The Demand for Money and Monetary Policy in Ethiopia

By:

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Abstract

It is repeatedly noted that the existence of a stable demand for money function is very crucial for the conduct of monetary policy. Accordingly this study attempted to estimate a demand for money function for Ethiopia using quarterly data ranging from 1970/71:I to 2003/04:IV. The study tried to estimate both the long-run and short-run demand for real narrow money balances using the Johansen multivariate framework by taking real GDP, the saving deposit rate, the inflation rate and the depreciation rate of the birr in the parallel market as explanatory variables. The depreciation rate of the birr in the parallel market was, however, dropped from the long-run model as its inclusion could not result in a meaningful cointegration relationship. Thus, in the long-run demand for real narrow money holdings was found to depend positively on real GDP and negatively on the saving deposit rate and the one period-lagged inflation rate. The coefficient of real GDP was also close to unity consistent with the quantity theory of money. Of the two opportunity cost variables in the model the inflation rate was found out to have a much pronounced impact on the demand for money reflecting the low level of development of the financial system.

In the short-run, only lagged values of money holdings and real GDP were found out to have significant impact on the demand for money. None of the opportunity cost variables were found to have any impact on the demand for money in the short-run. This is due to the low level of development of the financial system which limits the availability of many alternatives to money holdings. This observation is corroborated by the very low coefficient of the error correction term in the vector error correction model which shows the speed of adjustment to long-run equilibrium.

Chapter I: Introduction

1.1 Background

Estimating a stable demand for money function of an economy has been the quest of many research endeavors since the beginning of the previous century. The special role that money plays in the economy has made it an important research topic. The presence of a stable money demand function enables policy makers to influence changes in important economic variables such as output, interest rates and prices by manipulating the amount of money that is circulating in the economy (Judd & Scadding (1982)).

The Ethiopian economy has gone through two regime changes in the past four decades. The feudal regime which was in power until 1974/75 followed a somewhat market oriented economic arrangement before being replaced by the dergue regime whose style of economic management was a centrally planned socialist system. After about seventeen years of centrally planned economic system there was again a shift to a market friendly economic arrangement in 1992. A number of liberalization measures have been undertaken following this change.

The financial sector was one of the major areas where major liberalization measures were taken. Among these liberalization measures the main ones were significant devaluation of the birr, allowing private banks and insurance companies to operate, and easing of restrictions on foreign exchange market. These liberalization measures are bound to necessitate a shift from direct methods of monetary control to indirect ones. The presence of a stable money demand function greatly facilitates the conduct of monetary policy as it tells policy makers how different variables are affected by changes in the money supply. Thus, the liberalization measures that are being undertaken increase the need for estimating a demand for money function for the economy.

1.2 Statement of the Problem

The empirical literature on the demand for money is very vast, although the bulk of the works have been conducted on the economies of the United States and the United Kingdom (Fischer; 1995); Laidler; 1993). Money demand studies on developing countries have also been growing since the 1970's (Sriram; 1999a; Ghatak; 1995).

Only a handful of studies have attempted to estimate a demand for money function for Ethiopia. One such attempt was Lulseged (1996) which tried to determine whether monetization of the economy has an impact in influencing the demand for money in Ethiopia. This study used the broad definition of money (real M_2) as the relevant money stock variable, real GDP as the scale variable and the real exchange rate and the inflation rate as opportunity cost variables. The number of bank branches in the country was used as a proxy for monetization while population was also included in the model. Using annual data for the period 1961-1992 and employing the Engle-Granger two stages procedure this study found out the long-run income elasticity of money demand to be 0.29 which is way below the expected unit elasticity. The number of bank branches was also reported to have a significant impact on the demand for money. In the short-run model a 70% adjustment to long-run equilibrium money demand was reported.

Another subsequent attempt to estimate a demand for money equation for Ethiopia was Ergete (1998). This study tried to estimate demand functions for both the narrow and broad definitions of money using the Johansen multivariate framework. Nominal money stocks were used as the relevant variables in both cases. The scale variable employed was GDP for both definitions of money while the expected inflation rate and the black market premium were taken as relevant opportunity cost variables. One peculiar characteristic of this study is that it generated quarterly data based on annual data by interpolation for those variables for which quarterly series are lacking. The sample period covered by the study was 1970:I - 1995:IV. The long-run income elasticity of money demand was 1.05 for the narrow definition of money and 0.79 for the broad definition of money. The price elasticity of nominal money demand was found to be 0.83 for both definitions of money. The study

explicitly tested for the homogeneity of money demand with respect to price and income and concluded that the hypothesis of the homogeneity of money demand with respect to price and income holds for Ethiopia.

Streken (1999) also used quarterly data to estimate a demand for money function for Ethiopia. This study used the method developed by Boots et al (1976) to disaggregate annual GNP figures into quarterly series. The money stock variable used in this study was real M1 deflated by population (i.e. per capita real money stock) while real GNP was used as the scale variable. The black market premium and the real price of coffee were used as relevant opportunity cost variables. The ratio of food price index to non-food price index was used as a proxy for shortage of consumption goods. The study obtained a 1.39 long-run income elasticity of money demand. In addition, it was found out that shortage of food has a positive impact on the long-run demand for narrow money as does the real price of coffee. In the short-run, on the other hand, inflation was found to exert a negative impact on money demand while black market premium was found to be insignificant.

As is evident from the foregoing discussion very few attempts have been made so far to estimate a demand for money function for Ethiopia. In addition, the studies seem to have reached at diverging conclusions. While all the above cited studies concluded that the demand for money function has remained stable over their respective sample periods the parameter estimates could not have been more different. The long-run income elasticities estimated in all the three studies are very different from each other. This could be attributable to the different explanatory variables included in the respective money demand functions. The use of the Engle-Granger error correction procedure which is considered to be inferior to the Johanson multivariate framework in Lulseged (1996) can also be cited as a methodological difference. Thus, we can infer that there have not been any conclusive findings on the various aspects of the demand for money in Ethiopia. It's this lack of consensus on the subject that has motivated the current study. The current study will try to see if we can make the results more conclusive by adding new explanatory variables and by expanding the sample period covered.

1.3 Objectives of the Study

The main objective of the study is to estimate a demand for money function for Ethiopia and to check whether it has remained stable over the sample period. Other specific objectives include:-

- to examine the changes in the financial sector during the three different regimes
- to find out the major determinants of money demand both in the long-run and the short-run
- to compare the different kinds of monetary policy mechanisms employed by the three different regimes.

1.5 Hypotheses of the Study

As was mentioned above there were two major regime shifts in Ethiopia. The main hypothesis of this study is, therefore, that there were breaks in the demand for money function of the economy due to these regime shifts.

1.6 Organization of the Study

The paper is organized as follows. After this introductory chapter, different theories of demand for money and major empirical issues are discussed in chapter two. Then chapter three discusses the financial system of Ethiopia highlighting major problems in the sector. Different monetary policy instruments employed during the three regimes are also discussed in this chapter. The empirical analysis is presented in chapter four and chapter five concludes the study.

Chapter II: Literature Review

2.1 Theories of Demand for Money

Theoretical works on the demand for money started to appear only at the beginning of the twentieth century even though the special role that money plays in the economy was recognized by many analysts (McCallum and Goodfriend, 1987). The quantity theory of money is often mentioned as the beginning of a formal analysis of money demand. Irvin Fisher was the first to be associated with this theory in the form of his famous equation of exchange:-

$$MV = PY$$

where:

M = nominal stock of money
V = transactions velocity of money
P = the price level and
Y = nominal income

Using this equation, Fisher argued that money is neutral in that changes in the nominal stock of money do not have any influence on the determination of relative prices, real interest rates and real income. They just translate into proportionate changes in the price level (Sriram, 1999a).

Another class of the quantity theory of money was expounded by Arthur Pigou and Alfred Marshall. Popularly known as the Cambridge cash balance approach, this theory was the first to base the analysis of money demand on the individual (Laidler, 1993). Rather than focusing on the quantity of money that is needed to carry out transactions in the economy as Fisher did, this approach focused on the motives that lead individuals to hold money. According to the Cambridge approach, the most important motive for an individual to hold money is the universal acceptability of money in exchange for goods and services. That is,

individuals hold money because it enables them to make their transactions easily. They argued that other things being equal the demand for money in nominal terms is proportional to the nominal level of income for each person and hence for the aggregate economy. Using this relation they formulated their version of the equation of exchange which was different from Fisher's equation only in the concept of velocity. In Fisher's equation velocity is the transactions velocity of circulation of money while in the Cambridge cash balance approach it was the income velocity of circulation of money. They, however, also concluded that money is neutral.

One of the major drawbacks of the quantity theory of money is that it did not take into account the opportunity cost of holding money as a determinant of the demand for money (Sriram, 1999a). As there are alternative assets to money in forms of which individuals can hold their assets, opportunity cost variables are important determinants of money demand. Although the cash balance approach mentioned uncertainty about the future as determining the demand for money, there was no explicit mention of the interest rate in the analysis. It was John M. Keynes who built on this and formulated a demand for money function that explicitly included the interest rate as a determining variable.

Keynes's major difference from his predecessors was his emphasis on the different motives for holding money. He identified three motives viz. the transactions motive, the precautionary motive and the speculative motive. His analysis of the transactions and the precautionary motives were similar to the analysis of the quantity theorists. He argued that because of the non-synchronization of payments and receipts, individuals want to hold money to make transactions. There is a stable relationship between the level of transactions conducted by the individual and his level of income. Thus, the transactions demand for money depends on the individual's level of income. The precautionary demand for money, on the other hand, arises due to the uncertainty about the payments that the individual might want to make. Keynes argued that this also depends on the level of income.

The extensive analysis of the speculative motive for holding money is the most important distinguishing feature for Keynes's analysis on money demand. He assumed that an

individual has a choice of holding his wealth in the form of either money or bonds. Bonds offer the individual to pay interest income while money does not have any return. But there is also a risk associated with holding bonds as the price of bonds changes with changes in the interest rate. When the interest rate increases, the price of bonds falls and the individual faces the risk of a capital loss on his bond holdings due to the fall in the price of bonds. The reverse happens when the interest rate falls. Thus, Keynes argued that the individual's expectations about the future level of interest rate determine how much of his assets to hold in the form of bonds. If the individual expects the interest rate to fall he wants to hold more of his assets in the form of bonds because of the associated capital gain. On the other hand, if the individual expects the interest rate to rise he wants to hold less amount of bonds to avoid capital loss.

According to Keynes the individual's expectations about the future level of interest rate is influenced by the current level of interest rate. He argued that there is a value or a range of values of the interest rate that can be regarded as normal so that when the rate is above this normal range there is a tendency for people to expect it to fall and when it is below this normal range to expect it to rise. Thus, at higher levels of interest rate individuals expect the interest rate to fall and would want to hold more bonds (and less money) because of the expected capital gain. By similar reasoning, lower levels of interest rate are associated with higher demand for money. Therefore, Keynes concluded that the aggregate demand for money function is a negative function of the current level of interest rate. Keynes's demand for money function can be formulated as:-

$$M^d/P = f(y,r)$$

where

M^d = the demand for nominal money balances

P = the price level

y = real income

r = the interest rate

Another influential theory after the Keynesian theory of money demand was Milton Friedman's modern quantity theory of money. This theory differs from that of the Keynesian theory in that it treated the demand for money as the demand for any other durable good. Friedman argued that money, like any other asset, yields a flow of services to the agent who holds it since it is a temporary store of purchasing power. As any other demand analysis, Friedman focused on the constraints on the demand for money and the opportunity cost of holding money.

Friedman picked out wealth as the relevant constraint to the amount of money demanded. He distinguished between human and nonhuman wealth where the former refers to the present value of future labour income while the latter includes durable goods, bonds and equities. The substitutability between these two forms of wealth is limited and there may not be a market for human wealth. Thus, in order to make the measure of wealth included in the money demand function more inclusive, Friedman proposed the ratio of human to nonhuman wealth to be used as a variable in the demand for money function.

The opportunity cost of holding money is the income to be earned from holding bonds and equity instead of money. The return on these alternative assets includes the interest income earned and the capital gain (loss) associated with changes in their market prices. As discussed earlier, the percentage change in the interest rate is opposite in sign with the rate of capital gain (loss). Thus, the percentage change in the interest rate has to be subtracted from the interest rate to obtain the expected yields on the alternative assets. And the higher the expected yields of the alternative assets the lower the demand for money.

Friedman included changes in the price level as a relevant variable in his demand for money function since it can be regarded as a return on money. A rise in the price level means a fall in the real value of money holdings and vice versa. Thus, rising price levels imply negative return to money holding while falling price levels imply positive return to money holdings. Friedman argued that the expected percentage rate of change in the price level can be interpreted as an expected own rate of return to money holdings. The demand for money function proposed by Friedman can be stated as follows:-

$$M^d = f(W,r-(1/r)(dr/dt),(1/p)(dp/dt),h)P$$

where:

M^d = the demand for money in nominal terms

r = the rate of interest

W = wealth

h = ratio of human to nonhuman wealth

P = the price level

dr/dt = expected rate of change of r

dp/dt = expected rate of change of P

The effect of the ratio of human to nonhuman wealth (h) on the demand for money was not clearly stated in Friedman's demand function for money.

Subsequent theories on the demand for money revolved around the motives that lead individuals to hold money rather than analyzing it from a macroeconomic point of view. One class of the theories emphasized the medium of exchange role of money while another class focused on the store of value role. From the former class of theories the Baumol-Tobin transactions demand for money is the prominent one. This model assumes that the individual wants to minimize the total cost of holding money which includes the cost of transferring bonds in to money and foregone interest income. This model implies income and interest elasticity of money demand of 0.2 and -0.5, respectively (McCallum and Goodfriend, 1987).

Among the theories that emphasized the asset value of money, the most prominent one was that of James Tobin. In this model Tobin assumed that the individual's problem is to allocate his portfolio between money which is riskless and a bond which offers an uncertain interest income. He showed that the optimal portfolio mix of the individual depends on his degree of risk aversion, his wealth and the probability distribution of the return on the bond.

He also showed that the demand for real money balances is a negative function of the interest rate.

All the theories of demand for money discussed above imply a demand for money function that is a positive function of some scale variable (income or wealth) and a negative function of opportunity cost variables. The difference lies in the choice of these variables. Thus, a demand for money function can generally be stated as m = f(SV, OCV) where m is the stock of real money balances, SV is a measure of a scale variable and OCV is a measure of opportunity cost variable(s) (Sriram, 1999a).

2.2 Empirical Issues

One of the major issues one faces when setting out to estimate a demand for money function is the choice of relevant variables. The first issue that needs to be settled is which money stock variable to include. This depends on which role of money is assumed to be the primary motive for holding it. If the transactions role of money is assumed to be the prime motive for holding money, then narrower definitions of money are preferred. If, on the other hand, the portfolio role of money is assumed to be the driving force behind the holding of money, then broader definitions are appropriate (Sriram;1999a).

Generally, narrow money consists of currency in circulation which yields no interest and checkable deposits which bear little or no interest. These are believed to be held primarily for transactions purposes since they are highly liquid. Broad money, on the other hand, includes saving and time deposits which yield interest to holders and which are not highly liquid. The primary motive for holding these balances is considered to be portfolio diversification. With developments in the financial system, however, types of deposits which are highly liquid and which also bear interest have been created blurring the boundary between money balances considered to be held for transactions purposes and portfolio purposes. Thus, the choice of the appropriate money stock variable depends on the level of development of the financial system of the economy one sets out to estimate a demand for money function for.

Chapter III: Overview of the Financial System and Monetary Policy in Ethiopia

3.1 Macroeconomic Overview

Ethiopia is one of the poorest countries in the world with a per capita income of less than 100 US dollars. Its economy is dominated by a backward agricultural sector which contributes about half of its GDP, employs about 85 percent of its population and accounts for more than 90 percent of its export earnings. Three different regimes with different economic management systems have been witnessed in the past four decades in the country. The imperial regime which was in power until 1974 followed a somewhat feudo-capitalist economic system. The economic orientation of the dergue regime which came to power following the collapse of the imperial regime was a complete shift from the infant market oriented environment to a total control of almost all economic activity at the hands of the state. After seventeen or so years of centrally planned economic arrangement there was again a shift to a somewhat market friendly environment in 1992 where many sectors of the economy were opened up for the private sector.

Economic growth has been stagnant over the last four decades averaging at just 3.2 percent over the period 1960/61- 2003/04. Considering the growth performance in each of the three regimes, real GDP growth was 3.7 percent in the imperial period while it declined to 1.6 percent during the dergue regime. During the period 1992/93- 2003/04 real GDP growth rebounded averaging at 5.1 percent.

The economic structure of the country has remained fairly unchanged over the last four decades with agriculture still being the most important sector. The share of agriculture in total GDP which was 68.1 percent during the period 1960/61- 1973/74 declined to 55.6 percent during the dergue regime and 46.8 percent during the current government. This declining share of agriculture was not because of sectoral transformation in the economy.

are highly influenced by the weather as agriculture which is the mainstay of the economy is highly affected by weather conditions. In times of drought, significant price rises are witnessed triggered by shortage of agricultural output. In 1984/85 when there was a catastrophic drought in the country, for example, the inflation rate was 16.3 percent.

When we look at the external sector of the economy, the trade deficit has been widening continuously as a result of unchanging export structure in the face of rapidly rising import demand. The export structure of the economy is still at the stage of what it was four decades ago with one commodity (i.e. coffee) contributing a large share of export earnings. Most of the export items are agricultural products with very little value added. These contrasting growths of export earnings and import payments have made the country to be increasingly dependent on foreign loans and grants raising the country's external indebtedness.

Fiscal deficit (including grants) has been increasing sharply in the past three decades. Fiscal deficit which was just 0.2 percent of GDP during the imperial regime rose to 4.5 and 6.3 percent during the dergue and the present regimes, respectively. This is believed to have been primarily caused by higher defence spending and an increasingly larger government size.

3.2 The Financial System

Ethiopia's financial sector consists of commercial banks, micro-finance institutions, saving and credit associations, insurance companies and pension funds. Commercial banks have been the dominant type of institutions in the financial system accounting for about 94 percent of the total asset in the financial sector as at the end of 2003/04 (IMF, 2005).

Following the nationalization of all private commercial banks which were operating during the pre-1974 period, there was a government monopoly of the banking sector during the dergue regime. The banking system during the period comprised of the National Bank of Ethiopia which was the supervising and controlling body, the Commercial Bank of Ethiopia which was given the duty of providing commercial banking services, the Housing and

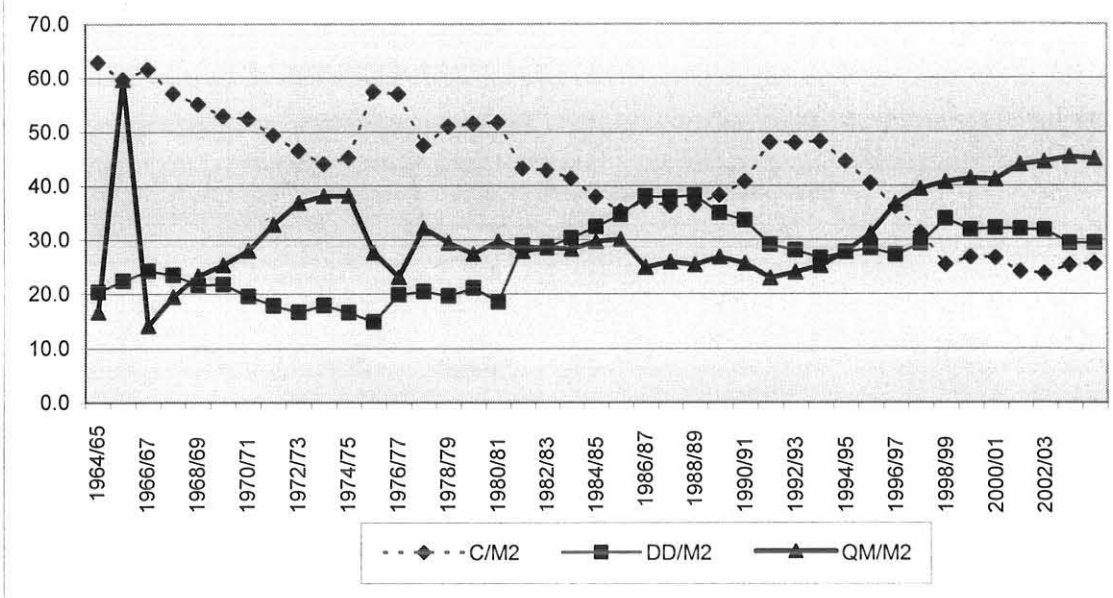
Savings Bank which specialized on giving loans to construction of buildings and low-cost housing and the Agricultural and Industrial Development Bank whose specialty was giving loans to the agriculture sector (mainly to state farms) and for state enterprises. (Birhane; 1992).

As part of the reform programme which started in 1992 private investment was allowed in the banking sector triggering the emergence of six private banks so far the first of which was Awash International Bank which began its operations in March 1995. In addition to the emergence of private commercial banks the government owned banks were restructured to fit in to a market-oriented environment. Although now the banking sector looks more diversified in terms of the number of commercial banks, the dominance of the state owned Commercial Bank of Ethiopia is still present. For instance, as at end 2003/04 CBE accounted for 78.1 percent of the total assets, 75.2 percent of total deposits and 56.1 percent of total lending of commercial banks (Table 3.2).

Despite the liberalization measures, the financial sector in Ethiopia is still not very well developed. It's dominated by commercial banks whose major task is accepting deposits from the public and giving out mostly short-term loans. Although the establishment of privately owned commercial banks and insurance companies can be taken as one important step for the development of the sector, there has not been any significant change in the sector in terms of the diversity of types of financial institutions. There is still no securities market where exchanges in different kinds of securities takes place.

The range of financial services that commercial banks provide has been limited to the provision of credit and accepting of demand, saving and time deposits. There has been little innovation in terms of creating new financial instruments. Looking at the composition of broad money (M_2) there has been a steady decline in the share of currency in circulation while the share of quasi-money (i.e. saving and time deposit) has been rising sharply especially starting from 1994/95. Demand deposits have also been showing a consistent upward trend (Fig. 3.1).

Fig. 3.1:- Components of Broad Money, M2



Currently one of the major problems of the banking sector is the persistence excess liquidity. Commercial banks, specially the largest state-owned CBE, hold large amount of reserves at National Bank of Ethiopia which is way above the required amount. The excess reserve of commercial banks reached Birr 11.9 billion at the end of December 2004. Excess liquidity in the banking system reflects both supply and demand factors. From the supply side, factors include restrained lending activity by banks under strengthened prudential regulations, steady deposit inflows owing to a lack of investment options other than bank deposits, and a constant inflow of remittances and donor assistance from abroad. On the demand side, excess liquidity has been driven by weak credit demand from the private sector, due to the uncertain business environment, cumbersome investment requirements, and the lack of infrastructure and readily available land. In addition, insufficient liquidity management by the NBE and liquidity risks associated with an outdated payments system contributed to the excess liquidity (IMF, 2005).

Table 3.2:- Some Financial Indicators of Commercial Banks
(In billions of birr)

	1999/2000	2000/01	2001/02	2002/03	2003/04
Assets	33.1	37.5	42.1	51.0	57.8
O/w CBE	28.3	31.7	34.6	41.2	45.1
%	85.5	84.6	82.2	80.9	78.1
Deposits	19.7	22.4	24.3	27.2	32.0
O/w CBE	16.9	18.8	19.6	21.1	24.1
%	86.1	84.0	80.5	77.6	75.2
Credit	12.8	13.7	13.5	13.3	14.2
O/w CBE	10.1	10.3	9.7	8.4	7.9
%	78.8	75.2	71.9	62.7	56.1
Excess Reserve	3.5	1.4	1.5	2.5	3.4
O/w CBE	3.2	1.2	1.3	2.3	2.9
%	92.9	84.7	83.7	92.7	84.9

Source: National Bank of Ethiopia, Annual bulletins

3.3 Monetary Policy Instruments

A) Reserve requirement

National Bank of Ethiopia (NBE) has imposed a reserve requirement of 5 percent of deposits on all commercial banks. Reserve requirement is imposed to limit the credit creation capacity of commercial banks and therefore to control the money supply. As was discussed in the preceding section, however, commercial banks maintain reserves which are way above the amount that is required of them making this policy instrument ineffective.

B) Interest rate policy

During the dergue regime the NBE was the body that formulated interest rate directives for the banks to implement. Two interest rate structures were implemented during the period. The first interest rate structure was operational until June 30, 1985. In that structure the

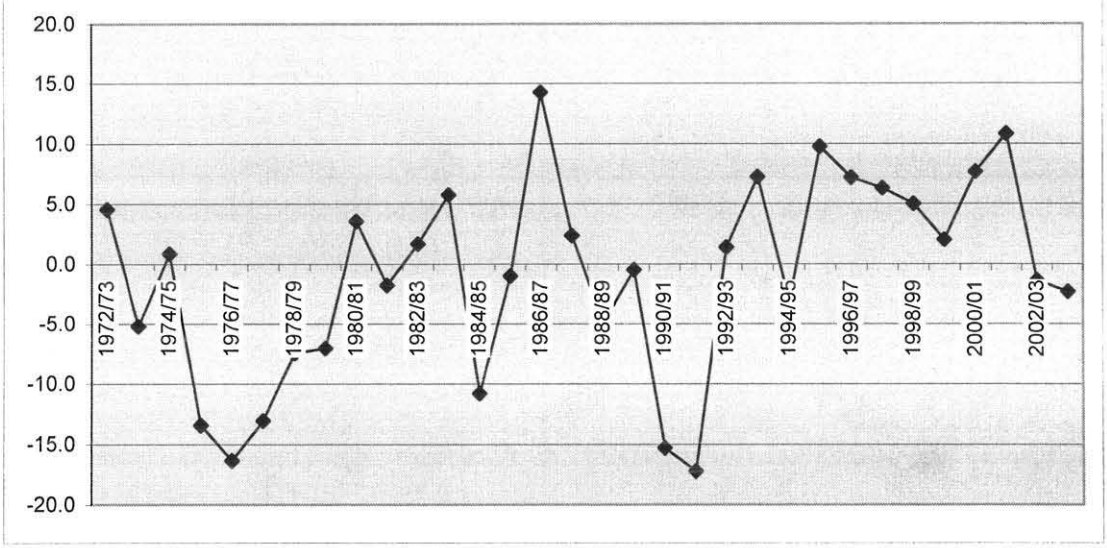
highest lending rate was 10% charged on personal loans and on purchase of houses. Most other sectors were charged 9.5 percent. The rate at which the central government could borrow from banks ranged between 3% and 7%, lower than the rate charged on other sectors. On the other hand interest rate for time as well as savings deposits was 6%.

The second interest rate structure that was operational beginning June 30, 1985 was discriminatory favouring cooperatives and the public sector rather than the private sector. In general, this interest rate structure made the rates lower than the previous one. Loans to construction of houses and to the agricultural sector were charged the least interest rates. Individuals and private organizations were charged interest rates ranging from 6 to 10%, cooperatives between 4.5 and 6% and public enterprises between 4.5 and 8%. Deposit rates also differed between the public and private sectors. The public enterprises and co-operatives (except for savings and credit co-operatives) were not allowed to maintain savings deposits while they earned interest ranging from 6 to 7.5% while their saving deposit rate was 6 percent for amounts not exceeding Birr 100,000 and 2% for amounts in excess of it.

Interest rate was not responsive to changes in the level of inflation. Thus, real interest rate was negative during most of the period (Fig. 3.2).

The interest rate structure was reformed on October 1992. In this new interest rate structure the rate differential among the different sectors of the economy was maintained while the discrimination between public and private sector was removed. Interest on loans to domestic and import trade, hotels & tourism and personal loans were charged the highest interest rate (14-15%) while agriculture and housing & construction were charged the lowest (11-12%). There was also rate differential among short term, medium term and long term loans. Deposit rates for both time and savings deposits were raised from their levels in the previous interest rate structure. In general the rates in the reformed interest structure were higher than those in the previous structure.

Fig. 3.2: Trends in Real Interest Rate



The reformed structure was operational for twenty-three months until August 31, 1994 before it was revised. In this revised structure (which was operational from September 1994 to December 1994) the rate for all sectors was the same. The fixed lending rates were 14% for short-term loans, 14.5% for medium term and 15% for long term loans. The rates for time and savings deposits, however, were not changed.

After January 1995, NBE started to set only the maximum lending rate and the minimum deposit rate. This practice of setting minimum and maximum rates continued until December 1997. Then staring from January 1998 the lending rate was liberalized while a 6% floor rate was set for deposits. The minimum deposit rate was then lowered to 3% and commercial banks were also allowed to pay interest on demand deposits starting from March 2002

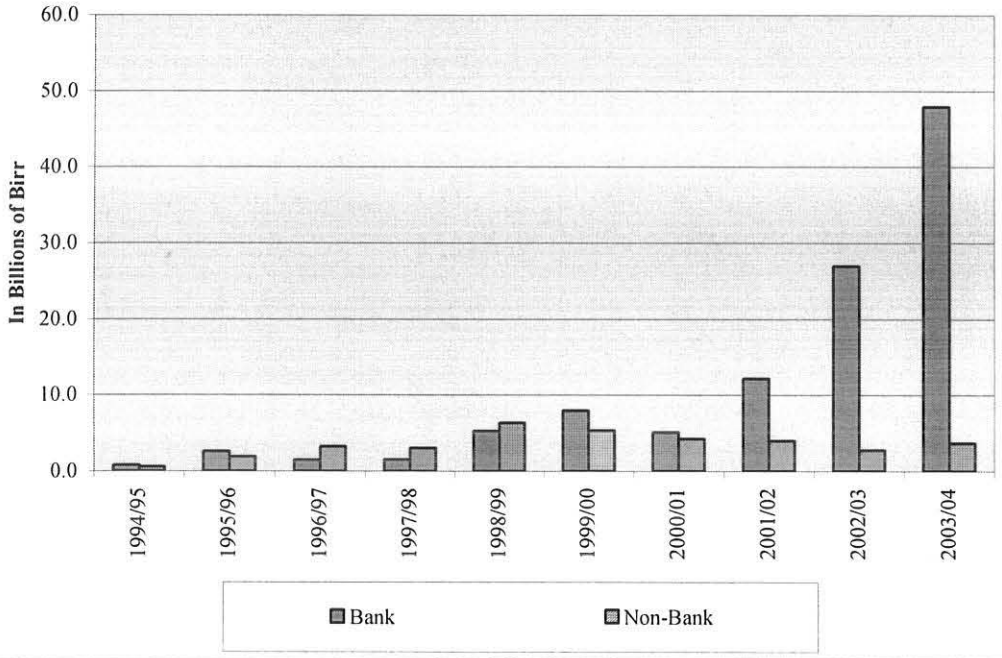
The explicit interest rate policy of NBE currently has been to maintain a positive real interest rate. Accordingly, the real interest rate has been mostly positive after 1992/93 except for a few instances when it was negative because of higher inflation rates associated with lower agricultural production.

C) Open market operations

The only securities market in the country is the primary market for government treasury bills on which bills are sold through regular auctions on the basis of competitive bids. Selling of government treasury bills through auction was begun in January 1995. Prior to that the government sold treasury bills and government bonds directly to government owned financial institutions such as National Bank of Ethiopia (NBE), Commercial Bank of Ethiopia (CBE) and Pension and Social Security Fund. The treasury bills auction was introduced in order to achieve two major objectives. The first envisaged objective was to improve the domestic financing of the fiscal deficit through non-inflationary financing and the second one was to serve as a monetary policy instrument for liquidity management.

A number of measures were taken to improve the treasury bills auction market. For example, only 91-day bills were auctioned at the beginning of the auctions. But starting from December 1996 28-day and 182-day bills were introduced. In addition, the frequency of the auctions was increased from monthly to fortnightly and the minimum bid amount was reduced from Birr 100,000 to Birr 50,000 to encourage the participation of the private sector and individuals. Moreover, CBE which was the largest buyer in the market was restricted to buy only 50 percent of the offered T-bills to give more chance and encouragement to other participants. The minimum bid amount was further reduced from Birr 50,000 to Birr 5,000 in August 1998.

Fig. 3.3:- Amount of T-bills Bought by Banks and Non-bank Institutions



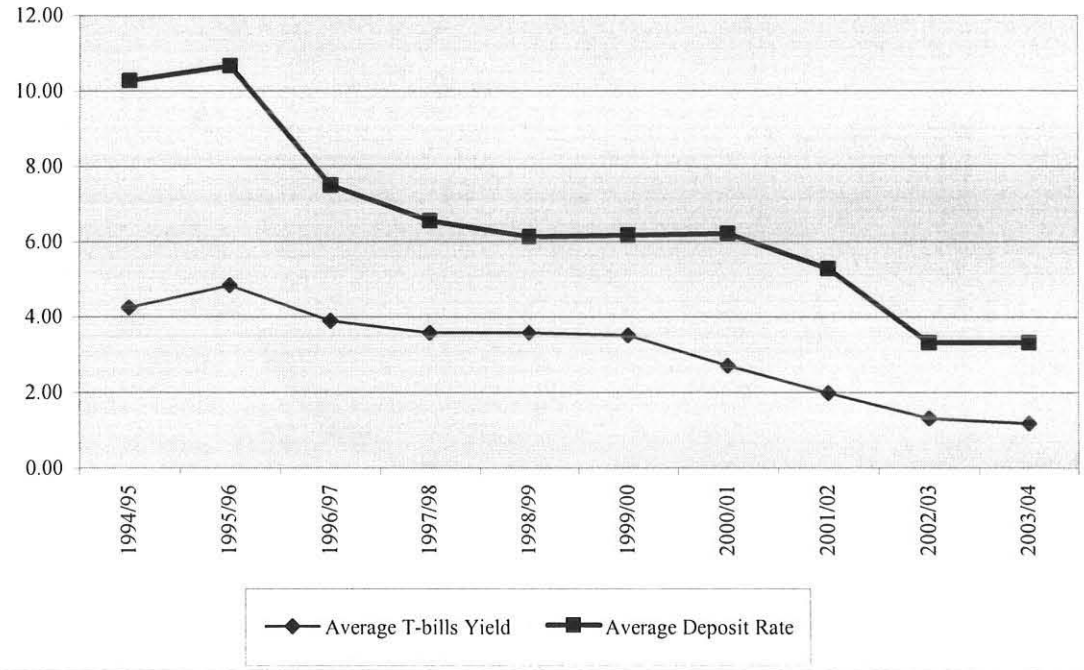
Despite the measures taken to improve the treasury bills market, it remains very shallow in that it has not been able to attract the private sector and individuals. The major participants in the market are commercial banks and large public enterprises which have large idle funds. The active participation of commercial banks in the market is due to the prevalence of excess liquidity in the banking sector. The treasury bills market has enabled commercial banks to earn interest on their idle reserves.

The dominance of participants which have large idle funds in the treasury bills market has led to very low level of yields in the market. The treasury bills yield in the auction market has always been well below the minimum deposit rate discouraging the private sector and individuals from participating in the auctions.

Due to the shallow nature of the treasury bills market, it has not been able to serve as an effective monetary policy instrument although it is helping to ease the excess liquidity

problem of commercial banks albeit temporarily. The treasury bills market has so far remained a cheaper source of finance for the government.

Fig. 3.4:- Average Deposit Rate and T-bills Yield



D) Interventions in the foreign exchange market

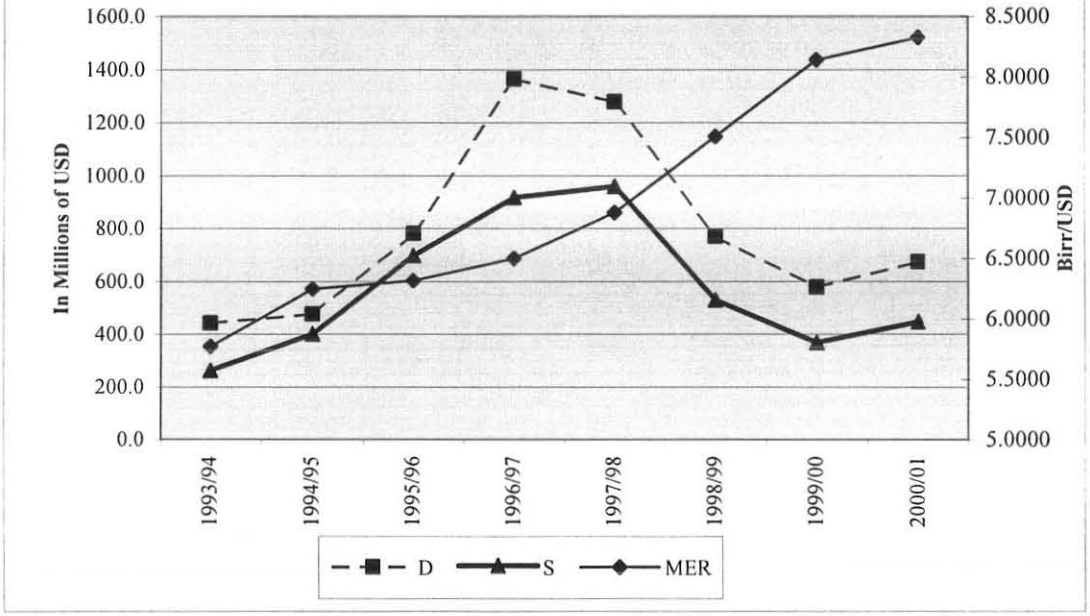
The Birr which was pegged to the US dollar for more than four decades has been devalued by a significant amount (142 percent) before the introduction of the Dutch system retail foreign exchange auction in May 1993. The objective of an auction-based allocation of foreign exchange was to allow the exchange rate to respond to changes in the demand for and supply of foreign exchange. At the retail auction importers directly competed in the auctions held by the NBE to get the required forex. But starting from August 1998 the retail auction was replaced by a wholesale one whereby commercial banks and investors who want to purchase a minimum of half a million US dollar were allowed to bid for foreign exchange on a weekly basis. Then, beginning from the end of October 2001 the auction

based foreign exchange allocation system was abandoned and replaced by daily inter-bank trading. This shows that the foreign exchange regime in Ethiopia has been moving gradually from a tightly managed floating to a more flexible one.

A number of liberalization measures have been taken in foreign exchange allocation system to make the process more and more market oriented. The import negative list was continuously reduced and was eventually eliminated (except for used clothing) from February 1995 thereby boosting the demand for foreign exchange. The 100 percent requirement to deposit the Birr equivalent of the forex bid amount for auction participants was reduced to 2 percent starting from August 1996. At the beginning, the marginal exchange rate determined in the forex auctions was not applicable to some of the transactions such as payments for the import of petroleum, fertilizers and pharmaceuticals, contributions for international organizations and official debt service payments. These transactions were met by a separate exchange rate which was referred to as the official exchange rate. After July 1995, however, the official and the marginal exchange rates were unified.

From Fig. 3.5 we can refer that until 1996/97 both demand and supply of foreign exchange at the auction market followed similar trends. Both showed rapid growth. The rate of depreciation of the Birr has accordingly been declining. The annual rate of depreciation in 1994/95 was 8.25 percent although it declined to 2.89 percent in 1996/97.

Fig. 3.5: The Marginal Exchange Rate and Demand and Supply of Forex in Foreign Exchange Auction



D = The amount of foreign exchange demanded in the auctions
S = The amount of foreign exchange supplied in the auctions
MER = The average marginal exchange rate

But starting from 1997/98 supply began to decline and demand also followed suit. The rate of depreciation, therefore, increased from 2.89 percent in 1996/97 to 5.86 percent in 1997/98, 9.45 percent in 1998/99 and 8.41 percent in 1999/2000. The continuous decline in the supply of foreign exchange to the auctions during these years may be attributed to the decline in the flow of funds from international donors as a result of the conflict between Ethiopia and Eritrea.

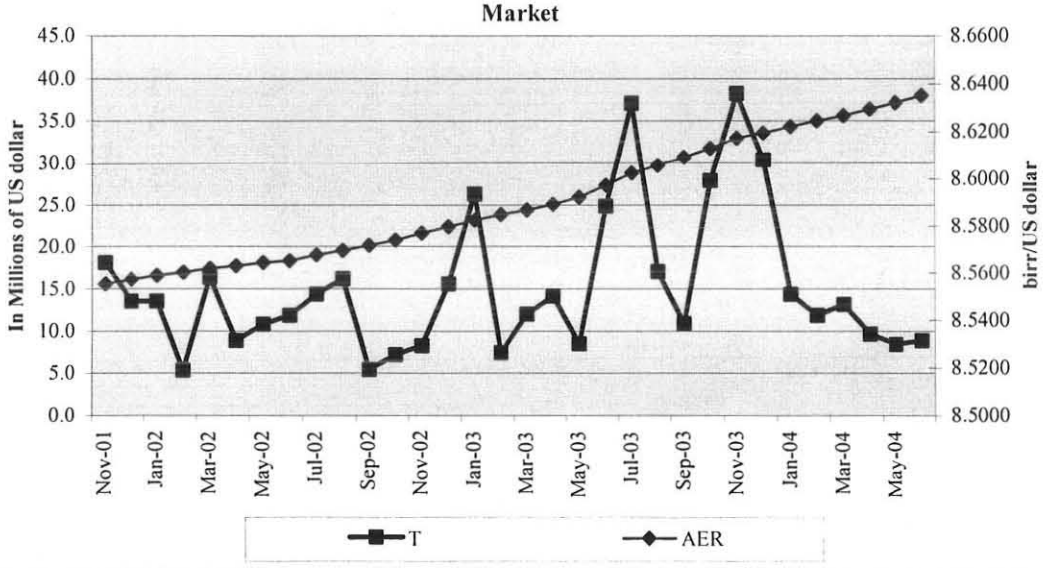
With the termination of the conflict in June 2000 the flow of funds from international donors began to pick-up and supply of foreign exchange in the auctions increased accordingly. The rate of depreciation, therefore, declined from 8.41 percent in 1999/2000 to 2.28 percent in 2000/01.

Starting from October 25, 2001 the weekly foreign exchange auctions were replaced by daily inter-bank trading. The exchange rate which used to be the marginal rate of the forex auctions is now being determined by daily trading in the inter-bank foreign exchange

market. Trading takes place among commercial banks and between commercial banks and National Bank of Ethiopia. But the majority of the trading takes place between commercial banks and NBE with the latter usually being the major supplier/seller.

The Birr showed a steady depreciation in the inter-bank market. The average monthly depreciation rate of the birr against the US dollar in the interbank market was just 0.03 percent during the period November 2001 to June 2004. On the other hand, the amount of foreign exchange traded in the market exhibited relatively high fluctuations. This shows that the weighted average exchange rate of Birr is not determined by the amount of foreign exchange traded in the market. Rather it is determined by the learned behaviour of commercial banks that quote a rate only slightly higher than the preceding day's rate no matter how much amount of foreign exchange they want to transact.

Fig. 3.6: Average Exchange Rate and Amount of Forex Traded in the Interbank Market



T = The amount of foreign exchange traded in the IBFEM

AER = The weighted average exchange rate in the IBFEM

Chapter IV: Model Specification and Estimation

4.1 Model Specification

Despite the number of theories on the demand for money, a kind of consensus is achieved in the literature that the demand for money is determined by a measure of real transactions and a set of opportunity cost variables. The general theoretical formulation of the long-run demand for money function is, thus, given by

$$M^d/P = f(y,\mathbf{r}) \quad \text{.......................................(4.1)}$$

where

M^d = the nominal monetary aggregate chosen

P = the price level

y = a measure of real transactions

r = a vector of opportunity cost variables

In the literature the demand for money is the demand for real balances which implies that price homogeneity is imposed. The variable which measures real transactions positively affects the demand for real money balances while the set of opportunity cost variables have negative impacts.

As has been discussed earlier, the choice of a relevant monetary aggregate depends on the level of development of the financial sector of the economy for which the demand for money is estimated. Of the few demand for money functions attempted for Ethiopia Lulseged (1996) used a broad definition of money (real M_2) while Ergete (1998) used both the narrow and broad definitions of money in nominal terms. Streken (1999), on the other hand, used stock of per capita real M_1. For this study, we are going to use the narrow definition of money (M_1) as the relevant money stock variable since it is assumed that the transactions motive of holding money is the dominant one due to the very low level of development of the financial sector.

Concerning the choice of a measure of real transactions, most of the demand for money studies used either real GDP or real GNP. In this study also real GDP will be used as a measure of real transactions.

The level of financial development of an economy strongly influences the choice of opportunity cost variables in the demand for money function. Usually, short-term interest rates such as those on government securities, commercial papers and saving deposits are included as opportunity cost variables in money demand studies of the developed economies. The reason for this is that these are thought to be close substitutes for money. However, in countries where the financial sector is not well developed it is difficult to find financial instruments which can serve as close substitutes for money which implies that interest rates may not be relevant opportunity cost variable. Therefore, it's usually recommended that inflation is a relevant opportunity cost variable in developing countries as people use real assets as substitutes for money. From the previous demand for money studies in Ethiopia, Lulseged (1996) used the lagged inflation rate while Streken (1999) used the real price of coffee as measures of opportunity cost of holding money.

In addition to domestic assets foreign assets could also be considered as substitutes for money in open economies. When the yield on the alternative foreign assets rise, people substitute their domestic money holding in to foreign assets. Previous studies on demand for money in Ethiopia have used real effective exchange rate and the black market premium as opportunity cost variables. This study utilizes the saving deposit rate (R), the expected inflation rate which is represented by the one period lagged annualized inflation rate (LAINF) and the expected rate of depreciation of the birr in the parallel market represented by the one period lagged annualized depreciation rate (LADEP)[1] as relevant opportunity cost variables.

Thus, the long-run demand for money function for Ethiopia can be specified as:-

$$LRM_1 = \beta_0 + \beta_1 LRGDP + \beta_2 R + \beta_3 LAINF + \beta_4 LADEP + \varepsilon_t \ldots\ldots\ldots\ldots (4.2)$$

where:

LRM_1 = log of real narrow money stock;

LRGDP = log of real GDP;

R = saving deposit rate;

LAINF = one-period lagged annualized inflation rate;

LADEP = one-period lagged annualized depreciation of the birr;

ε_t = a stochastic error term.

The coefficient of LRGDP is expected to have a positive sign and to be close to unity while coefficients β_2, β_3 and β_4 are expected to have negative signs.

4.2 Data Issues

This study utilizes quarterly data over the period 1970:I – 2003/04:IV. Quarterly data on the monetary aggregate and consumer price index were obtained from quarterly bulletins of the National Bank of Ethiopia while quarterly data on the parallel exchange rate were obtained from Pick's Currency Yearbook and quarterly bulletins of National Bank of Ethiopia.

Quarterly data on GDP are not available in Ethiopia. Therefore, there was a need to disaggregate the annual GDP figures in to quarterly figures. For this disaggregation purpose this study has utilized the method developed by Friedman and used by Jefferis and Kayawe (1998) to obtain quarterly GDP data for Botswana. This method is described in Appendix A.

4.3 Estimation Method

Directly estimating a model that utilizes time series variables can result in spurious regression. Spurious regression may arise when we try to use the standard regression

[1] The rate of depreciation was annualized as $(\ln PMER_t - \ln PMER_{t-1})*4$. The inflation rate was also annualized

methodology on variables that are not stationary[2]. In this case we may get "very good" regression results not because the variables in the model are necessarily related but because of the common trend present in them. The standard t- and F-tests are not valid in this case. Therefore, there is a need to examine the time series properties of the variables before proceeding to the estimation.

Even though variables entering a model are non-stationary, there may not arise a spurious regression if they can form a cointegration[3] relationship. Cointegration entails the existence of a long-run relationship among variables which may contain stochastic trends. There are two methods that are widely utilized to test for the existence of cointegration among a set of variables. The first one is the single equation based Engle-Granger two steps procedure while the second one is the multivariate Johansen methodology. The fact that the Engle-Granger method presupposes one cointegrating vector and that it apriori categorizes variables into endogenous and exogenous variables has rendered the Johansen multivariate framework superior. Therefore, the Johansen methodology which is described below will be utilized in this study.

The Johansen Procedure

Consider the following vector autorgression (VAR) process of order p

$$\mathbf{Z_t} = \mathbf{A_1 Z_{t-1}} + ... + \mathbf{A_p Z_{t-p}} + \mathbf{U_t} \qquad \mathbf{U_t} \sim \mathbf{NID}\ (0, \Sigma) \quad .....(4.3)$$

where $\mathbf{Z_t}$ is (nx1) vector of variables and $\mathbf{A_i}$ is (nxn) vector of parameters while $\mathbf{U_t}$ is independently and normally distributed with mean of null vector and vector of variances Σ. In this specification all variables are potentially endogenous and there is no apriori assumption about the existence of a particular structural relationship.

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by the same method.

[2] A stationary variable is a variable which has the tendency to return to its mean and which has a finite variance.

[3] Given two or more variables which are integrated of order d (i.e. I(d)), we say that they are cointegrated if their linear combination can yield a lower order of integration (i.e. I(d-b) where b>0).

The vector error correction counterpart of equation 4.3 can be written as

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + ... + \Gamma_{k-1} \Delta Z_{t-k+1} + \Pi Z_{t-k} + U_t \quad .....(4.4)$$

where $\Gamma_i = -(\mathbf{I} - \mathbf{A}_1 - ..... - \mathbf{A}_i)$, (i = 1,.....$k$-1) and $\Pi = -(\mathbf{I} - \mathbf{A}_1 - .... - \mathbf{A}_k)$

The estimate of Γ_i contains short-run information while the estimate of Π contains long-run information. In testing for the existence of cointegration among the variables in vector Z_t we determine the rank of the matrix Π. There are three possible outcomes in trying to determine the rank of matrix Π. The first possible outcome is that Π has full rank which implies that all the variables in Z_t are stationary and that there is no threat of spurious regression. In this case we can estimate a standard VAR model in levels. The second possible outcome is finding a rank of zero which implies that there is no cointegration among the variables and the only appropriate model is to estimate a VAR in first differences which entails no long-run relationships. Finding a rank of $r \leq (n-1)$ implies that there are n-1 cointegration vectors which entail the existence of a long-run relationship among the variables in Z_t.

There are two alternative tests in the Johansen multivariate framework which are used to test for the rank of the matrix Π. The rank of a matrix is equal to the number of its non-zero eigen values. Thus both type of tests are used to test the number of non-zero eigen values in the matrix. The first test is known as the λ-trace statistic which tests the null hypothesis that the number of cointegrating vectors is $\leq r$ against a general alternative. On the other hand, the second test which is known as the λ-max statistic tests the null hypothesis that the number of cointegrating vectors is r against the alternative $r+1$.

4.4 Order of Integration of Variables

As was pointed out earlier knowing the order of integration of the variables entering the VAR model is very crucial for the conduct of cointegration analysis. The Dickey-Fuller (DF) and the Augmented Dickey-Fuller (ADF) tests which are described below are used to test the order of integration of variables.

Table 4.2:- Results of the Cointegration Test

Eigenvalues	0.4843	0.1337	0.0350	0.0006
Null hypothesis[1/]	r=0	r<=1	r<=2	r<=3
λ -trace[2/]	88.0800**	19.0900	4.7430	0.0735
Adjusted for degrees of freedom	85.4300**	18.5200	4.6000	0.7129
95 percent critical values	27.1000	21.0000	14.1000	3.8000
λ -max[2/]	112.0000**	23.9100	4.8160	0.0735
Adjusted for degrees of freedom	108.6000**	23.1900	4.6710	0.07129
95 percent critical values	47.2000	29.7000	15.4000	3.8000

Standardized eigenvectors β'

LRM1	LRGDP	R	LAINF
1.0000	-1.1299	0.0616	12.5100
-0.5035	1.0000	-0.0123	0.0341
-1.6697	7.6170	1.0000	0.21140
6.2587	9.0158	-1.4304	1.0000

Standardized adjustment coefficients α

LRM1	LRGDP	R	LAINF
-0.0071	0.0015	0.0306	-0.0743
0.1479	-0.1533	-0.0995	-0.0231
0.0015	0.0013	-0.0532	-0.0029
-0.0023	0.0000	-0.0007	0.0000

1/ r stands for the number of ranks.

2/ ** indicates significance at 1 percent level.

4.5 Cointegration Analysis

The unit root tests have shown that the variables that enter the model are either I(0) or I(1) implying that we can proceed to the cointegration analysis. The endogenous variables that were included in the analysis were LRM_1, *LRGDP*, *R*, *LAINF* and *LADEP* while a constant, a devaluation dummy (*DDEV*), a regime change dummy (*DREG*) and seasonal dummies entered the analysis unrestricted. The analysis was begun with four lags as we used quarterly data and successive lag reductions were made till we find an appropriate specification. The annualized depreciation rate of the birr in the parallel market *(LADEP)* was found out to have the wrong sign and its inclusion could not result in sensible cointegrating vectors[4]. Thus, it was decided to drop this variable from the analysis and the cointegration test was conducted with the remaining variables. By conducting F-tests on the model reduction process, the appropriate model was found out to be the model with one lag the result of which is shown in Table 4.2.

As the results clearly show the hypothesis of zero cointegrating vector is rejected in favour of at least one cointegrating vector by both the λ - trace and λ - max tests. The dominance of the eigenvalue associated with the first vector suggests the presence of a unique cointegrating vector in the model. In order to identify the unique cointegrating vector weak exogeneity tests were undertaken by imposing zero restrictions on the α -coefficients. These tests show that the hypothesis of weak exogeniety is not rejected in the case of *LRGDP*, *R* and *LAINF* while it is rejected in the case of *LRM1*.

Table 4.3:- Weak Exogenity Tests

	LNRM1	LRGDP	R	LAINF
α -coefficients	-0.00714	0.147870	0.001521	-0.00231
LR-test: χ^2 (=1)	68.9000	0.46765	0.98958	0.042263
p-value	0.0000 **	0.4941	0.3198	0.8371

It is, therefore, possible to write the single equation representing the long-run demand for money function as follows:-

$$LRM1 = 1.1299*LRGDP - 0.0616*R - 12.5100*LAINF \quad \ldots\ldots\ldots\ldots\ldots\ldots (4.10)$$

As can be seen from the long-run demand for money function all the coefficients have the expected signs. The coefficient of LRGDP is close to unity as suggested by the quantity theory of money. This is contrary to findings that support higher than unity income elasticity of money demand for developing countries due to the lower degree of monetization of their economies (Adekunle, 1968). From the previous demand for money studies in Ethiopia, Ergete (1998) also found close to unity income elasticity although he used nominal broad money balances while Streken (1999) got an income elasticity of 1.3 using per capita real narrow money stock.

Concerning the coefficients of the opportunity cost variables both have the expected negative signs while it was the expected rate of inflation which seems to have a pronounced impact on money demand. This is in line with the general consensus that economic agents in developing countries sway away from money holdings to real assets when they expect the inflation rate to rise (Sriram, 1999b).

[4] Other variations of the variable such as the parallel market rate and the parallel market premium were experimented but couldn't result in a meaningful cointegration relationship

In the Johansen multivariate framework the coefficients in the α -matrix measure the speed of adjustment to long-run equilibrium when there is disequilibrium in the respective endogenous variables in the system. Accordingly the first coefficient in the α -matrix (i.e. – 0.007) represents the speed at which LRM1 moves toward restoring the long-run equilibrium. The fact that it is negative implies that when there is excess money holdings in previous periods agents hold less money in the current period. The speed of adjustment is, however, very small (i.e. about 0.7 percent in a quarter) probably reflecting the low level of development of the financial system which precludes many alternatives to money holdings.

The stability of the demand for money function is very crucial in order for it to be of relevance for policy purposes. A recursive cointegration analysis was undertaken to test for the stability of the model (i.e. the parameter constancy of the model) and the graphical results of the analysis are presented in Appendix B. As can be seen from the stability graphs LRM1 has been largely stable with few instances of instability pertaining to major revisions in the interest rate structure. The instability was not due to regime changes. Thus we can safely say that the demand for money function has remained stable over the sample period despite two regime changes. The same conclusion has been reached by Ergete (1998).

4.6 Vector Error Correction Model

After establishing the existence of a cointegration relationship among the variables in the system, the next task in the Johansen multivariate procedure is to estimate the vector error correction model (VECM). This will enable us to estimate the coefficients of the short-run dynamics i.e. the coefficients of the Γ_i matrix in equation 4.4.

We first specified the unrestricted model by including the first difference of *LRM1* in the left hand side and the right hand side containing the first differences of *LRM1*, *LRGDP*, *R* and *LAINF* each variable having two lags. In addition, a constant, seasonal dummies, the regime change dummy and the one period lagged error correction term (*EC*) which is obtained from the cointegration vector were included on the right hand side. After

estimating the unrestricted model, we followed David Hendry's method of general to specific model reduction in order to arrive at the parsimonious model. The results of the parsimonious model are reported in Table 4.4.

Table 4.4: Result of the Parsimonious Vector Error Correction Model

The Dependent Variable is DLRM1

Variable	Coefficient	Std.Error	t-value	t-prob
DLRM1_1	-0.2112	0.087356	-2.418	0.0171
DLRM1_2	-0.3840	0.099689	-3.852	0.0002
DLRGDP_2	0.3002	0.143260	2.095	0.0383
EC_1	-0.0165	0.004809	-3.445	0.0008

$\sigma = 0.0700986$, $R^2 = 0.78$, AR 1- 5 F(5,117) = 0.62864 [0.6782] ,

Normality $\chi^2(2)$ = 3.7512 [0.1533] , ARCH 4 F(4,114) = 0.36814 [0.8309]

χ^2 F(8,113) = 0.49455 [0.8579] , Xi*Xj F(14,107) = 0.39963 [0.9723]

As we can see from the results the different diagnostic tests did not detect any statistical problem in the vector error correction model. However, only the lagged values of money holdings and real GDP were found out to have significant impact on the short run demand for money function. This may be a reflection of the very low level of development of the financial system as agents do not have many alternatives to money holdings. This observation can also be corroborated by the very low coefficient of the error term (-0.0165) which implies that agents adjust by just 1.7 percent in one quarter when there is disequilibrium in the system.

Chapter V: Conclusion and Policy Implications

In this paper we tried to estimate a demand for money function for Ethiopia by using the Johansen multivariate framework as the existence of a stable demand for money function is highly crucial for the conduct of monetary policy. As we have seen the financial system in Ethiopia is at a very low level of development. The types of financial institutions are not diversified limiting the range of financial services available in the economy. It was only recently that private financial institutions were allowed to participate in the financial sector. Not long ago the government had a monopoly over all the financial institutions in the country. Even now government owned financial institutions are the dominant ones over the newly established private institutions.

There is virtually no market for securities in the country except for a primary government treasury bills market on which bills are sold on auction basis. This auction market, however, is very shallow as it has not been able to attract the private sector and individuals. The existence of huge excess reserves in the banking sector has hindered the auction market from growing in to a vibrant government securities market. Commercial banks are willing to buy treasury bills in the auctions at rates well below the minimum deposit rate because of their accumulated excess reserves. They find the treasury bills market attractive since they do not earn any interest from the reserves in their vault or at the National Bank of Ethiopia. This fact has prevented the treasury bills auction market from becoming an effective market in terms of serving as an interest rate indicator.

It was against this back ground that we have tried to estimate a demand for money function for Ethiopia. For this purpose quarterly data were used and the Johansen multivariate procedure was employed for the estimation. As any standard demand for money function, we specified a demand for narrow money holdings to be a function of a transactions variable which we represented by real GDP and some opportunity cost variables viz the saving deposit rate, the expected inflation rate (represented by the one-period lagged inflation rate) and the expected depreciation rate of the birr in the parallel market (also represented by the one-period lagged depreciation rate).

The cointegration test has confirmed the existence a unique cointegrating vector among the variables of interest although the expected depreciation rate of the birr in the parallel market was dropped as it didn't constitute the cointegration space. According to the cointegration results the coefficient of real GDP was close to one consistent with the quantity theory of money while the coefficients of the saving deposit rate and the expected inflation rate were negative as expected with the latter having a pronounced impact on money holdings. The significant impact of inflation on money holdings is a manifestation of the low level of development of the financial sector as agents move away from money holdings to real assets when they expect a rise in the inflation rate for lack of other alternative instruments.

The adjustment coefficient for the demand for money in the cointegration analysis was found to be very small although it had the expected negative sign. The slow adjustment to the long-run equilibrium is also a reflection of the low level of financial development as economic agents can not quickly respond to disequilibrium in the system as there are very few alternatives to holding money.

The short-run demand for money function was estimated by the vector error correction model. In the short-run only real GDP and lagged values of money holdings were found to be significant determinants of money holdings. The fact that neither interest rate nor the expected inflation rate were found out to have no impact on the short-run demand for money may again be a reflection of the very low level of development of the financial system. This result implies that agents do not respond to changes in the opportunity cost variables in the short-run as they do not have many alternatives to money holdings. The very low coefficient of the error correction term in the vector error correction model corroborates this observation.

Therefore, the low level of development of the financial system means that direct monetary policy instruments have to be relied on instead of the indirect ones which are known to be more effective. The absence of a vibrant securities market makes it difficult for monetary authorities to transmit signals to the market. The persistence excess liquidity problem of

commercial banks which has prevented the existing treasury bills market from serving as an effective monetary policy instrument is, therefore, the major monetary policy challenge in Ethiopia.

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Appendix A: Method of Disaggregating Annual Data into Quarterly Data

Two broad approaches can be employed in interpolating data in the case where quarterly observations do not exist. The first draws on information contained in the series itself to provide the basis for interpolation. This involves linear or log-linear interpolation of the missing quarterly observations from the existing annual observations. The second approach uses information on known correlation with existing data series on which we have both quarterly and annual observations. The Friedman (1967) technique uses the second approach.

Suppose a variable Y is available at annual, but not at quarterly frequency, and a set of k variables, making up a vector **X**, is available at both annual and quarterly frequencies. Further assume that the Vector **X** does not contain any variable that will be included in the vector of explanatory variables in the Y function. Friedman's method of interpolation uses the calculated coefficients of the regression of Y on the **X** variables with annual data, as weights for assigning calculated errors in the log-linear interpolation of the **X** variables to the log-linear interpolation of the Y variable.

As a first step of the process, compute the mean quarterly growth for Y and **X** using only annual observations and use this to derive log-linear interpolation of quarterly values for both Y and **X**. The linear interpolation of quarterly y is:

$$y^*_{t+i} = y_t + iT_y$$

where:

i = 1,2,3;

T_y = $(Y_{t+1} - Y_t)/4$:

Y = annual data observations;

y = quarterly data observations;

y^*_{t+i} = quarterly observations derived from (log-)linear interpolation;

y_t = quarterly observations derived from actual annual data (i.e. one in every four).

The linear interpolation for the elements of vector **X** is:

$$x^*_{j\ t+i} = x_{jt} + iT_{xj}$$

where: $i = 1,2,3.$

$j = 1...k;$

$T_{xj} = (X_{jt+1} - X_{jt})/4;$

X = annual data observations;

x = quarterly data observations;

$x^*_{j\ t+i}$ = quarterly observations derived from (log-)linear interpolation;

x_{jt} = quarterly observations derived from actual annual data (i.e. one in every four).

This method is called linear interpolation if original data levels are used, implying a constant absolute quarterly change. On the other hand, the method is called log-linear interpolation if original data is transformed to logs, implying a constant quarterly growth rate. Generally, log-linear interpolation is preferable since it gives a constant growth rate, while the linear interpolation gives a declining growth rate. Nevertheless, the final choice between the two approaches depends upon the nature of the underlying change process.

In the second step of the disaggregation process, run the following regression using the annual observations.

$$Y_{At} = X_{At}\beta + e_t$$

where the subscript (A) denotes annual observations. This provides a vector of estimated coefficients (β), describing the relationship between **X** and Y.

Next compute the actual error in trend interpolation for the elements of x from the actual quarterly values of the x_j variables and their interpolated values (x^*_j) which will be expressed as:-

$$\delta_{jt+i} = (x_{jt+i} - x^*_{jt+i})$$

This provides the difference between the actual quarterly value of x_{jt+i} and the value x^*_{jt+i} obtained by (log-)linear interpolation.

This error term is then used to adjust the simple (log-)linear interpolation for y* by the weighted individual error in trend for each regressor (where the weights are given by the β_j coefficients on the x_j variables in the annual regression). Hence the final interpolation for y is:

$$\hat{y}_{t+i} = y^*_{t+i} + \sum_{j=1}^{k} \hat{\beta}_j \delta_{jt+i}$$

where:

k = the number of x variables;

$\hat{y}$ = final interpolated quarterly observation;

y* = quarterly observations interpolated in the first step;

δ_j = actual error on trend interpolation for x_j;

$\hat{\beta}_j$ = coefficients of regressors X_j on Y.

For this study, we have used exports and imports as the related variables to interpolate the quarterly GDP series. Quarterly and annual data on the related variables are obtained from quarterly and annual bulletins of the National Bank of Ethiopia.

In the first step, we interpolated quarterly data from annual data for both the variable to be disaggregated (real GDP) and the related series (real exports and real imports) using log-linear interpolation. Nominal exports and imports were transformed to real values using the Consumer Price Index. After that, we calculated the error in trend of the related series variables by subtracting their interpolated figures from the actual quarterly figures.

Then we regressed real GDP over real exports and imports using annual data and found the following results.

Dependent Variable: LOG(RGDP)
Method: Least Squares
Date: 04/20/05 Time: 01:37
Sample: 1971 2004
Included observations: 34

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	6.562524	0.269591	24.34251	0.0000
LOG(REXP)	-0.233932	0.042924	-5.449853	0.0000
LOG(RIMP)	0.532608	0.037876	14.06186	0.0000

R-squared	0.878813	Mean dependent var	9.302704
Adjusted R-squared	0.870994	S.D. dependent var	0.268809
S.E. of regression	0.096549	Akaike info criterion	-1.753430
Sum squared resid	0.288974	Schwarz criterion	-1.618751
Log likelihood	32.80832	F-statistic	112.4014
Durbin-Watson stat	1.374381	Prob(F-statistic)	0.000000

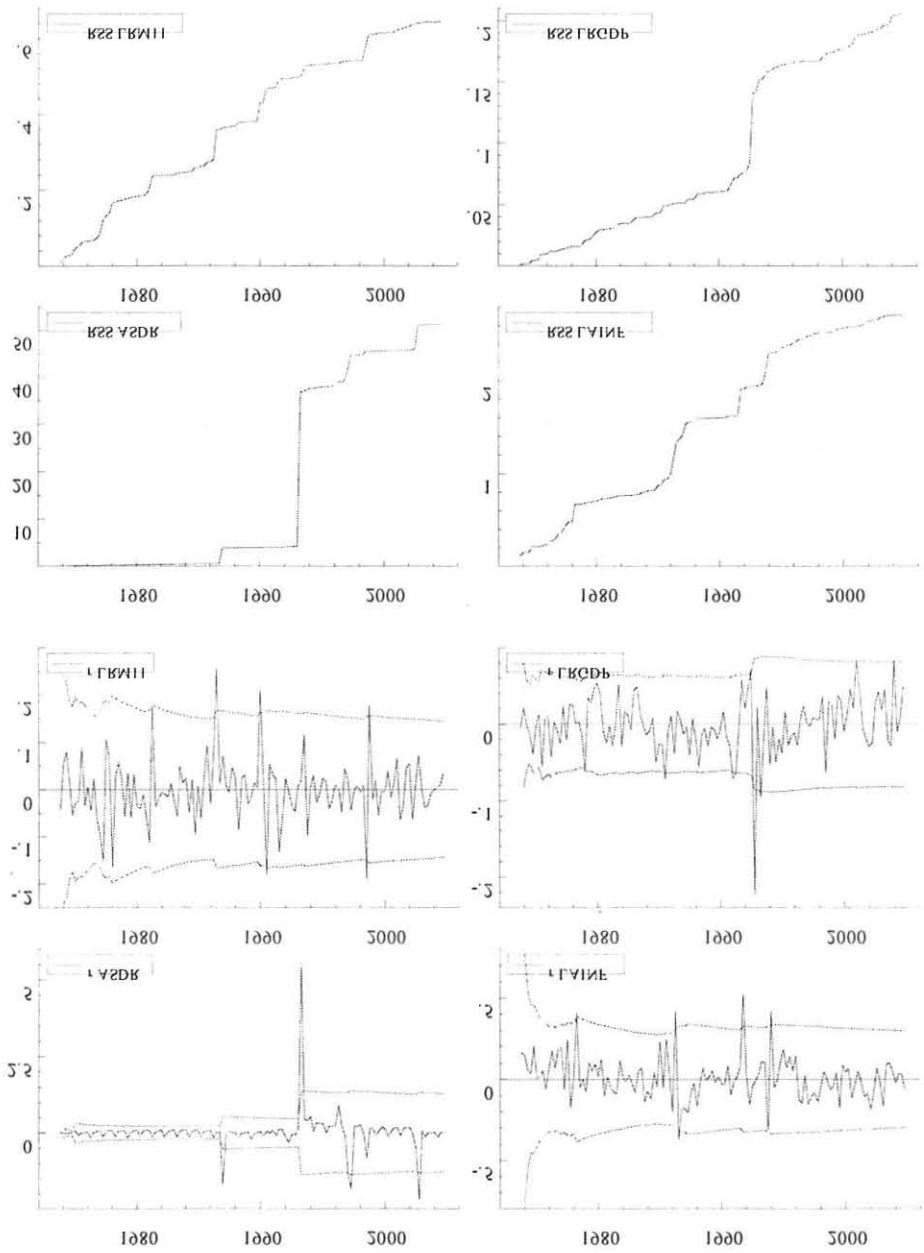
We then used the coefficients obtained from this regression to weight the error in trends of each related series (real exports and real imports) and arrived at the final disaggregated series of real GDP.

Table A.1: Disaggregation of Real GDP

	Annualized EXP	Annualized IMP	CPI	REXP	RIMP	LREXP	LRIMP	Interpolated LREXP	Interpolated LRIMP	Error in trend LREXP	Error in trend LRIMP	Interpolated RGDP	Interpolated LRGDP	Disaggregated RGDP	Disaggregated LRGDP
1970/71QI	61.2	111.6	15.6	392.0	715.0	6.0	6.6	7.8	8.0	1.8	1.4	7,363.4	8.9	10,614.9	9.2
QII	115.6	212.8	15.4	748.8	1,378.3	6.6	7.2	7.7	8.0	1.1	0.8	7,431.5	8.9	9,861.2	9.1
QIII	229.6	325.1	15.1	1,518.9	2,150.6	7.3	7.7	7.7	8.0	0.4	0.3	7,499.7	8.9	8,718.4	9.0
QIV	313.6	436.8	16.1	1,950.1	2,716.2	7.6	7.9	7.7	8.0	0.1	0.1	7,567.9	8.9	7,988.1	9.0
1971/72QI	304.1	444.0	15.4	1,975.3	2,883.9	7.6	8.0	7.7	8.0	0.1	0.1	7,627.1	8.9	7,994.0	9.0
QII	313.6	457.7	14.8	2,115.2	3,087.0	7.7	8.0	7.7	8.1	0.1	0.0	7,686.3	8.9	7,888.0	9.0
QIII	303.6	462.8	14.6	2,080.2	3,170.7	7.6	8.1	7.7	8.1	0.1	0.0	7,745.5	9.0	8,004.8	9.0
QIV	319.5	461.8	14.2	2,247.5	3,248.6	7.7	8.1	7.8	8.1	0.0	0.0	7,804.8	9.0	7,978.4	9.0
1972/73QI	348.9	448.5	14.5	2,406.0	3,092.2	7.8	8.0	7.8	8.1	0.1	0.1	7,857.5	9.0	8,143.5	9.0
QII	377.1	435.6	14.4	2,624.1	3,030.9	7.9	8.0	7.9	8.1	0.1	0.1	7,910.1	9.0	8,189.3	9.0
QIII	429.5	417.8	14.8	2,905.1	2,826.0	8.0	7.9	8.0	8.0	0.0	0.1	7,962.8	9.0	8,303.5	9.0
QIV	452.1	418.9	15.9	2,834.7	2,626.8	7.9	7.9	8.1	8.0	0.1	0.1	8,015.5	9.0	8,670.1	9.0
1973/74QI	471.6	425.2	16.2	2,904.4	2,618.8	8.0	7.9	8.1	8.0	0.2	0.2	8,060.3	9.0	8,812.0	9.0
QII	497.4	448.2	15.9	3,136.7	2,826.7	8.1	7.9	8.2	8.0	0.1	0.1	8,105.2	9.0	8,663.0	9.0
QIII	561.0	460.6	16.7	3,351.9	2,752.2	8.1	7.9	8.2	8.1	0.1	0.1	8,150.0	9.0	8,751.4	9.1
QIV	590.9	489.1	17.1	3,448.6	2,854.5	8.1	8.0	8.3	8.1	0.1	0.1	8,194.8	9.0	8,785.7	9.0
1974/75QI	575.1	548.7	17.1	3,360.3	3,206.0	8.1	8.1	8.2	8.1	0.1	0.1	8,217.9	9.0	8,579.9	9.0
QII	547.3	574.2	17.2	3,173.7	3,329.7	8.1	8.1	8.1	8.2	0.0	0.1	8,241.0	9.0	8,627.6	9.1
QIII	486.8	646.4	16.9	2,883.8	3,828.9	8.0	8.3	8.0	8.3	0.1	0.0	8,264.2	9.0	8,451.6	9.0
QIV	452.9	653.2	17.8	2,542.1	3,666.6	7.8	8.2	8.0	8.3	0.1	0.1	8,287.3	9.0	8,840.6	9.1
1975/76QI	470.8	611.1	18.8	2,501.7	3,247.3	7.8	8.1	7.9	8.3	0.1	0.2	8,301.3	9.0	9,098.4	9.1
QII	468.4	647.9	19.2	2,442.5	3,378.3	7.8	8.1	7.9	8.2	0.1	0.1	8,315.3	9.0	8,931.5	9.1
QIII	472.8	631.5	20.7	2,288.7	3,057.2	7.7	8.0	7.9	8.2	0.2	0.2	8,329.4	9.0	9,194.0	9.1
QIV	525.6	674.6	23.4	2,242.0	2,877.4	7.7	8.0	7.9	8.2	0.2	0.2	8,343.4	9.0	9,265.7	9.1
1976/77QI	545.3	716.8	24.0	2,268.6	2,982.0	7.7	8.0	7.9	8.2	0.2	0.2	8,364.7	9.0	9,119.0	9.1
QII	572.8	729.5	25.3	2,264.2	2,883.5	7.7	8.0	7.9	8.1	0.2	0.2	8,386.1	9.0	9,156.7	9.1
QIII	635.6	787.0	24.9	2,555.3	3,164.0	7.8	8.1	7.9	8.1	0.1	0.0	8,407.4	9.0	8,676.6	9.0
QIV	636.8	749.6	25.9	2,462.0	2,897.9	7.8	8.0	7.9	8.1	0.1	0.1	8,428.7	9.0	8,912.8	9.1
1977/78QI	645.1	711.2	29.0	2,222.9	2,450.7	7.7	7.8	7.9	8.0	0.2	0.2	8,416.9	9.0	9,206.2	9.1
QII	688.6	727.9	29.2	2,354.7	2,488.8	7.8	7.8	7.8	7.9	0.1	0.1	8,405.0	9.0	8,841.8	9.1
QIII	628.1	677.5	29.8	2,109.6	2,275.5	7.7	7.7	7.8	7.9	0.2	0.1	8,393.1	9.0	8,953.1	9.1
QIV	650.9	673.3	30.6	2,126.7	2,200.0	7.7	7.7	7.8	7.8	0.1	0.1	8,381.2	9.0	8,763.1	9.1
1978/79QI	658.2	882.2	31.8	2,068.2	2,772.3	7.6	7.9	7.8	7.9	0.1	0.0	8,481.6	9.0	8,725.7	9.0
QII	632.3	942.7	32.4	1,951.6	2,909.7	7.6	8.0	7.8	8.0	0.2	0.1	8,582.1	9.1	9,077.3	9.0
QIII	646.7	1,044.4	33.9	1,908.7	3,082.4	7.6	8.0	7.8	8.1	0.2	0.1	8,682.6	9.1	9,346.8	9.1
QIV	730.6	1,192.8	35.9	2,034.4	3,321.4	7.6	8.1	7.8	8.3	0.1	0.1	8,783.0	9.1	9,440.2	9.1
1979/80QI	821.4	1,186.8	37.8	2,171.8	3,138.0	7.7	8.1	7.8	8.3	0.1	0.2	8,889.5	9.1	9,674.3	9.2
QII	888.2	1,174.6	37.0	2,402.9	3,177.5	7.8	8.1	7.8	8.3	0.1	0.2	8,996.0	9.1	9,662.6	9.2
QIII	950.4	1,267.5	37.4	2,540.1	3,387.4	7.8	8.1	7.9	8.3	0.0	0.1	9,102.4	9.1	9,583.5	9.2
QIV	948.5	1,369.9	38.6	2,458.9	3,551.3	7.8	8.2	7.9	8.3	0.1	0.1	9,208.9	9.1	9,700.8	9.2
1980/81QI	923.4	1,383.3	38.2	2,420.5	3,625.9	7.8	8.2	7.9	8.3	0.1	0.1	9,237.8	9.1	9,626.2	9.2
QII	878.7	1,494.7	36.9	2,380.4	4,049.0	7.8	8.3	7.8	8.3	0.1	0.0	9,266.7	9.1	9,275.2	9.1
QIII	835.3	1,485.9	38.3	2,182.1	3,881.8	7.7	8.3	7.8	8.3	0.1	0.0	9,295.6	9.1	9,510.1	9.1
QIV	839.6	1,384.3	40.4	2,080.6	3,430.6	7.6	8.1	7.8	8.3	0.1	0.1	9,324.5	9.1	9,900.6	9.2
1981/82QI	797.5	1,495.2	40.8	1,953.5	3,662.5	7.6	8.2	7.7	8.3	0.2	0.1	9,322.2	9.1	9,830.3	9.1
QII	792.1	1,528.9	40.9	1,938.8	3,742.4	7.6	8.2	7.7	8.3	0.1	0.1	9,320.0	9.1	9,799.0	9.2
QIII	794.3	1,543.9	41.1	1,930.5	3,752.2	7.6	8.2	7.7	8.3	0.1	0.1	9,317.7	9.1	9,818.8	9.2
QIV	793.6	1,629.2	42.1	1,886.5	3,873.1	7.5	8.3	7.6	8.4	0.1	0.1	9,315.4	9.1	9,776.3	9.1
1982/83QI	817.9	1,603.4	42.8	1,910.9	3,745.8	7.6	8.2	7.6	8.4	0.1	0.1	9,550.0	9.2	10,116.7	9.2
QII	833.6	1,610.7	43.2	1,928.4	3,726.4	7.6	8.2	7.6	8.4	0.1	0.2	9,784.6	9.2	10,376.2	9.3
QIII	842.0	1,664.6	42.3	1,991.1	3,936.4	7.6	8.3	7.6	8.4	0.0	0.1	10,019.2	9.2	10,419.9	9.3
QIV	810.5	1,748.2	42.9	1,888.6	4,073.3	7.5	8.3	7.6	8.4	0.1	0.1	10,253.8	9.2	10,642.7	9.3
1983/84QI	835.0	1,773.8	41.8	1,995.8	4,239.5	7.6	8.4	7.7	8.4	0.1	0.1	10,092.4	9.2	10,490.1	9.2
QII	833.4	1,810.4	41.5	2,006.2	4,358.2	7.6	8.4	7.7	8.5	0.1	0.1	9,931.0	9.2	10,446.2	9.2
QIII	877.2	1,777.7	41.5	2,112.9	4,282.0	7.7	8.4	7.7	8.5	0.1	0.2	9,769.6	9.2	10,487.1	9.3
QIV	929.1	2,068.6	45.8	2,029.3	4,518.1	7.6	8.4	7.8	8.6	0.1	0.1	9,608.2	9.2	10,418.3	9.2
1984/85QI	937.2	1,987.8	46.4	2,020.6	4,285.6	7.6	8.4	7.7	8.5	0.1	0.1	9,375.4	9.1	9,966.7	9.2
QII	862.6	1,949.2	49.1	1,755.5	3,966.8	7.5	8.3	7.6	8.4	0.1	0.1	9,142.6	9.1	9,771.2	9.2
QIII	783.7	1,973.4	51.5	1,522.9	3,835.1	7.3	8.3	7.5	8.3	0.2	0.1	8,909.7	9.1	9,403.0	9.1
QIV	743.6	1,768.4	51.6	1,440.1	3,424.8	7.3	8.1	7.4	8.3	0.1	0.1	8,676.9	9.1	9,147.2	9.1
1985/86QI	693.1	1,870.3	58.0	1,194.7	3,223.9	7.1	8.1	7.4	8.3	0.3	0.2	8,891.7	9.1	9,868.2	9.1
QII	692.4	2,056.5	53.0	1,306.4	3,879.9	7.2	8.3	7.4	8.3	0.3	0.1	9,106.5	9.1	9,645.4	9.1
QIII	824.3	2,187.4	50.7	1,625.5	4,313.6	7.4	8.4	7.5	8.4	0.1	0.0	9,321.2	9.1	9,448.2	9.1
QIV	880.7	2,211.3	49.8	1,768.4	4,439.8	7.5	8.4	7.5	8.4	0.0	0.0	9,536.0	9.2	9,624.7	9.2
1986/87QI	946.8	2,400.3	48.5	1,950.5	4,944.8	7.6	8.5	7.5	8.4	-0.1	-0.1	9,870.7	9.2	9,530.2	9.2
QII	941.7	2,280.3	47.3	1,992.4	4,824.8	7.6	8.5	7.5	8.5	-0.1	0.0	10,205.4	9.2	10,036.2	9.2
QIII	845.0	2,353.5	47.8	1,768.2	4,924.8	7.5	8.5	7.5	8.5	0.0	0.0	10,540.1	9.3	10,561.5	9.3
QIV	794.8	2,226.9	47.7	1,667.7	4,694.1	7.4	8.5	7.5	8.5	0.1	0.1	10,874.8	9.3	11,259.7	9.3
1987/88QI	721.3	2,079.5	47.7	1,511.7	4,358.4	7.3	8.4	7.5	8.5	0.2	0.1	10,873.3	9.3	11,617.5	9.3
QII	735.3	2,279.8	48.1	1,527.6	4,736.2	7.3	8.5	7.5	8.5	0.1	0.1	10,871.9	9.3	11,281.2	9.3
QIII	740.3	2,258.1	48.8	1,518.1	4,630.2	7.3	8.4	7.5	8.5	0.1	0.1	10,870.4	9.3	11,348.8	9.3
QIV	773.1	2,274.6	51.0	1,515.2	4,458.0	7.3	8.4	7.4	8.5	0.1	0.1	10,869.0	9.3	11,464.4	9.3
1988/89QI	868.6	2,374.0	52.8	1,645.2	4,496.4	7.4	8.4	7.5	8.5	0.1	0.1	10,878.3	9.3	11,214.9	9.3
QII	870.9	2,247.7	52.5	1,658.0	4,279.2	7.4	8.4	7.5	8.4	0.1	0.1	10,887.5	9.3	11,254.7	9.3
QIII	884.6	2,141.5	53.6	1,651.4	3,998.0	7.4	8.3	7.5	8.4	0.1	0.1	10,896.8	9.3	11,359.7	9.3
QIV	902.8	2,110.4	55.5	1,625.3	3,799.3	7.4	8.2	7.5	8.4	0.1	0.1	10,906.1	9.3	11,413.3	9.3
1989/90QI	834.0	2,006.9	55.8	1,495.6	3,598.9	7.3	8.2	7.4	8.3	0.1	0.1	11,016.9	9.3	11,553.5	9.3
QII	914.7	1,966.3	56.3	1,625.5	3,494.0	7.4	8.2	7.4	8.3	0.0	0.1	11,127.8	9.3	11,427.8	9.4
QIII	860.5	1,875.3	55.9	1,540.5	3,357.5	7.3	8.1	7.3	8.2	0.0	0.1	11,238.7	9.3	11,484.4	9.4
QIV	736.8	1,824.9	57.6	1,279.3	3,168.7	7.2	8.1	7.3	8.2	0.1	0.1	11,349.6	9.3	11,711.5	9.4
1990/91QI	688.8	2,057.9	58.4	1,179.7	3,524.4	7.1	8.2	7.1	8.2	0.1	0.0	11,246.7	9.3	11,279.5	9.3
QII	607.4	2,241.6	58.7	1,034.6	3,818.1	6.9	8.2	7.0	8.1	0.1	-0.1	11,143.9	9.3	10,930.1	9.2
QIII	561.1	2,408.6	71.5	784.4	3,366.7	6.7	8.1	6.9	8.1	0.2	0.0	11,041.1	9.3	11,251.1	9.3
QIV	542.5	2,130.3	81.9	662.3	2,600.9	6.5	7.9	6.8	8.1	0.3	0.3	10,938.2	9.3	11,728.9	9.4
1991/92QI	452.4	1,537.9	81.6	554.2	1,883.9	6.3	7.5	6.5	7.9	0.2	0.4	10,837.3	9.3	11,788.0	9.4
QII	390.4	1,151.9	80.5	484.8	1,430.3	6.2	7.3	6.3	7.7	0.2	0.4	10,736.4	9.3	11,608.8	9.5
QIII	343.8	820.4	81.8	420.5	1,003.4	6.0	6.9	6.1	7.5	0.1	0.6	10,635.5	9.3	11,404.7	9.6
QIV	279.0	1,070.5	85.9	324.8	1,246.2	5.8	7.1	5.9	7.2	0.1	0.1	10,534.6	9.3	10,690.1	9.3

	Annualized EXP	Annualized IMP	CPI	REXP	RIMP	LREXP	LRIMP	Interpolated LREXP	Interpolated LRIMP	Error in trend LREXP	Error in trend LRIMP	Interpolated RGDP	Interpolated LRGDP	Disaggregated RGDP	Disaggregated LRGDP
1992/93QI	318.6	1,382.2	90.3	352.9	1,530.7	5.9	7.3	6.1	7.5	0.3	0.2	10,850.7	9.3	11,468.1	9.3
QII	450.4	2,480.0	90.9	495.6	2,728.8	6.2	7.9	6.4	7.8	0.2	-0.1	11,166.7	9.3	11,434.6	9.2
QIII	604.2	3,065.6	81.8	739.0	3,749.7	6.6	8.2	6.6	8.1	0.0	-0.1	11,482.7	9.3	11,468.7	9.3
QIV	800.8	3,618.7	92.3	867.7	3,920.9	6.8	8.3	6.9	8.4	0.1	0.1	11,798.8	9.4	12,263.4	9.4
1993/94QI	917.4	4,056.8	91.1	1,007.6	4,455.4	6.9	8.4	7.0	8.4	0.1	0.0	11,848.9	9.4	12,109.1	9.4
QII	994.2	3,936.7	88.5	1,122.8	4,446.1	7.0	8.4	7.1	8.5	0.1	0.1	11,899.0	9.4	12,405.9	9.4
QIII	1,030.7	4,257.9	90.3	1,141.8	4,716.8	7.0	8.5	7.2	8.6	0.1	0.1	11,949.1	9.4	12,550.0	9.4
QIV	1,238.7	4,740.0	97.1	1,275.2	4,879.5	7.2	8.5	7.3	8.6	0.1	0.1	11,999.2	9.4	12,696.5	9.4
1994/95QI	1,582.8	5,423.4	99.6	1,589.7	5,447.2	7.4	8.6	7.5	8.7	0.1	0.1	12,160.5	9.4	12,671.0	9.4
QII	2,062.9	5,658.6	101.6	2,029.8	5,567.7	7.6	8.6	7.6	8.7	0.0	0.1	12,321.8	9.4	12,909.7	9.5
QIII	2,259.3	5,941.2	103.5	2,181.9	5,737.7	7.7	8.7	7.8	8.8	0.1	0.1	12,483.1	9.4	13,319.5	9.5
QIV	2,732.0	6,546.3	111.3	2,455.2	5,882.9	7.8	8.7	8.0	8.8	0.1	0.1	12,644.4	9.4	13,660.6	9.5
1995/96QI	2,874.2	7,154.0	109.3	2,628.9	6,543.4	7.9	8.8	7.9	8.9	0.1	0.1	12,980.0	9.5	13,527.9	9.5
QII	2,603.0	7,521.6	103.4	2,516.9	7,272.9	7.8	8.9	7.9	8.9	0.1	0.0	13,315.7	9.5	13,549.3	9.5
QIII	2,683.5	7,889.5	104.0	2,579.1	7,582.6	7.9	8.9	7.9	8.9	0.0	0.0	13,651.4	9.5	13,777.6	9.5
QIV	2,539.1	7,708.2	103.0	2,464.1	7,480.6	7.8	8.9	7.9	9.0	0.1	0.1	13,987.1	9.5	14,463.5	9.6
1996/97QI	2,531.7	7,190.9	101.0	2,506.6	7,119.7	7.8	8.9	7.9	9.0	0.1	0.1	14,150.4	9.6	14,987.4	9.6
QII	2,650.6	7,098.6	97.6	2,714.8	7,270.6	7.9	8.9	8.0	9.0	0.1	0.1	14,313.7	9.6	14,982.5	9.6
QIII	2,962.6	7,072.9	94.6	3,132.8	7,479.3	8.0	8.9	8.1	8.9	0.1	0.0	14,477.0	9.6	14,778.2	9.6
QIV	3,485.6	7,379.3	96.3	3,619.5	7,662.8	8.2	8.9	8.2	8.9	0.0	0.0	14,640.3	9.6	14,543.7	9.6
1997/98QI	3,559.9	7,731.0	98.5	3,614.1	7,848.7	8.2	9.0	8.2	9.0	0.0	0.0	14,587.5	9.6	14,864.6	9.6
QII	3,954.1	7,901.0	97.2	4,068.0	8,128.6	8.3	9.0	8.3	9.0	0.0	0.0	14,534.7	9.6	14,774.7	9.6
QIII	4,141.5	9,359.6	96.4	4,296.2	9,709.1	8.4	9.2	8.3	9.1	-0.1	-0.1	14,481.9	9.6	13,813.9	9.6
QIV	4,142.5	9,338.5	98.4	4,208.4	9,487.1	8.3	9.2	8.4	9.2	0.0	0.0	14,429.1	9.6	14,519.9	9.6
1998/99QI	4,301.9	10,088.3	100.5	4,279.1	10,034.8	8.4	9.2	8.3	9.2	0.0	0.0	14,645.4	9.6	14,589.2	9.6
QII	3,966.9	11,071.9	94.9	4,178.6	11,662.8	8.3	9.4	8.3	9.3	-0.1	-0.1	14,861.6	9.6	13,922.9	9.6
QIII	3,713.0	11,073.7	97.3	3,816.0	11,381.0	8.2	9.3	8.2	9.3	0.0	0.0	15,077.9	9.6	14,969.8	9.6
QIV	3,569.9	11,702.0	102.0	3,498.7	11,468.8	8.2	9.3	8.2	9.4	0.0	0.0	15,294.1	9.6	15,689.1	9.6
1999/2000QI	3,571.7	12,308.6	105.0	3,400.5	11,718.8	8.1	9.4	8.2	9.4	0.1	0.0	15,498.7	9.6	15,663.7	9.6
QII	3,711.1	12,273.5	100.8	3,680.4	12,172.1	8.2	9.4	8.2	9.3	0.0	-0.1	15,703.2	9.7	15,200.0	9.6
QIII	3,958.1	11,507.8	100.4	3,943.7	11,465.7	8.3	9.3	8.2	9.3	0.0	0.0	15,907.8	9.7	15,672.1	9.7
QIV	3,957.8	11,438.7	105.0	3,769.3	10,894.0	8.2	9.3	8.3	9.3	0.0	0.0	16,112.3	9.7	16,357.1	9.7
2000/01QI	4,077.9	10,657.9	105.8	3,853.2	10,070.4	8.3	9.2	8.3	9.3	0.0	0.1	16,423.7	9.7	17,462.0	9.8
QII	3,990.7	10,368.6	101.8	3,921.4	10,188.6	8.3	9.2	8.3	9.4	0.0	0.1	16,735.0	9.7	17,828.2	9.8
QIII	3,975.8	11,247.7	99.8	3,983.7	11,270.2	8.3	9.3	8.2	9.4	0.0	0.1	17,046.4	9.7	17,431.2	9.8
QIV	3,866.6	12,314.0	97.9	3,949.5	12,578.1	8.3	9.4	8.2	9.4	0.0	0.0	17,357.7	9.8	16,924.5	9.8
2001/02QI	3,633.6	13,351.3	96.3	3,774.5	13,869.1	8.2	9.5	8.3	9.5	0.0	-0.1	17,411.5	9.8	16,701.3	9.7
QII	3,850.0	15,297.1	96.1	4,007.6	15,923.4	8.3	9.7	8.3	9.5	0.0	-0.2	17,465.3	9.8	15,571.7	9.7
QIII	3,740.6	14,926.2	95.8	3,903.2	15,575.1	8.3	9.7	8.3	9.6	0.0	-0.1	17,519.0	9.8	16,602.9	9.7
QIV	3,864.3	14,435.6	94.7	4,082.0	15,248.9	8.3	9.6	8.3	9.6	0.0	0.0	17,572.8	9.8	17,409.4	9.8
2002/03QI	4,017.5	14,523.6	97.5	4,121.9	14,901.1	8.3	9.6	8.3	9.6	0.0	0.0	17,400.4	9.8	17,666.9	9.8
QII	4,114.5	13,903.7	98.8	4,164.4	14,072.5	8.3	9.6	8.3	9.6	0.0	0.1	17,228.0	9.8	18,305.5	9.8
QIII	4,269.9	15,037.3	100.8	4,237.4	14,922.9	8.4	9.6	8.3	9.7	0.0	0.1	17,055.5	9.7	17,584.2	9.8
QIV	4,142.4	15,936.8	103.6	3,999.7	15,388.0	8.3	9.6	8.3	9.7	0.0	0.0	16,883.1	9.7	17,397.2	9.7
2003/04QI	4,300.8	15,533.7	105.7	4,068.9	14,696.0	8.3	9.6	8.4	9.7	0.1	0.1	17,366.9	9.8	19,549.1	9.8
QII	4,268.6	18,224.5	105.3	4,052.4	17,301.7	8.3	9.8	8.4	9.8	0.1	0.1	17,850.7	9.8	19,136.5	9.8
QIII	4,671.8	20,789.7	104.3	4,479.2	19,932.6	8.4	9.9	8.5	9.9	0.0	0.0	18,334.4	9.8	18,379.8	9.8
QIV	5,176.6	22,297.7	107.9	4,796.1	20,658.8	8.5	9.9	8.5	10.0	0.0	0.0	18,818.2	9.8	19,220.8	9.8

Appendix B: Graphical Results of Recursive Tests



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Declaration

I, the undersigned, declare that this thesis is my original work and it has never been presented in any other university. All sources of materials used for this thesis have been duly acknowledged.

Name: Samuel Mulugeta Badwaza

Place: Addis Ababa University

Date: July 20, 2005

Signature: