değişkenler arasında eşbütünleşim (cointegration) varsa, VAR modeli uzun dönemde ve kısa dönemdeki ilişkiyi tahmin etmeye yardımcı olmaktadır. Bu bağlamda, eşbütünleşik VAR modelinde ekonomik teorinin öngördüğü hipotezler test edilmiştir. Kısa dönem modelleri tahmin edilerek, modelin istikrarlı olup olmadığı incelenmiştir. İstikrarlı bir model elde edildikten sonra, modelin kısa ve orta dönemdeki dinamikleri etki tepki analizi ile irdelenmiştir. Tahminler ekonomik teoriye aykırı bazı sonuçlar içermektedir. Şöyle ki, etki tepki analizlerinde GSYIH'ya verilen bir standart sapmalık şok, ilk dönemlerde para talebinde negatif yönlü bir etki yaratmaktadır, tahmin edilen kısa dönemli para talebi tahmin modelinde de, GSYIH değişkeninin katsayısı pozitif fakat istatistiksel açıdan anlamsız bulunmuştur. Bu ekonomik teoriye göre açıklanamayan sonuçlar, doğrusal olmayan model ile teoriye daha örtüşür olarak açıklanabilmektedir. Para talebi ilişkisinin doğrusal olmaması ve modelin yanlış modellenmesi bazı beklenmedik tahminlere yol açabilmektedir.

Beşinci bölümde ise para talebi ilişkisinin doğrusal olup olmadığına bakılmıştır. Bu bölümün amacı doğrusal model ile doğrusal olmayan modeli karşılaştırmaktır. Bu kapsamda öncelikle doğrusal modelden eşbütünleşim vektörü (hata terimi, ECT) elde edilir. Hata terimi bilindiği üzere, para talebi, GSYIH, enflasyon ve faiz oranları değişkenlerinin doğrusal bir fonksiyonundan elde edilmektedir. Her değişkenin ve hata teriminin doğrusal olduğu test edildikten sonra çeşitli eşik değişkenlerine göre doğrusal olmayan modeller tahmin edilmiş ve en iyi model uzun dönem hata teriminin eşik değişkeni olarak alındığı model bulunmuştur. Rejim katsayılarının istatistiksel açıdan anlamlı farklılığı da test edilerek anlamlı sonuçlara ulaşılmıştır. Son olarak kısa ve orta dönemdeki dinamik etkileri ölçmeye yarayan etki tepki analizi (IRF) yapılmış, doğrusal ve doğrusal olmayan modeller karşılaştırıldığında doğrusal olmayan modelin ekonomik açıdan daha anlamlı sonuçlar verdiği çıkarımına ulaşılmıştır. Aynı zamanda, sadece istatistiksel açıdan anlamlı değişkenlerden oluşan M-TAR eşik eşbütünleşim modeli sonuçlarına göre GSYIH, para talebi üzerinde anlamlı ve pozitif etkiye sahip bulunmuştur.

Para ve fiyatlar arasındaki uzun dönemli ilişki yüzyıllardır para politikaları literatürü için popular bir konu olmuştur. Para bileşenleri, Avrupa Merkez Bankası (ECB) para politikaları stratejilerinde de önemli bir yere sahiptir. Bunlardan ilki fiyat riskinin kısa dönemde ekonomik analizlerde incelenmesidir. İkincisi ise parasal analizlerde fiyat istikrarının orta ve uzun vadede sürekliliğidir. M3 para bileşeni, en azından uzun dönemli bir referans olarak, hala önemli bir role sahiptir (ECB, 2004a, s.64). Para talebi literatürü incelendiğinde, çalışmaların ana amacının para talebi modelinin istikrarlılığını incelemek olduğu görülmektedir.

Genel olarak para talebi çalışmaları Amerika ve İngiltere'de yoğunluk göstermiştir. (Örneğin Amerika için; Rose, 1985; Baba, Hendry ve Starr, 1992; Hendry ve Ericsson, 1991b ve Mehra, 1997; İngiltere için ise Adam, 1991; Hendry ve Ericsson, 1991b; Hendry, 1995 çalışmaları incelenebilir). 1990ların başlarına kadar Amerika para talebini inceleyen çalışmalarda istikrarlı bir ilişkiye rastlanırken, daha sonra istikrarlılık özellikleri Amerika için kaybolmaya başlamıştır. İstikrarlı bir model elde etmek için araştırmacılar çeşitli yolları denemişlerdir. Bunlar farklı açıklayıcı değişkenler eklemek, farklı değişkenler arasında eşbütünleşim ilişkilerini araştırmak, farklı tahmin yöntemleri denemek, verilerin farklı zaman aralıklarını denemek gibi yollar olmuştur. Farklı parasal bileşen tanımları da modellenmiştir, örneğin Ericsson (1999) çalışmasında, M1 parasal bileşeni istikrarlı bulunurken, M4 parasal bileşeni istikrarlı bulunamamıştır. Amerika için, M2 parasal bileşeni 1990lara kadar istikrarlı bir model sergilemektedir (Carlson ve Parrott, 1991; Duca, 1995; Whitesell, 1997). Finansal gelişmelere bağlı olarak istikrarlı ilişki bozulmaya başlamıştır.

Amerika ve İngiltere'de olduğu kadar diğer ülke ve bölgelerde de para talebi çalışmaları para politikaları için önemli bir yere sahip olmuştur. Avrupa Bölgesi'de bunlardan en önemlilerinden biridir. Bu literatür taramasında daha çok Avrupa Bölgesini kapsayan çalışmalara yer verilmiştir. Fakat literatürde İspanya, Yunanistan, Norveç, Finlandiya, Kanada, Çin, Tayvan, Japonya başta olmak üzere bir çok ülkeye ait çalışmalara rastlanabilir.

Avrupa Bölgesi para talebi çalışmalarına geçmeden önce Almanya üzerine yapılan çalışmalar incelenebilir. Almanya'nın Avrupa Bölgesi ekonomik yapısı üzerindeki etkisi Avrupa Merkez Bankası yapısının Almanya Merkez Bankası'na (Deutsche Bundesbank) dayanmasından da anlaşılabilir. Avrupa Bölgesi yapısal olarak Almanya ekonomisi temellerine dayanmaktadır. Bu nedenledir ki bazı çalışmalar[97], 1998 dönemi öncesinde Avrupa Bölgesi veri setini temsilen Almanya verisini kullanmış ve anlamlı, istikrarlı sonuçlara ulaşmıştır. Hem Almanya hem de Avrupa Merkez Bankaları M3 para talebini hedef değişkeni olarak seçtiklerinden, Almanya için yapılan çalışmalarda da genellikle M3 para talebi değişkeni modellenmiştir (Lütkepohl ve Wolters, 1999; Wolters, Terasvirta ve Lütkepohl, 1998; Wolters ve Lütkepohl, 1997; Buscher ve Frowen, 1993; Hansen ve Kim, 1995). Lutkepohl, Terasvirta ve Wolters (1999) çalışmalarında Almanya için para talebini doğrusal olmayan modelleme yöntemi olan yumuşak geçişli hata düzeltme modeli (Smooth Transition Error Correction Model/STECM) kullanarak modellemişlerdir. Bu kapsamda, literatürde MTAR eşik eşbütünleşim modeli kullanılarak Avrupa Bölgesi para talebini modelleyen çalışmaya rastlanmamıştır. Bu tez literatürdeki bu eksiği doldurmayı amaçlamaktadır.

Avrupa Bölgesi için para talebini doğrusal olarak modelleyen çalışmaların ortak özelliği modelde istikrarlılık (stability) olup olmadığını irdelemektir. Avrupa Birliği'nin kurulmasıyla, 90'lı yılların sonundan itibaren Avrupa Bölgesi para talebi çalışmalarının popülerliği artmıştır. Avrupa Bölgesi verisi 1999 yılından itibaren mevcut olduğundan, 1999 yılı öncesi veri setine ulaşmak için Bölüm 2.4'de detaylı anlatılan belli yöntemlere göre, ülke verilerinden toplulaştırılmış (aggregated) Avrupa Bölgesi verisi elde edilmektedir. Bu toplulaştırma yöntemlerinin çeşitli avantaj ve dezavantajları bulunmaktadır. Model sonuçları bazen toplulaştırma yöntemine göre farklılık gösterebilmektedir.

Literatürde, toplulaştırılmış veri kullanılarak Avrupa Bölgesi için para talebini tahmin eden ilk çalışma Kremers ve Lane (1990)[98] çalışmasıdır. Kremers ve Lane (1990) çalışmalarında Avrupa Bölgesi için M1 para bileşenini 1979-1984 yılları için enflasyon, faiz oranları ve döviz kurları değişkenlerini kullanarak modellemişler ve

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[97] Örnek olarak Brüggemann ve Lütkepohl (2006) çalışması görülebilir.

[98] Kremers ve Lane (1990) çalışmalarında verilerine ulaşılabilirliklerine gore, Belçika, Danimarka, Fransa, Almanya, İrlanda, İtalya ve Hollanda olmak üzere toplamda 7 ülkeyi kapsamışlardır.

istikrarlı bir ilişkiye ulaşmışlardır. Avrupa Merkez Bankası para politikaları M3 para bileşeni üzerine kurulu olduğundan ilgili çalışmalarda genel olarak M3 para bileşeni üzerine kuruludur. Coenen ve Vega (2001), Brand ve Cassola (2000), Hahn ve Müller (2000), Calza, Gerdesmeier ve Levy (2001), Golinelli ve Pastorello (2002), Hayo (1999) ve Kontolemis (2002) çalışmaları Avrupa Bölgesi M3 para bileşeni için istikrarlı bir ilişki bulmuşlardır. Bruggeman, Donati ve Warne (2003) 1981-2001 dönemini kapsayan Avrupa Bölgesi M3 para bileşeni için istikrarlı bir model bulurken, toplulaştırma yöntemine de değinmişlerdir. Filosa (1995) tüm Avrupa Bölgesi yerine 6 ülkeyi[99] kapsayan çalışmasında istikrarlı para talebine ulaşmıştır.

M1 para bileşenini inceleyen çalışmalarda bulunmakla birlikte (Fagan ve Henry, 1998; Hayo, 1999) Fagan ve Henry (1998) çalışmalarında M1 para bileşeni ile diğer değişkenler arasında bir eşbütünleşik (cointegrated) ilişkiye rastlayamamışlardır. 2001 sonrasında yapılan bazı çalışmalarda para bileşenleri ile diğer değişkenler arasında eşbütünleşik ilişkiye rastlanamaması, istikrarlı bir ilişki bulunamamasının önemli nedenlerinden biri olarak belirtilmektedir.

Fakat, 2001'de Euro'nun fiilen de kullanıma geçmesiyle, yapılan çalışmalarda istikrarlılık özelliği kaybolmaya başlamıştır (Dreger ve Wolters, 2010). Bu nedenledir ki, yapılan çalışmalar değişik yaklaşımlarla para talebini modellemeye çalışmışlardır. Bu farklı yaklaşımlar, tahmin yöntemleri, farklı açıklayıcı değişkenler arasındaki eşbütünleşim ilişkileri, farklı periyodlar için modelleme yapmak, modele değişik açıklayıcı değişkenler eklemek şeklinde sayılabilir. Para talebini literatürde açıklanan temel açıklayıcı değişkenlerle (GSYIH/GSMH, enflasyon ve faizler) modelleyerek 1980-2010 dönemi için istikrarlı bulan bir çalışmaya da literatürde rastlanamamıştır. Bu bağlamda, bu tez Avrupa Bölgesi para talebine doğrusal model yaklaşımı ile literatürdeki bu eksiği doldurmayı amaçlamaktadır.

2001 sonrasında yapılan çalışmalarda genel olarak istikrarlılık özelliğinin kaybolmuş görünmesi, araştırmacıların farklı değişkenleri modele dahil etmek gibi çözümler üretmesine neden olmuştur. Bu farklı değişkenler, servet (wealth), ev fiyatları, finans değişkenleri gibi değişkenlerdir. Zenginleşmenin, servet değişkeninin önemli bir

[99] İlgili çalışma, Belçika, Fransa, Almanya, İtalya, Hoolanda ve Birleşik Krallık olmak üzere 6 ülkeyi kapsamaktadır.

göstergesi olarak ev fiyatları kullanılmıştır. Modele farklı değişken dahil etmenin yanı sıra farklı tahmin yöntemleri kullanılmıştır. Arnold ve Roelands (2010) farklı bir yöntem seçerek, para talebini 1999- 2008 dönemi için panel veri analizi yöntemi ile modellemiştir. Hamori ve Hamori (2008)'de çalışmalarında panel veri analizini kullanarak M1, M2 ve M3 para bileşenleri için istikrarlı bir ilişkiye ulaşmıştır. Diğer servet değişkenini kullanan çalışmalar arasında Boone ve Noord (2008); Beyer (2009) çalışmaları sayılabilir. Stok fiyatları (Dreger ve Wolters, 2009, 2010) ve esneklik (Carstensen, 2006) değişkenleri de para talebi modellenirken kullanılan diğer açıklayıcı değişkenler arasında sayılabilir. Beyer (2009) çalışmasında belirttiği gibi, Avrupa Merkez Bankası'nın hanehalkı servet hareketleri üzerinde direkt bir etkisi bulunmamaktadır. Bu nedenledir ki, hanehalkı serveti, hem uzun dönemde hem de kısa dönemde, büyüme, enflasyon ve faiz oranları değişkenleri ile açıklanamamaktadır. Fase ve Winder (1998) 1971-1995 dönemlerini kapsayan, servetin M2 ve M3 üzerindeki etkisini ölçmeyi amaçlayan bir çalışmadır. Servet değişkenlerini kullanan diğer bir çalışma Boone ve Noord (2008) çalışmasıdır. Çalışmalarında ev ve stok fiyatları ile serveti para talebi modelinde açıklayıcı değişken olarak kullanmışlardır. Greiber ve Setzer (2007) Avrupa Bölgesi ve Amerika için para talebi değişkeni ile ev fiyatları arasında eşbütünleşik bir ilişki bulmuşlardır.

Farklı açıklayıcı değişkenlerle para talebini modelleyerek istikrarlı bir model elde eden çalışmaların yanında, bazı çalışmalarda da farklı açıklayıcı değişkenler arasındaki eşbütünleşik ilişki araştırılmış ona göre model kurulmuştur. Para talebi, GSYIH, enflasyon ve faiz oranları arasında bir eşbütünleşik ilişki bulunurken, faiz oranları değişkeni dışsal olarak alınarak, para talebi, GSYIH ve enflasyon oranı arasında bir eşbütünleşik ilişki bulunarak istikrarlı bir modele ulaşılmıştır.

Para talebi modeli panel veri analizinin yanı sıra hem sistem tahminleri hem de tek denklem tahminleri ile modellenerek istikrarlı bir ilişki bulunmuştur. Bazı çalışmalar tek denklem hata düzeltme modeli (Error correction Model, ECM) ile para talebini modellerken (Coenen ve Vega, 2001) diğerleri sistem yaklaşımı (Vector Error Correction Model, VECM) ile modellemiştir (Brand ve Cassola, 2000; Calza, Gerdesmeier ve Levy, 2001; Hendry, 1995). Belke ve Czudaj (2010) tek denklem ve sistem tahminlerini karşılaştırmış ve tek denklem yaklaşımında istikrarlı bir ilişki bulabilmişlerdir. Calza, Gerdesmeier ve Levy (2001) Avrupa Bölgesi için M3 para bileşeninin tek denklem yaklaşımı yerine sistem yaklaşımı ile tahmin edilmesinin uzun dönem ilişkileri kapsamak açısından daha etkin olacağını önermişlerdir.

Literatür taramasına ikinci yaklaşım, doğrusal olmayan zaman serisi modellerinin para talebi ve diğer başlıca makroekonomik değişkenlere uygulanmasını incelemektir. Bu kapsamda literatürde rejim geçişli modeller düşünüldüğü zaman üç model akla gelmektedir. Bunlardan ilki eşik kendiyle bağlaşımlı model (threshold autoregressive model, TAR) Tong (1977b) tarafından sunulmuş, Chan ve Tong (1990), Tsay (1989) ve Hansen (1997) tarafından geliştirilmiştir. TAR modelleri, içsel/dışsal değişken ya da onların bir fonksiyonundan oluşan eşik değişkeninin gecikmeli değerine göre keskin bir geçiş içermektedir. TAR modellerinin Terasvirta ve Anderson (1992); Granger ve Terasvirta (1994); Terasvirta (1994, 1996a, 1996) tarafından geliştirilen yumuşak geçişli versiyonu, rejimler arasındaki keskin geçiş yerine yumuşak geçişe izin vermektedir. Üçüncü yaklaşım ise Neftçi (1982) ve Hamilton (1989) tarafından geliştirilen Markov geçişli (Markov Switching) modellerdir. Markov geçişli modellerde rejimler arasındaki geçişler olasılıksal bir fonksiyonla açıklanır.

Rejim geçişli modeller, makroekonomi de bir çok modelde kendine uygulama alanı bulmuştur. İlk olarak, TAR modeli başlıcaları büyüme, faiz oranları, döviz kurları, işsizlik ve finans olmak üzere bir çok modelde kullanılmaktadır. Gayri Safi Milli Hasıla (GSMH, GNP) popular bir uygulama alanı olmuştur. Beudry ve Koop (1993); Potter (1995); Pesaran ve Potter (1997); Enders, Falk ve Siklos (2007); Tiao ve Tsay (1994) GSMH değişkeninde asimetrik etkileri modelleyen önde gelen çalışmalardır.

Döviz kuru değişkeni çalışmalarına örnek olarak Obstfeld ve Taylor (1997); Sarno, Taylor ve Chowdhury (2004) çalışmaları verilebilir. Asimetrik etkileri gösterilen diğer bir değişken işsizlik oranları değişkenidir. Hansen (1997), ABD için işsizlik oranlarında 1959-1996 dönemi için asimetrik bir model tahmin etmiştir. Diğer çalışmalara örnek olarak, Rothman (1998) verilebilir.

Faiz oranları ve fiyatlar doğrusalsızlığı modellenen diğer değişkenlerdir. Tsay (1998) çoklu eşik modeli yaklaşımıyla ABD için faiz oranlarını modellemiş ve doğrusalsızlık tespit etmiştir. Wu ve Chen (2006) İngiltere ve Yeni Zelanda için fiyatlardaki asimetrik etkileri modellemiştir. TAR modelleri finansda da kullanılmaktadır (Cao ve Tsay, 1992). Temel makroekonomik değişkenlerin asimetrik etkiler gösterdiği bir ekonomide, bu asimetrik değişkenleri içeren modellerinde doğrusal olmayan yöntemlerle tahmin edilmesi gerekmektedir.

Bu kapsamda, doğrusal olmayan modellerin para talebi fonksiyonları üzerinde uygulaması incelenecek olursa, doğrusal modelde de olduğu gibi özellikle Amerika ve İngiltere üzerine yapılmış çalışmalara rastlanabilir. Chen ve Wu (2005), Amerika ve İngiltere için para talebini üstel yumuşak geçişli (ESTR, Exponential smooth transition) modeller ile tahmin etmiştir. Yumuşak geçişe olanak sağladığından literatürde STR modelleri üzerine daha çok uygulama bulunabilir. Bunlar, Amerika için Haug ve Tam (2007); Sarno, Taylor ve Peel (2003) çalışmalarıdır. İngiltere için Khadaroo (2003); Terasvirta ve Eliason (2001) çalışmaları sayılabilir. Çeşitli Avrupa ülkelerinin para talebi fonksiyonlarındaki doğrusalsızlığı modelleyen çalışmalar ise Sarno (1999); Lutkepohl, Terasvirta ve Wolters (1999); Ordonez (2003) çalışmalarıdır. Literatürde, Avrupa Bölgesi için para talebi doğrusalsızlığını modelleyen sadece 2 çalışmaya rastlanmıştır. Bunlardan ilki Markov rejim modelini kullanan Calza ve Zaghini (2006) çalışmasıdır. Calza ve Zaghini (2006) çalışmalarında M1 para talebi için 1971:4-2003:3 dönemini kapsamışlar ve kısa dönem ilişkiyi gösteren modelde doğrusalsızlığı Markov rejim hata düzeltme modeli (Markov Switching Error Correction Model) kullanarak analiz etmişlerdir. Literatürde bulunan ikinci çalışma ise Dreger ve Wolters (2010) çalışmasıdır. Dreger ve Wolters (2010) çalışmalarında, 1983:1-2004:4 dönemi için TAR modelini kullanarak M3 para talebi modelindeki doğrusalsızlığı göstermişlerdir. Her iki çalışmada tek denklem tahmin yaklaşımını kullanmış, para talebini sistem tahmini ile modellememiştir. Avrupa Merkez Bankası'nın M3 para talebini hedeflediği düşünülürse Calza ve Zaghini (2006) çalışmalarında M1 para talebinin doğrusalsızlığını göstermişlerdir. Bu nedenle bu tez çalışması, kapsadığı uzun dönem

(1980-2010), yöntem (M-TAR tipi eşik eşbütünleşim metodu) para bileşeni (M3) değişkenleri düşünüldüğünde literatür için ilk olma özelliği taşımaktadır.

Literatür taraması özetlenecek olursa, para politikaları ve politika yapıcılar için istikrarlı ya da en azından öngörülebilir bir para talebi, GSYIH, enflasyon ve faiz oranı ilişkisi önemlidir. Fakat para talebi modelinin istikrarlılık özelliği 2000'li yıllardan sonra azalmaya başlamıştır. Avrupa Bölgesinde yaşanan ekonomik kriz ile birlikte, 2007 yılından sonra para talebi çalışmaları tekrar popular olmaya başlamıştır. Para politikaları ekonomiler için oldukça önemli bir yere sahiptirler. Bu nedenle ekonomik krizi yönetmekte ve sonlandırmakta da etkisi göz ardı edilmemelidir. Fakat 2001 yılında Euro madeni para ve banknotların piyasaya girişiyle beraber, para talebi modelleri de istikrarlılığını kaybetmeye başlamıştır. Bu nedenle de literatürdeki çalışmalar farklı yaklaşımlarla istikrarlılık özelliğine sahip para talebi fonksiyonları modellemeyi amaçlamışlardır. Doğrusal olmayan literatüre göre, bulgular iki şekilde özetlenebilir. Birincisi, para talebinin belirleyicileri, faiz oranları, büyüme ve enflasyon değişkenleri doğrusalsızlık içermektedir. İkincisi ise, yapılan nadir Avrupa Bölgesi çalışmalarının yanında, Avrupa Bölgesi ekonomisine yön veren Almanya para talebinde doğrusalsızlık gözlenmiştir. Bu bulgular çerçevesinde M3 para talebi modelinde doğrusal olmayan bir ilişki olabileceği hipotezi desteklenmektedir.

Avrupa Bölgesi M3 para talebinin, GSYIH, enflasyon ve faiz oranları değişkenleri ile doğrusal olmayan rejim geçişli modeller ile tahmin edileceği hipotezi literatür tarafından da desteklendikten sonra para talebi modeli önce doğrusal tahmin yöntemleriyle daha sonra da doğrusal olmayan yöntemlerle modellenmiş ve etki tepki analizleri ile karşılaştırma yapılmıştır.

İlk olarak, doğrusal tahmin modelleri açıklanacak ve tahminler yorumlanacaktır. Yöney kendiyle bağlaşım modeli (Vector autoregression model, VAR) ve yöney hata düzeltme modeli (Vector error correction, VEC) içsel değişkenlerin birlikte modellenmesine olanak sağlayan modellerdir. Doğrusal Model Döngüsü şöyle özetlenebilir:

I. Öncelikle ekonomik teoriye uygun olarak model için gereken değişkenleri seçerek y_t vektörü oluşturulur.

II. Bütün değişkenlerin I(1) seviyesinde birim köke sahip olduğunun testi için ADF, KPSS, Phillips-Perron birim kök testleri yapılır ve sonuçlar yorumlanır.

III. VAR modeli gecikme değerinin derecesinin belirlenmesi için model seçme ölçütlerinden Akaike Bilgi Ölçütü (Akaike Information Criteria, AIC), Schwarz Bayesci Bilgi Ölçütü (Schwarz Bayesian Information Criteria, SIC), Olabilirlik Oranı (Likelihood Ratio, LR) ve Hannan-Quinn Ölçütleri kullanılır.

IV. VAR modeline göre gölge değişkenlere karar verilir ve model tanısal test sonuçları (diagnostic tests) analiz edilir.

V. Eşbütünleşim kertesi (cointegration rank) ve tahminlerine karar verilir. Eşbütünleşim kertesinin sayısı Johansen (1995) metoduna göre belirlenir.

VI. Eşbütünleşim ilişkileri belirlenir ve eşbütünleşim ilişkilerine ekonomik teorinin belirlediği kısıtlar tanımlanır.

VII. Uzun dönem ilişkiyi tahmin etmek için VEC modeli tahmin edilir. Tutumlu model (Parsimonious model) tahmin edilir. Tam Bilgi Ençok Olabilirlik Modeli (Full Information Maximum Likelihood Model, FIML) ile kısa dönem parametreleri tahmin edilir. Son olarak tüm model tanısal test sonuçları analiz edilir.

VIII. Sonraki aşama, modelin istikrarlılık özelliklerini CUSUM ve CUSUMSQ sınamaları ile analiz etmektir.

IX. Doğrusal modellemenin son aşaması ise etki tepki analizleri ile modeldeki dinamik etkileri ölçmek ve karşılaştırmaktır. Etki tepki analizleri, bir değişkene verilen şokun, kısa ve orta vadede, eşbütünleşik sistemde diğer içsel değişkenlere nasıl geçtiğini, etkilediğini göstermektedir.

Yukarıda belirtilen doğrusal modelleme döngüsü çerçevesinde, Avrupa para talebi doğrusal olarak modellenmiş ve Bölüm IV'de sunulmuştur. Doğrusal model sonuçlarına göre Avrupa para talebi, GSYIH, enflasyon ve faiz oranları arasında 1980-2010 dönemi için literatürün aksine istikrarlı bir ilişki bulunmuştur. Öncelikle literatür tarandığında, temel alınan çalışmalarda, örneğin, Browne, Fagan ve Henry

(1997); Goldfeld ve Sichel (1990); Fase (1993); Filosa (1995); Sriram (2001); Yıldırım (2003), para talebi, GSYIH, enflasyon ve faiz değişkenleri kullanılarak modellenmiştir. Bu bağlamda, değişkenler belirlendikten sonra, veri setleri düzenlenmiştir. Faiz oranı olarak, kısa dönem faiz oranlarını temsilen, 3 aylık interbank kuru alınmıştır. Literatürde uzun dönem faiz oranlarını temsilen ise 10 yıllık hükümet bonoları alınmaktadır. Laidler (1971)'e göre, para talebi açıklanırken uzun dönem ve kısa dönem faiz oranlarını içermekte sistematik açıdan bir farklılık bulunmamaktadır. Enflasyon olarak üretici fiyat indekslerindeki (Producer Price Indeks, PPI) yıllık değişim yüzdesi alınmıştır. PPI verisi Avrupa Merkez Bankası (ECB) veri tabanından elde edilmiştir. Veri elde etme aşamasında toplulaştırma sorunlarından kaçınmak amacıyla, Brand ve Cassola (2000) çalışmasında sunulan veri seti, IFS (International Financial Statistics, Uluslararası Finansal İstatistikler) ve Avrupa Merkez Bankası veri tabanı kullanılmıştır.

VAR modeli kurulmadan önce, ADF (Genişletilmiş Dickey-Fuller istatistiği, Augmented Dickey Fuller), Phillips-Perron ve KPSS birim kök testleri uygulanmış ve bütün değişkenlerin I(1) seviyesinde durağan olduğu sonucuna varılmıştır. Daha sonra birinci dereceden farklar alınarak uç değerler incelendiğinde, VAR modeline dahil edilecek gölge değişkenler belirlenmiştir. Birinci dereceden fark grafiklerine göre, 2008 ekonomik krizi son aylarda etkisini göstermeye başlamaktadır. Modelleme aşamasının diğer bir aşamasında gecikme değerleri seçilmiştir. Gecikme değerleri belirlenirken, En çok olabilirlik (LR), Schwarz Bayesci Bilgi Ölçütü (SIC), Akaike Bilgi Ölçütü (AIC) ve Hannan-Quinn (HQ) Ölçütleri kullanılmıştır. SIC ve HQ ölçütlerine göre gecikme değeri 4 seçilirken, LR ve AIC ölçütlerine göre gecikme değeri 9 seçilmiştir. Tahmin edilen modellerin tanısal test sonuçlarının karşılaştırılması, serbestlik derecesinin düşürülmemesi ve veri kaybından kaçınılması amacıyla modelin fazla gecikme değeri içermesinden kaçınılmış ve modelin gecikme değeri olarak 4 alınmıştır. Öncelikle VAR modeli tahmin edilmiş ve modele göre gölge değişkenlere karar verilmiştir. Alınan gölge değişkenler VEC modelde ve karşılaştırma kolaylığı olması açısından da doğrusal olmayan eşik VEC modelde de modele dahil edilmiştir. VAR modeli tanısal test sonuçlarına göre modelde herhangi bir ardışık bağımlılık (AR, auto regression), değişen varyans (heteroscedasticity) ve normallik problemlerine rastlanmamıştır.

Sonraki aşama eşbütünleşim analizidir. Eşbütünleşim analizi Johansen (1995) yaklaşımına göre içsel değişkenler olan, para talebi, GSYIH, enflasyon ve faiz oranı değişkenleri arasındaki ilişkiyi araştırmaktadır. Test sonuçlarına göre dört değişken arasında bir eşbütünleşik ilişki bulunmuştur. İçsel değişkenler eşbütünleşik olduğunda modelde hata düzeltme terimi de içerilir ki, elde edilen yeni modele hata düzeltme modeli (ECM, error correction model) adı verilir. VEC modelde ekonomik teorinin önerdiği kısıtlar modele dahil edilmiştir. İlgili kısıtlar sırasıyla, gelir, enflasyon ve faiz oranları değişkenlerinin zayıf dışsal oluşudur. İkinci kısıt para talebinin gelir esnekliğini kapsarken, son kısıt fiyatların homojenliğidir. Eğer zayıf dışsallık hipotezi red edilemez ise eşbütünleşim vektörü, GSYIH, enflasyon ve faiz oranları değişkenlerinin kısa dönem tahmin modellerinde görünmeyecektir. Bu bağlamda uygulanan testlere göre, zayıf dışsallık hipotezi red edilemezken, bireysel olarak test sonuçlarında da ilgili değişkenlerin zayıf dışsal olduğu sonucuna varılmıştır. Birim gelir esnekliği ve fiyatların homojenliği hipotezleri istatistiksel açıdan anlamsız bulunarak red edilmiştir.

Bu bağlamda, elde edilen uzun dönem tahmin sonuçlarına göre, para talebi, GSYIH arasında pozitif yönlü, para talebi ile enflasyon ve faiz oranları arasında negatif yönlü uzun dönem ilişki bulunmuştur. Para talebinin gelir esnekliği 2.07 bulunurken, göreceli olarak yüksek bulunan bu esneklik literatür ile karşılaştırıldığında Avrupa para talebi için 2001 sonrası dönem içerildiğinde gelir esnekliğinin yükseldiği bulgusuna ulaşılır. Şöyle ki, Dreger ve Wolters (2010) çalışmalarında Avrupa Bölgesi için para talebini tahmin etmişler ve 2002'ye kadar olan veri setini kullandıklarında para talebinin uzun dönem gelir esnekliğini 1.292 bulurken, veri setlerini 2007'ye kadar uzattıklarında para talebinin uzun dönem gelir esnekliğini 2.976 bulmaktadırlar. Literatürde örnek verilecek olursa, Yıldırım (1997) çalışmasında Almanya için yapılan araştırmada, gelir esnekliği 2.21 bulunurken Avrupa Bölgesi için 1.77 bulunmuştur. Avrupa Bölgesi için yapılan çalışmalar, para talebinin uzun dönem gelir esnekliğini birim esneklikden yüksek 2'ye yakın bulmaktadır (Örneğin, Dregers, Reimers ve Roffia, 2007; de Santis, Favero ve Roffia, 2008).

Uzun dönem tahmin modellerinden sonra, FIML model tahminleri ile kısa dönem ilişki modellenmiştir. Elde edilen kısa dönem model tahminlerine göre, para talebi modelinde hata düzeltme terimi (ECT, error correction term) -0.130 ve istatistiksel açıdan anlamlı bulunmuştur. -0.130 olan hata düzeltme katsayısı, modeldeki herhangi bir dönemde dengeden sapmanın 1 çeyrekte %13'ünün düzeltilerek modelin yaklaşık olarak 2 yılda dengeye geleceğini göstermektedir. Hata düzelteme teriminin katsayısı da, literatürde yapılan çalışmalarda gösterilmektedir ki, 2001 yılı sonrasını içeren çalışmalarda göreceli olarak daha düşük bulunmaktadır. Yapılan bu çalışmada, elde edilen doğrusal modelde hata düzeltme terimi literatürdeki bazı çalışmalardan yüksek bulunmuştur.[100] Kısa dönem para talebi tahmin modelinde göze çarpan bir diğer bulgu ise, GSYIH değişkeninin katsayısının pozitif fakat istatistiksel açıdan anlamsız bulunmasıdır. Bu ekonomik teoriyle çelişen sonuç, modelin doğrusalsızlık içerirken doğrusal tahmin yöntemleriyle modellenmesinden kaynaklanabilir. Nitekim, doğrusal olmayan tahmin sonuçları ekonomik teoriye daha uyumlu sonuçlar vermektedir. Tahmin edilen kısa dönem faiz oranı modeline göre, faiz oranları sadece kendi gecikmeli değerinden etkilenmektedir. Bu bulgu göstermektedir ki, faiz oranı değişkeni dışsal olarak alınabilir. Faiz değişkeni dışsal olarak alınarak FIML modelleri tekrar tahmin edildiğinde, elde edilen yeni model katsayılarında işaret ve büyüklük açısından anlamlı bir farklılık gözlenmemiştir. Modele uygulanan tanısal test sonuçlarına göre de ardışık bağımlılık, normallik ve değişen varyans gibi sorunlara rastlanmamıştır.

Doğrusal modelleme sürecinde diğer bir aşama, istikrarlılık testi sonuçlarıdır. Daha önceden de belirtildiği gibi, doğrusal para talebi literatürünün asıl amacı, para talebi modelinde istikrarlı bir ilişki elde etmektir. Bu istikrarlı ilişki para politikaları ve ekonomi için de önem taşımaktadır. CUSUM ve CUSUMSQ istikrarlılık testi sonuçlarına göre 1980-2010 dönemi Avrupa para talebi modeli istikrarlı bulunmuştur. Son olarak, doğrusal modellemenin son aşamasında etki tepki analizi

[100] Örnek olarak; Kremers ve Lane (1990), Fase ve Winder (1993), Monticelli ve Strauss-Kahn (1993), Coenen ve Vega (2001), Golinelli ve Pastorello (2002) çalışmaları incelenebilir.

ile kısa ve orta vadedeki dinamikler analiz edilmiştir. Etki tepki analizleri VAR ve VEC modelllerinin politika analizlerinde kullanılmasını kolaylaştırır. Değişkenlere gelen şokların sistemdeki etkisini ölçmektedir. Her değişken için, 1 standart sapmalık şokun ilgili değişkene etkisi analiz edildiğinde, GSYIH değişkenine gelen 1 standart sapmalık şok para talebi değişkeninde ilk periyotlarda negatif bir etki yaratmaktadır. Ekonomik teoriyle de çelişen bu sonuç, doğrusal olmayan modeller ile karşılaştırılacaktır. FIML kısa dönem tahminlerinde görüldüğü gibi, faiz oranı sadece kendi gecikmeli değerinden etkilenmektedir. Etki tepki analizlerinden de görülebileceği gibi, faiz değişkeninin diğer değişkenlere verilen şoklara tepkisi anlamlı görünmemektedir. Bu durumda, faiz oranının dışsal olarak alındığı 3 içsel değişkenli model için etki tepki analizileri tekrarlanmış ve önceki etki tepki analizilerine benzer sonuçlar elde edilmiştir.

Tezin ana amacı Avrupa para talebi modelini doğrusal ve doğrusal olmayan çerçevede karşılaştırmak olduğundan, bu amaç doğrultusunda, doğrusal model tahminlerinin ardından, doğrusal olmayan modeller tahmin edilmiştir. Doğrusal olmayan modellerde önceden belirtildiği gibi Momentum-TAR tipi eşik eşbütünleşim (M-TAR type threshold cointegration) modeli uygulanmıştır. Ekonomik veriler krizler/şoklara açık verilerdir. Momentum modelin en önemli özelliği, modeldeki şoklara verilen farklı tepkileri iyi kapsamasıdır. Çünkü ekonomik verilerde inişler ve çıkışlardaki salınımlar simetrik olmayabilir. Yani, bir ekonomide resesyon ve büyüme dönemlerinde bir değişkenin yükselişi ve düşüşü simetrik olmayacaktır. Momentum model bu asimetrileri kapsamada etkin olmaktadır. TAR modelde belirlenen eşik değişkeni Momentum TAR modeli için farkı alınarak oluşturulan yeni eşik değişkeni olarak değiştirilir. MTAR modelinin detayları ve uygulaması Enders ve Granger (1998); Enders ve Siklos (2001); Öcal ve Yıldırım (2009) çalışmalarında incelenebilir. Kullanılan eşik değişkeni için belirlenen eşik değeri, sıfırın yanında başka değerde alabilir. Eşik değeri Chan (1993) metoduyla etkin sonucu veren değeri almak suretiyle seçilir. Bu çerçevede, çalışmadaki doğrusal olmayan model tahmini prosedürü aşağıdaki gibi sıralanabilir:

I. Eşbütünleşim vektörünün birinci dereceden gecikmeli değeri doğrusal VAR modelinden elde edilir. Eşik değişkeni olarak eşbütünleşim vektörünün kullanıldığı, rejimler arasında sadece uzun dönem düzeltme katsayılarının değiştiği varsayımıyla eşik VEC (Threshold VEC, TVEC) modeli tahmin edilir.

II. I. aşama tekrarlanarak, bu kez rejimler arası hem kısa hem uzun dönemde modeldeki tüm dinamiklerin değişmesine izin veren model tahmin edilir.

III. I. ve II. aşamalar tekrarlanarak, eşbütünleşme vektörünün ilk gecikme değeri yanında, onun bileşenleri, para talebi, GSYIH, enflasyon ve faiz oranları değişkenlerinin her biri tek tek eşik değişkeni olarak alınır. Bu modeller sadece uzun dönem düzeltme katsayılarının değiştiği ve hem uzun dönem hem de kısa dönem katsayılarının değiştiği varsayımları altında tahmin edilir. Model seçme ölçütleri, AIC, SIC ve SSR (kalıntı kareleri toplamı) değerleri karşılaştırılarak en iyi model seçilir.

IV. Son aşama etki tepki analizlerinin hesaplanarak, sisteme gelen bir şok sonucunda meydana gelen dinamiklerin yorumlanmasıdır. Bu kapsamda, Genelleştirilmiş Etki Tepki Analizleri (Generalized Impulse Responses, GIRFs) kullanılmıştır. Burada iki farklı yaklaşım izlenmiştir. İlkinde model, eşik değerinin altı ve eşik değerinin üzeri olmak üzere ikiye ayrılmıştır. Her rejim için para talebi modeli tahmin edilmiş ve ayrı ayrı GIRF analizleri yapılmıştır. Diğer bir yaklaşım, simulasyon yöntemidir. Simulasyon yöntemi rejimin herhangi bir şokta, birinden diğerine geçmesine olanak sağlar, Bu da GIRFlerin hem üst hem de alt rejimlerdeki şokları kapsamasını sağlar.

Bu kapsamda, öncelikle doğrusal VAR modelinden eşbütünleşme vektörünün ilk gecikmeli değerleri elde edilip eşik değişken olarak alınan TVEC modeli tahmin edilmiştir. Bu modelde çeşitli varsayımlar kullanılmıştır. İlk varsayım rejimler arası sadece uzun dönem katsayılarının değiştiği varsayımıdır. İkinci varsayım ise, hem uzun dönem hem de kısa dönem olmak üzere rejimler arası iki ayrı model elde eden yaklaşımdır. Aynı varsayımlarla, eşik değişkenini diğer değişkenlerden alan modellerde tahmin edilmiştir. En sonunda tüm modeller karşılaştırıldığında, model seçme ölçütlerine göre en iyi model, eşbütünleşme vektörünün ilk gecikmiş değerinin eşik değişkeni olarak alındığı ve sadece uzun dönem düzeltme katsayılarının değişiklik gösterdiği model olarak seçilmiştir. Bu nedenle bu çalışmada sadece bu model sunulmuş, diğer modeller sunulmamıştır. Eşbütünleşme vektörü, tüm değişkenlerin doğrusal bir fonksiyonu olduğundan, tüm değişkenlerdeki dinamikleri yansıtacaktır.

Elde edilen tahmin sonuçları sunulduğunda, Enders ve Granger (1998) çalışmasındaki 4 tahmin yaklaşımı uygulanmıştır. Öncelikle eşik değişkeni olarak, eşbütünleşim vektörünün ilk gecikmeli değeri ve eşik değeri olarak da 0 değeri alınmıştır (TAR model). İkinci modelde, eşik değeri olarak Chan (1993)'e göre tutarlı bir eşik değeri tahmin edilip, ilgili değer alınmıştır (Tutatlı TAR modeli). Üçüncü yaklaşım, eşik değişkeni olarak eşbütünleşim vektörünün ilk gecikmeli değerinin farkının alındığı, eşik değeri olarak ise 0 değerinin alındığı yaklaşımdır (M-TAR modeli). Son ve en önemli model ise eşik değeri olarak, Chan (1993)'e göre tutarlı bir eşik değerinin tahmin edildiği modeldir (Turarlı M-TAR modeli). M-TAR modeli sonuçlarına göre, tahmin edilen eşik değeri, -0.00224 olarak bulunmuştur. Bu eşik değerinin üzeri üst rejimi, aşağısı alt rejimi göstermektedir. Her iki rejim için de uzun dönem düzeltme katsayıları negatif ve istatistiksel açıdan anlamlıdır. Negatif olması modelin bir şok karşısında dengeye gelebildiğini gösterir. Üst rejim için -0.0907, alt rejim için -0.107 bulunan düzeltme katsayılarının anlamlı farklılığı test edilmiş ve istatistiksel açıdan da 2 rejim birbirinden farklı bulunmuştur. Rejimler için düzeltme katsayıları doğrusal modele çok yakın olmakla birlikte, sadece istatistiksel açıdan anlamlı katsayıların olduğu indirgenmiş model hesaplanmıştır. İndirgenmiş modelde, üst rejim katsayısı -0.05, alt rejim katsayısı ise -0.11 olarak bulunmuştur. Üst rejim için katsayının anlamlılığı da daha düşüktür (p değeri daha yüksektir). Bu model göstermektedir ki, ekonomi üst rejimde olduğunda sisteme gelen bir şokun tamir edilip, dengeye dönülmesi çok uzun zaman alacak fakat ekonomi alt rejimde ise sisteme gelen bir şoku tamir edip dengeye geri gelmek yaklaşık 2 yılı alacaktır. Sistemin tekrar dengeye dönüşü ekonomi üst rejimdeyse 5 yılı bulmaktadır. Etki tepki analizlerinin ilk yaklaşımı olan, üst ve alt rejim için farklı IRF hesaplama yaklaşımına göre, alt rejime gelen şoklar daha kısa sürede yok olurken, üst rejime gelen şokların etkisi daha uzun sürmektedir. Göze çarpan en önemli bulgu, üst rejimde GSYIH değişkenine gelen şok etkisi, para talebinde negatif tepki oluştururken, alt rejimde pozitif tepki oluşturmaktadır. Benzer sonuçlar simulasyon yöntemiyle elde edilen GIRF analizlerinde de gözlemlenebilmektedir. Doğrusal ve doğrusal olmayan etki tepki analizleri sonuçları karşılaştırıldığında, GSYIH ve enflasyon analizlerinin ekonomik teoriye daha uygun sonuçlar verdiği söylenebilir. Etki tepki analizlerinde, doğrusal VEC ve eşik VEC modelleri karşılaştırıldığında, işaret ve büyüklük açısından çok farketmemekle birlikte şokların etkisi doğrusal olmayan modelde daha çabuk yok olmaktadır. GSYIH değişkenine gelen 1 standart sapmalık şoka para talebinin tepkisini pozitif veren GIRF analizi sonuçları ekonomik teori tarafından da açıklanabilmektedir.

Sonuç olarak tüm bulgular ve çalışmanın amacı özetlenecek olursa, bu çalışma uzun bir dönem olan 1980-2010 dönemi için Avrupa para talebini, GSYIH, enflasyon ve faiz oranları değişkenleri ile modellemiştir. Tezin temel amacı bu ilişkiyi doğrusal ve doğrusal olmayan modeller çerçevesinde tahmin edip karşılaştırmaktır. Bu kapsamda doğrusal VEC ve eşik VEC (TVEC) modelleri tahmin edilmiş ve etki tepki analizleri karşılaştırılmıştır. Elde ettiği bulgular çerçevesinde, bu tez çalışması 1980-2010 dönemi için Avrupa para talebini geleneksel değişkenlerle modelleyen ve istikrarlı bir ilişki bulan ilk çalışma olmuştur. Aynı zamanda M-TAR eşik eşbütünleşim sistem modeli yaklaşımıyla Avrupa para talebini modelleyen ilk çalışma olma özelliği ile Avrupa para talebinin doğrusal olmayan modellerle, doğrusal modellere göre daha iyi açıklanabileceğini vurgulamıştır. Çalışmada M-TAR TVEC modeli yaklaşımı kullanılmasının yanında, ileriki araştırma planları kapsamında çalışma Yumuşak geçişli VEC (Smooth transition VEC) modeli kullanılarak genişletilecektir.

APPENDIX D

TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü	
Sosyal Bilimler Enstitüsü	x
Uygulamalı Matematik Enstitüsü	
Enformatik Enstitüsü	
Deniz Bilimleri Enstitüsü	

YAZARIN

Soyadı : KORUCU GÜMÜŞOĞLU

Adı : NEBİLE

Bölümü : İKTİSAT

TEZİN ADI (İngilizce) : "MODELLING NONLINEARITIES IN EUROPEAN MONEY DEMAND: AN APPLICATION OF THRESHOLD COINTEGRATION MODEL"

TEZİN TÜRÜ : Yüksek Lisans [ ] Doktora [x]

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir. [ ]
2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir. [ ]
3. Tezimden bir (1) yıl süreyle fotokopi alınamaz. [x]

TEZİN KÜTÜPHANEYE TESLİM TARİHİ: