Essays on Monetary Policy and Economic Growth

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Submitted for the Degree of Doctor of Philosophy in Economics

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ABSTRACT

This thesis consists of three essays concerning money supply growth, one of the main objectives in monetary policy, and economic growth. The aim of this work is to investigate the role of money in monetary policy and how money supply and seigniorage impact on output growth. The findings are derived from theoretical models and modern econometric techniques. First of all, I shall evaluate the role of money in the conduct of monetary policy in South Korea. This research analyses the effect of monetary aggregates on prices and output and examines its transmission mechanism using recursive and non-recursive vector autoregressive models. The expansionary monetary policy shocks have substantial effects on output. Specific channels of the transmission operate through the effects which monetary aggregates have on banking lending, stock prices, exchange rates and investment, export, and government consumption. Then, a cash-in-advanced model and human capital based endogenous growth model is developed. Through employing Bayesian maximum likelihood estimation, a positive money shock is created leading to an increase in seigniorage, which also has a positive impact on output growth. This is because there is a growth-enhancing effect from human capital production since seigniorage is spent by a government on public education. I shall show that money within the model also generates a connection between seigniorage and inflation. However, in the long run, the theoretical model also captures the adverse effect of seigniorage due to inflation so that I shall examine the existence of threshold effects between seigniorage and growth in developing countries using Hansen (1999)'s panel threshold methodology. The threshold level of seigniorage above which seigniorage significantly slows output growth is set at 2.27%. This thesis confirms that money supply and seigniorage have a substantial impact on output so that money is an important factor to be considered in the architecture of macroeconomic policy.

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Declaration

I hereby declare that this thesis, which I submit for the degree of Doctor of Philosophy at Durham University Business School, has been written by me, that it is the record of work carried out by me and that it has not been submitted in any previous application for another degree qualification or any other university.

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ACKNOWLEDGEMENTS

"When you want something, all the universe conspires in helping you to achieve it. Remember that wherever your heart is, there you will find your treasure. You've got to find the treasure, so that everything you have learned along the way can make sense." (Coelho, 1988, p.22 & p.122)

My thanks are due to many people who made the completion of this thesis possible through their positive support and continuous encouragement in various capacities. Firstly, I thank to my thesis supervisor Professor Parantap Basu with all my heart for his continuous encouragement, outstanding support, and guidance. I consider myself exceptionally fortunate to have had him as a thesis supervisor. He has been a real inspiration for taking a creative and innovative approach to Economics. He is now and will continue to my fabulous role model: sharp, intellectual, perceptive, and mindful of the things that truly matters. I am also greatly indebted to my second supervisor, Professor Guido Cozzi for his encouragement, comments and assistance throughout this process. I also thank Dr. Anamaria Nicolae and Dr. Keshab Bhattarai for their encouragement and insightful comments.

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Finally, this thesis would not have been possible without the love and support of my family who are my source of inspiration and strength. Specially, I would like to my parents thank most of all, Oh Soon-San and Yeo Im-Soo to whom this work is dedicated.

To My Parents

(사랑하는 아버지 어머니께 드립니다)

Chapter 1

Introduction

1.1 Introduction

"*The privilege of creating and issuing money is not only the supreme prerogative of Government, but it is the Government's greatest creative opportunity. By the adoption of these principles, the long-felt want for a uniform medium will be satisfied. The taxpayers will be saved immense sums of interest, discounts and exchanges. The financing of all public enterprises, the maintenance of stable government and ordered progress, and the conduct of the Treasury will become matters of practical administration. The people can and will be furnished with a currency as safe as their own government. Money will cease to be the master and become the servant of humanity. Democracy will raise superior to the money power." (Lincoln, 1865, P.91)*

Monetary policy refers to the action a central bank takes when it attempts to achieve a particular macroeconomic goal. For instance, the aims of monetary policy in the Federal Reserve Act of 1913 were to stabilise prices, maximise employment and moderate long-term interest rates. The formation of monetary policy involves determining the size and rate of money supply growth and influencing the demand for money. If the central bank increases the size of the money supply, the policy is regarded as expansionary. On the other hand, a contractionary monetary policy attempts to slow down the expansion of the money supply. In order to modify the amount of money, particularly monetary base, in circulation, there are various types of monetary policy such as the inflation targeting, the monetary targeting, the fixed exchange rate, the floating exchange rate, exchange rate targeting and price level targeting.

Money or credit supply and interest rates are two major monetary policy tools. Over recent decades, monetary policy has been changed especially from the quantity of money in the economy to inflation targeting. In the 1980s, several industrialised countries, such as the

United States, Canada and the United Kingdom, adopted the policy of monetary targeting. The money targeting regime believes that price growth is influenced by money supply growth. However, in the US, deregulation and the Monetary Control Act of 1980 made the policy makers focus on the empirical links between the existing monetary aggregates and the economy. An empirical monetarist model demonstrated the relative stability of velocity over the post-war period (Rasche, 1972). However, unexpected and large movements in velocity reduced the accuracy of the monetarist model in the 1980s. In light of these events, policy makers quickly turned to inflation targeting. A central bank controls the federal funds rate to achieve policy goals. In inflation targeting policy, the Taylor rule adjusts the interest rate with regard to shifts in the inflation rate and the output gap. In this framework, monetary aggregates are endogenous and play a minimal role in the conduct of monetary policy.

1.2 Research Motivation

Substantial controversy persists regarding the role of money in the design of monetary policy strategies (Kahn and Benolkin, 2007). Two sets of issues will motivate my investigation.

First, the current financial crisis has led to a return to debates on the role of money in the formation of monetary policy. The recent crises have shown that monetary policy based on the interest rate rule may not be very effective in stabilising the economy. A lesson from the crises is that price stability and interest rate policy are not enough to achieve financial stability (Svensson, 2013). Monetary policy should be conducted taking the financial stability policy and the role of money into account.

The standard New Keynesian model assumes that financial markets work perfectly however the recent financial crisis has revived attention in business cycle models with financial frictions. The financial crises of 2008 have highlighted the importance of addressing new questions regarding the conduct of monetary policy, along with the relevance of the transmission mechanism. Bean et al (2010) and Mishkin (2010) mentioned that the lack of financial stability could have a negative impact on price stability. In addition, central banks set the macro prudential policy inspired by Crockett (2000). This intends to identify risks to systemic stability that it can reduce the cost to the economy from a disruption in financial services that support the workings of financial markets (IMF 2013). To my knowledge, nevertheless, few papers explore the role of money and the transmission mechanism of money empirically.

Hence, policy makers started to reconsider the role of money in monetary policy. For instance, in response to the financial crisis in 2008, developed countries such as the United States, United Kingdom and Japan launched quantitative easing (hereafter referred to as QE). QE policies include increasing the money base through asset purchases and lending programmes. In addition, the European Central Bank has adopted the two-pillar monetary policy strategy (Angeloni *et al.*, 2000). The two-pillar approach describes two complementary perspectives with regard to the determinants of inflation. The first pillar emphasises the monetary analysis and the second one stresses the economic analysis. The first pillar is a reference value for a single monetary aggregate, M3. This implies that money matters in shaping current thinking regarding the conduct of monetary policy. This aims to detect the medium to long-term risks to price stability. The second pillar identifies the short to medium-run risks by analysing real activity and financial conditions in the economy. It represents how the interplay of supply and demand in the services, goods and factor markets influence the price developments in the medium-term. The two-pillar approach attempts to focus on different perspectives without neglecting relevant information and this cross-checking enables policy makers to lead an overall analysis on the risks to price stability.

The current events motivated me to set up the benchmark model. It includes output, prices, short-term interest rates, commodity prices and monetary aggregates. Following the New Keynesian approach, money is set after the interest rate as the identification imposes that money shocks have no effect on any other variable other than money itself and commodity prices. This helps me to examine if money has a role in determining the output and inflation as suggested by Woodford (2003).

Second, in the quantity theory of money, the expansion of the money supply leads to inflation. If the velocity of the money is stable over time[1], there is a positive relationship between money and inflation. This means that the real wealth of the money holder decreases while the wealth of the money issuer increases. This is very similar to a tax as there is a redistribution of wealth from people to the issuers of money. This inflation tax can be seen as seigniorage, one of the government's revenues. Seigniorage is the net revenue from issuing fiat money. This is the difference between the face value of fiat money and the cost of producing it. This made me think that, if revenues are used to finance government services that have an effect on economic activities, the money supply may have a crucial role in output growth.

1.3 Aims and Objectives

Even though monetary aggregates have seemed to be non-crucial in the formulation of monetary policy since the 1990s, I consider this as a weakness in the actual monetary debate. It is a central argument in this thesis that the money growth affects output growth significantly. This research, hence, aims to explore and analyse how the money supply impacts on economic growth by using both theoretical and empirical approaches.

[1] However empirically the monetary velocity does not stay unchanged, as there was an unpredictable drop in the US velocity during 1980s. More detailed information is in section 2.3.5.

In order to fulfil these aims, the following objectives were formulated:

- to discuss the role of money in monetary policy;
- to explore the transmission mechanism through which money supply impacts on the output level;
- to develop an understanding of the concept of seigniorage regarding the money supply;
- to assess the effect of seigniorage on output growth when the government spends on public education;
- to assess the effects of money growth on seigniorage and output growth in the short run;
- to identify the benefits and costs in the economy from seigniorage;
- to critically examine and evaluate the possibility of non-linearity in the seigniorage-output growth relationship;

It will be helpful to know that money supply impacts on economic growth for the formulation of macroeconomic policies. The results of this study provide strong theoretical and empirical support for this view. Policymakers and scholars over recent decades have argued that money has a minimal role. However, the research confirms that it is necessary to undertake a cross-check between the optimal model-based interest rate policy and monetary aggregates as the money has a real effect on output growth. In order to reveal the transmission mechanism from money growth to economic growth, the main focus of this research is on the model between interdependence of monetary and fiscal policy due to the government budget constraint. Money supply growth and seigniorage can have real effects and the final empirical finding identifies the level of seigniorage that should not be exceeded in the selected developing countries. Considering that there has not been any significant research attempt in the field in the last decade regarding the role of monetary aggregates and, in particular, seigniorage in monetary policy, this research should be considered as an important, yet humble, contribution to the existing body of knowledge on monetary policy.

1.4 Outline of Thesis

The thesis comprises three main chapters in total. Figure 1.1 demonstrates the structure of the thesis and how the main chapters contribute to the thesis's objectives that are being investigated.

The second chapter is devoted to examining the role of money in monetary policy. First of all, I shall review the role of money in terms of monetarism and New Keynesianism over recent decades. The first empirical test examines the role of money in output and prices in South Korea over the last 30 years. This will be contrasted with New Keynesian policy, which asserts that money has no effect on output and inflation; I allow the money supply to enter into the monetary policy rule. The benchmark model includes output, prices, short-term interest rates, commodity prices and monetary aggregates in order to examine if money has a role in determining output and inflation.

In order to examine the empirical models, recursive and non-recursive Vector Autoregressive (hereafter referred to as VAR) approaches are adopted. In the recursive VAR model, shocks to money can be identified with money ordered last using South Korean data over the period from 1981 to 2012. In the non-recursive VAR model, more general contemporaneous interactions among variables are available. In this case, the restriction that the interest rate does not respond to monetary base within the period is dismissed. The results are reconfirmed by a robust check such as replacing the alternative variables or using another simple methodology such as the Granger-causality test. Contrary to the New Keynesian model investigated by Woodford (2003), I found that money shocks significantly affect the dynamic behaviour of output. This is in line with Favara and Giordani (2009)'s work that observed the money role in US on output.

After investigating the role of money in the benchmark model, I shall examine the transmission mechanism of the money supply. Monetary transmission is a complex topic as there are many channels through which money supply operates (Mishkin, 1996). Decisions about money supply have an impact on economic growth through several channels, known as the transmission mechanism of monetary policy. One of the primary goals of central banks now is the pursuit of financial stability (Willem, 2007). This requires them to pay attention to the key services that the financial markets provide to the real economy. Injecting money into the economy may also impact on the spending and investment behaviour of economic agents. Therefore, this transmission mechanism will be explained in terms of financial and non-financial variables. Each financial and non-financial variable will be added to the benchmark model. The quantitative effect of a change in the money supply is transmitted to the financial market. The changes in money supply affect banking lending, exchange rates, long-term nominal interest rates and stock prices. A money supply shock increases banking lending by 0.02%. The nominal exchange rate immediately goes up to 0.02% after a money shock. A money shock causes the stock prices to increase by 0.09%. Then, these changes in turn affect the trade (export and import), investment behaviour of individuals and firms and government spending in the economy. There is an increase of 0.04% in imports after a shock to money. The money supply shock increases the investment by 0.02%. After 7 quarters government consumption is increased by 0.02% in response to a money supply shock. Most of the results are similar to the monetary policy committee report (Bank of England, 2012).

After the confirmation of the role of money in monetary policy, I shall examine the transmission mechanism from money growth to economic growth incorporating fiscal policy. Numerous pieces of literature have argued that money growth is highly related to seigniorage[2]. Hence, *the third chapter* explores the effect of money supply growth and seigniorage on output growth. Firstly, I shall review the existing literature of different economic theories and approaches to money supply, seigniorage and government spending. This provides an idea about the relationship between money supply and seigniorage as well as the effect of government spending on output.

The ideas gained from the literature review contribute to developing a cash-in-advance model. The starting point for our theoretical analysis is Lucas' (1988) endogenous two-sector growth model incorporating the cash-in-advance model and government spending into the human-capital production function. There are three types of economic agents, which are households, firms and the government. In this model, the agent purchases the consumption goods with cash. The government spends its revenue from printing money and tax revenue on education. After demonstrating each agent's condition, the competitive equilibrium and the balance growth are conducted and short run equations are presented.

[2] See section 3.2 for more detailed information.

In order to solve a dynamic stochastic general equilibrium model, a log-linear approximation of equilibrium is performed using dynare programme. I shall attempt to estimate the role of a money shock in the short run using a likelihood-based Bayesian estimation. The Bayesian estimation enables us to find the posterior distributions of parameters using both the calibration method and maximum likelihood estimation. Using US quarterly data from 1960 to 2007 as observable variables and prior distribution for structural parameters, I shall obtain the posterior distributions for the parameters of the model. My aim is to give the posterior means of the estimated structural parameters in the baseline model. I shall then examine the responses to the three shocks, a positive physical capital technology shock, human capital technology shock and a money shock for the first ten years. In particular, I aim to observe how a positive monetary level affects output, seigniorage, and inflation in the short run. The result shows a positive money shock leads to a positive seigniorage that is one of the revenues of government spending on education and an inflation rate. In contrast to Basu *et al.* (2012) and Gillman (2005), a positive monetary shock leads to a positive impact on output growth. Following Lucas (1988), the growth of human capital shocks leads to a growth of output in this model. This concludes that the positive money shock increases output growth through the public education spending financed by seigniorage.

The fourth chapter of the thesis examines the nonlinear relationship between seigniorage and economic growth. Based on the theoretical model in chapter 3, a dynamic stochastic general equilibrium model infers how a change in seigniorage impact on output growth. The effect of seigniorage in the short run is positive on output growth. However, the long-run impact of seigniorage is not clear. The balanced growth equation in chapter 3, infers that the effect of seigniorage on output growth may have two opposing effects. One is a growth-enhancing effect and the other is a diverse effect on output growth. The nonlinearity in the short run may exist, which I could not explore due to the log-linearised model. In order to explore the nonlinearity between the seigniorage and output growth, empirical analysis using cross-country-data is conducted.

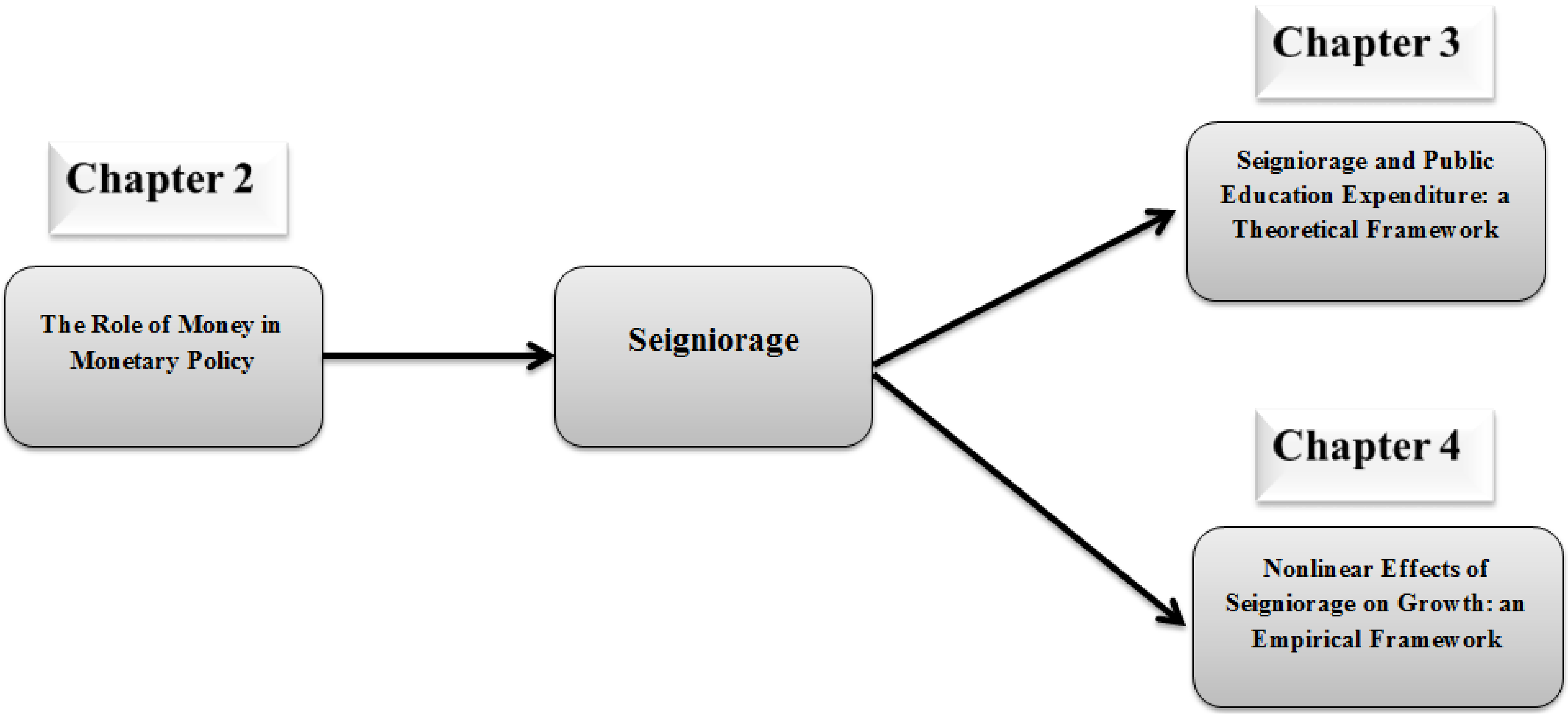
First, the preliminary analysis is examined to provide some general ideas of seigniorage rates and output growth in 70 developing countries over the period from 1994 to 2006. Second, the standard quadratic model is explored. However, the quadratic function form has some shortcomings. It has to know the shape of non-linearity prior to the estimation and the conventional gradient search techniques cannot be adopted, as the threshold level is unknown.

Therefore, I employ the advanced econometric methodology which is Hansen's (1999) panel threshold model. This enables us to find the number of seigniorage thresholds, the seigniorage threshold value, and the marginal impact of seigniorage on output growth in different regimes. This methodology can be applied even when the asymptotic distribution of the t-statistic on the threshold variable is non-standard. The result confirms that there is a single threshold level. 2.2715 %. The seigniorage has a positive impact on economic growth up to 2.2715% and negative impact beyond the threshold level in developing countries. Agenor and Neanidis (2006) presented that there is a positive relationship between public expenditure on economic growth. And seigniorage is crucial government revenue in developing countries since the finance system is not developed. This may indicate that productive government spending causes a positive effect of seigniorage on output. There is a negative effect of seigniorage on output as higher inflation owing to deficit financing causes a substantial welfare cost on the real balances of money holders (Friedman, 1971).

In order to check the robustness, a model with instrumental variables is developed by Bick (2010) is followed. Instrumental variables are one lag of government spending, Investment, Trade Openness and Initial Income.

The fifth chapter presents a summary, conclusion and recommendations.

Figure 1.1 Structure of the Thesis



Chapter 2

Does Money Really Play No Explicit Role in Monetary Policy? : The Case of South Korea

Abstract

Most New Keynesian approaches ignore the role of money in the conduct of monetary policy and construct the transmission of a short-run dynamic model through interest rates. I shall examine the role of money in output and prices and its transmission mechanism, based on the Recursive and Non-Recursive Vector Autoregressive methodology. To ascertain the transmission mechanism, financial and non-financial variables are included in the VAR system. The results confirm that money has a substantial role in terms of output in contrast with the New Keynesian approach. In relation to the transmission, a money supply shock has a positive impact on the aggregate output through bank lending, exchange rates, stock prices, exports, imports, investment and government consumption channels.

2.1 Introduction

In recent years, monetary policy has focused more on the use of one instrument, the short-term interest rate without any reference to money. The money is redundant in monetary policy once the short-term interest rate is present. However, concerns about the ease with which money is dismissed have emerged and the question of the role of monetary aggregates in the economy has been of great interest to the profession.[3] For example, the European Central Bank considers a prominent role for money and monetary analysis in its two-pillar monetary policy strategy and some countries, such as Japan and the U.S., have embarked on Quantitative Easing (QE)[4] in order to boost their economies.

When both inflation and unemployment were increasing in the United States in the 1970s, monetarism rose to prominence. One of the key points of monetarism is that money supply is the tool for the anti-inflationary policy and setting market expectations. Monetarism obtained full attention from policy makers. Both the Federal Reserve and Bank of England stated in the late 1970s that monetary policy would be set not by targeting interest rates but by targeting the aggregate money stock (Volcker and Gyohten, 1993). Paul Volcker, a former chairman of the Federal Reserve in 1979, limited the growth of the money supply after interest rate targets for monetary policy were abandoned in order to tackle the higher inflation rate because of high oil prices and the failure of the Bretton Woods. It turned out that the changes in money supply helped to reduce the inflation rates from double digits to single figures.

However, targeting monetary aggregate policy during Volcker's period of disinflation led to a recession in the economy. In order to tackle the high inflation, monetary policy was tightened

[3] Friedman (2003) and Goodhart (2007).
[4] Quantitative Easing is the policy utilised to increase money supply by purchasing government securities and flooding financial markets with capital, which leads to an increase in lending and liquidity.

which led to an increase in interest rates. Higher interest rates discouraged investment which, in turn, affected output growth. Since the fall in output in the early 1980s, a short-term interest rate has been set by many central banks[5] relative to output and prices without specifying money. This New Keynesian model of monetary policy has become the principal model in monetary economics[6]. An optimal interest rate policy should be considered based on inflation forecasts but without monetary aggregates. 'Monetary policy without money' is a concept widely accepted as clearly demonstrated in the following words by Mervyn King, the former governor of the Bank of England.

"Nowadays monetary aggregates play little role in monetary policy deliberations at most central banks." In discussing this a few years ago, Mervyn King of the Bank of England noted that then-Bank of England Governor Eddie George had mentioned money only one time out of 29 speeches given over the previous two years, and that then-Fed Chairman Alan Greenspan had only mentioned money once in 17 speeches given over the same period. Moreover, he quoted then-Fed Governor Larry Meyer as stating that "…money plays no explicit role in today's consensus macro model, and it plays virtually no role in the conduct of monetary policy." (King, 2003, p. 162)

In line with this recent debate on the role of money, this chapter will address the following two questions:

(1) Does money play a role in the dynamics of output and prices in South Korea?

(2) What is the transmission mechanism through which the money supply affects the output level in South Korea?

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[5] These include the central banks of New Zealand, Chile, Canada, Israel, Sweden, Finland, Spain and Australia

[6] Rotemberg and Woodford (1997), Goodfriend and King(1997) and Woodford (2003).

In order to answer the first question, two theoretical paradigms, Monetarism and New Keynesian economics, in monetary policy should be reviewed. From the perspective of monetarism, money supply has a major impact on output in the short-term and price in the longer term (Friedman (1952); Cagan (1987)). This indicates money as being neutral in the long run. Since money has an important role in the conduct of monetary policy, monetary targeting set the objectives of monetary policy during the 1970s. However, because of the instability of velocity, central banks shifted from monetary targeting to inflation targeting. According to the New Keynesian approach, the money supply is endogenously determined so that central banks supply money in order to meet the interest rate (Woodford (2003); Ireland (2004)). In spite of an insightful monetary model investigated by Woodford (2003), numerous examples in the empirical literature demonstrate that money plays an important role in the economy. For example, Nelson (2003) showed that money is a significant element of aggregate demand in the U.S and the U.K. even though they controlled short-term interest rates. Leeper and Rousch (2003) argued that controlling the interest rate was based on money, rather than on output and prices, and thus enhance the identification of monetary policy shocks. Moreover, the inclusion of money within monetary policy eliminates the price and liquidity puzzles.

In order to gain an insight into the situation underlying the money supply, I have investigated the correlation between money growth, GDP and inflation using annual data taken from South Korea over the period 1970 - 2012 from OECD, World Development Indicator and IMF International Finance Statistics. I shall show that there is a positive relationship between the growth rate of GDP and money growth. The correlation between real M0 growth and real GDP growth for South Korea is 0.418 at the 1 % significance level and using M2, the annual correlation is 0.681 at the 1% significance level. The money-inflation relationship is also positive as the average correlation between M0 and inflation is 0.265 at the 10% significance level whilst the correlation between M2 and inflation is 0.685 at the 1% significance level.

Table 2.1 Correlations between Money Supply, GDP and Inflation

	M0	M1	M2
GDP	0.418*** (0.006)	0.557*** (0.000)	0.681*** (0.000)
Inflation	0.265* (0.094)	0.440*** (0.003)	0.685*** (0.000)

Note: P-values are given in parentheses, */**/*** indicate the 10%/5%/1% significance level. M is the money growth and all variables are measured as logarithmic first differences.

When using the larger measure, a higher correlation is observed. It shows that the choice of the monetary aggregate has some effects on the correlation test outcome. Table 2.1 demonstrates a positive correlation exists between these variables, so that money seems to matter in policy.

Figure 2.1 Real GDP Growth and Real Money Supply: South Korea

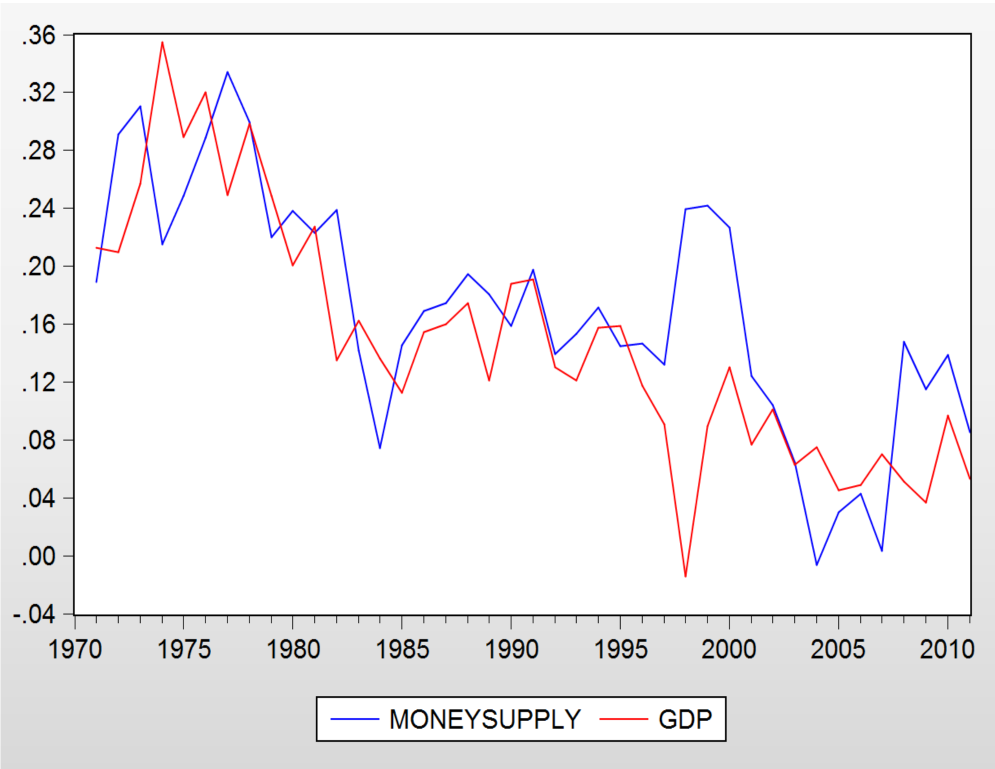


Figure 2.2 Inflation and Money Supply: South Korea

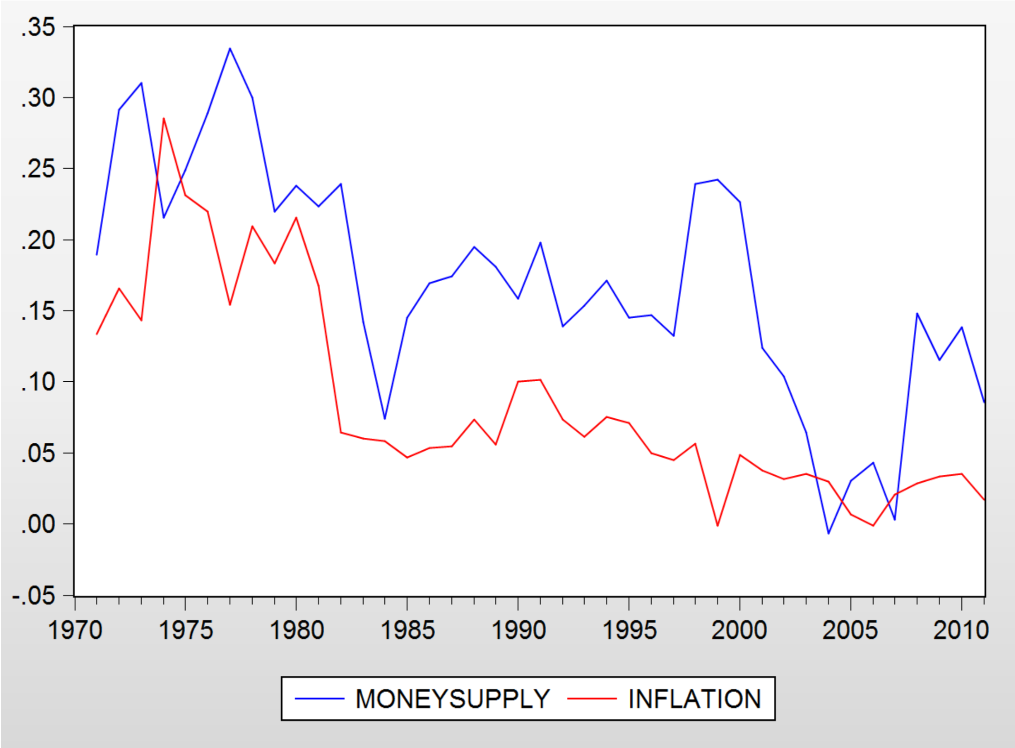


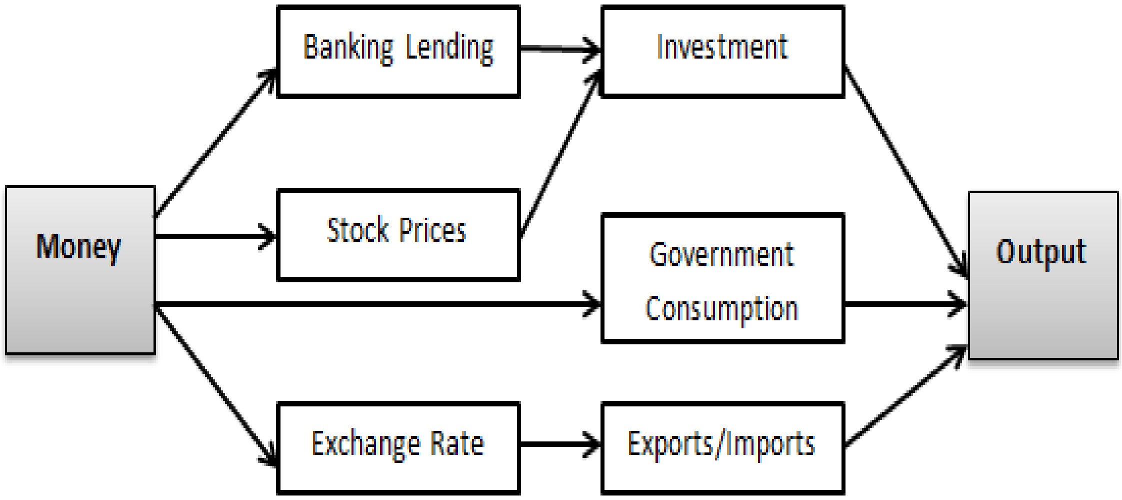
Figure 2.1 plots the annual growth rate of money and GDP. Figure 2.2 shows the annual rate of money and inflation in South Korea. We can observe a similar movement between money growth and GDP growth excluding the period of the Asian financial crisis in 1997. When GDP growth and inflation are relatively high (low), this appears to coincide with periods where the money supply growth is relatively high (low). The main exception is the period from 1998 onwards, during which the money supply is volatile while GDP growth and inflation rates are quite steady. Although there are several periods when the growths in the two variables do not seem to be strongly related, overall there is a positive correlation between money supply, output growth and inflation.

These questions have long been discussed, but remain controversial. In order to resolve these ambiguous questions, I first estimate a minimal Vector Autoregression (hereafter referred to as VAR) model, which consists only of output, prices, short-term interest rates, commodity prices and monetary aggregates using South Korean data for the period 1981-2012. South Korea has been chosen because its experience of economic growth has been different from other countries. Over the last four decades, South Korea has shown astonishing GDP growth by allowing its government to interfere significantly with the control of the bank reserve ratio, and money supply (Cho, 1989).

Since a rigorousness test the information content of money supply is needed, I shall conduct an econometric analysis based on both the recursive and non-recursive VAR methodologies in this chapter. I shall test the theoretical prediction that money supply is irrelevant by means of impulse responses of all variables in the VAR. VAR enables us to identify the economic shocks or causes in a system of equations, where each equation includes lagged values of all the variables. The results indicate that money does affect output, and that it has a crucial role. In order to check the robustness of these models, I shall replace alternative variables. I shall use M1 instead of M0, which confirms that a broad monetary aggregate also has an impact on output.

A change in the money supply has a lagged impact on the economy. However, it is unclear exactly how impulses are transmitted to the output level in terms of a money approach policy. I shall next add several financial and non-financial variables to the above-five-variable VAR to investigate the transmission mechanism of the money supply. Money may also have an indirect effect on output through other variables. The financial variables that I shall consider are bank lending, exchange rates, long-term nominal interest rates and stock prices. The non-financial variables are exports, imports, investment and government consumption. From these six-variable VAR estimations, I shall argue that money supply has an effect on output through lending by banks, stock prices, exchange rates, exports, imports, investment, and government consumption channels. The main channels of money supply transmission are set out in a simplified form in Figure 2.3.

Figure 2.3 The Transmission Mechanism of Money in South Korea



Overall the main aim of this chapter is to examine the role of the money supply in South Korea over the period 1981-2012 with advance econometric techniques. There are two differences between existing studies and this chapter. Firstly, most studies which examine the role of money deal with developed countries such as the U.S. and the U.K., but studies focusing on a newly developed economy, such as South Korea, are relatively rare. Secondly, two different policy reaction functions are considered using recursive and non-recursive VAR to examine the role of money. Thirdly, the analysis of the transmission mechanism of money supply is added in this chapter. The answer to the question which is posed in this chapter lies in whether it is useful to discuss the role of money in monetary policy.

This chapter is structured as follows. Section 2 provides the motivation for this chapter. Section 3 reviews a theoretical and empirical overview on the role of money in the economy. Section 4 introduces data and methodology. Section 5 presents the empirical framework of the recursive and non-recursive VAR analysis and performs a robustness check and section 6 presents the conclusion.

2.2 Motivation

In order to conduct a preliminary analysis regarding the role of money, bivariate Granger-causality tests are carried out. The examination is done by the standard Granger procedure with 5, 3, and 7 lags based on log differences of the representative variables[7]. I employ quarterly South Korean data covering the period from 1981:01 to 2012:04 from the Bank of Korea. Notice that money growth, interest rate and output growth in South Korea are stationary. Three bivariate causality tests are conducted. Table 2.2 shows the first test between money growth and output growth $X_1 = (\Delta M, \Delta Y)$. Table 2.3 presents the Granger-causality test between interest rate and output growth $X_2 = (\Delta R, \Delta Y)$. The last Table 2.4 demonstrates the relationship between money growth and interest rate $X_3 = (\Delta M, \Delta R)$. I report p-values for the null hypothesis that an independent variable does not Granger-cause dependent variable.

This clearly suggests that money growth does Granger-cause output at the 10 % significance level. However, output growth does not Granger-cause money growth. There is a

[7] Money growth (the growth of monetary base), Real GDP output growth, and short-term interest rate.

unidirectional Granger-causality running from money growth to output growth. This result is similar to Sims (1972)'s arguing that money Granger-causes output, but output does not Granger-cause money. Interest rates Granger-cause output at the 1% significance level and output also Granger-causes interest rates at the 10% significance level. Moreover, money growth Granger-causes interest rates at the 10 % significance level but interest rates do not Granger-cause money growth.

The New Keynesians postulated that money supply endogenously reacts to an increase in interest rates and output so that monetary expansion will have no effect on output. However, in contrast to this view, the Granger-causality tests confirm that the past values of money growth helps to predict the current values of output growth and interest rates. The results of Granger-causality tests serve to answer the primary question of whether money impacts on output and interest rates but it is not clear since the Granger-causality test has a few drawbacks [8]. I will employ a recursive and non-recursive VAR model, to which the policy reaction function can be applied in order to analyse the role of money further.

Table 2.2 Granger-causality Test: Money and Output

Null Hypothesis	*F*	*P*
$X_1 = (\Delta M, \Delta Y)$		
Money growth does not Granger -cause Output growth	2.00619	0.0833*
Output growth does not Granger -cause Money growth	0.63107	0.6764

Notes: One (two, three) stars indicate statistical significance at a level 10% (5%, 1%). F indicates F-statistics and P is probability. Lags: 5

[8] More discussion about a pros and cons of Granger-causality, see Granger (1980).

Table 2.3 Granger-causality Test: Interest Rate and Output

Null Hypothesis	*F*	*P*
$X_2 = (\Delta R, \Delta Y)$		
Interest rates do not Granger-cause Output Growth	6.04657	2.E-05***
Output growth does not Granger-cause Interest rates	1.86558	0.0934*

Notes: One (two, three) stars indicate statistical significance at a level 10% (5%, 1%). F indicates F-statistics and P is probability. Lags: 3

Table 2.4 Granger-causality Test: Money and Interest rate

Null Hypothesis	*F*	*P*
$X_3 = (\Delta M, \Delta R)$		
Money growth does not Granger -cause Interest Rates	2.01937	0.0594*
Interest rates do not Granger- cause Output growth	0.77675	0.6081

Notes: One (two, three) stars indicate statistical significance at a level 10% (5%, 1%). F indicates F-statistics and P is probability. Lags: 7

2.3 Literature Review

There are two different perspectives in terms of the conduct of monetary policy. One way of achieving the long-run inflation goal is to determine an appropriate money supply growth and another approach is to set short-term interest rates. The role of money in the macroeconomic theories between 1930 and 1960 was negligible since the dominant view following the Great Depression was fiscal policy (Hafer and Wheelock, 2001). From the early studies of Friedman (1956) and Warburton (1966), the role of money in the 1960s and 1970s received full attention from economists. Before the 1990s, the money approach was widely accepted. However, the status of money in both theoretical macroeconomics and the practical formation of monetary policy have been considerably downgraded over the past two decades. There has been a shift in the conduct of monetary policy from monetary targeting to inflation targeting and interest rate (Taylor Type) rules.

However, in recent times, some central banks such as those in the U.S., the U.K. and Japan, seem to have shed light on the role of money in the conduct of monetary policy by introducing Quantitative Easing (QE). For example, the U.K. undertook asset purchases financed by the central bank between March 2009 and February 2010 which boosted the broad money supply by around 8% (Bridges and Ryland, 2012). In addition, the European Central Bank (ECB) gives monetary analysis an important role in the formulation of monetary policy. The ECB introduced its two-pillar concept of policy-making in 1999. The first pillar is monetary analysis, which furnishes a prominent role to money and credit aggregates and the second pillar is economic analysis. In this section, I shall review how the monetary policy in South Korea has changed and how the view of the role of money has developed.

2.3.1 History of Monetary Policy in South Korea

In terms of the conduct of monetary policy, the Korean economy can be divided into three different economic environments over the last 50 years. The first period (1965-1990) represents the start of the five decades of high economic growth. Under the nation-wide economic development programme, the monetary authority played an important role in financing the government and constraining the conduct of monetary policy. Until the late 1980s, in particular, the Bank of Korea depended on reserve requirements in order to control its money supply. For instance, the financial market was not developed enough and the Bank of Korea set the reserve ratio in the banking sector as high as 11.5 % at the end of the 1980s.

In addition, the Bank of Korea was highly reliant on manipulating the money supply since the financial markets remained underdeveloped and there was a huge demand for funds (Kim and Lee, 2011). The second period (1990-1998) is considered as the liberalization of the financial system. As the government selected the financial liberalization policy, reserve requirements for demand and time deposits decreased by 7 % in 1996 and decreased by 2 % in terms of time deposit. This also increased the ratios of M1 and M2 to the monetary base. However, the pace of liberalization turned into a shock, which caused South Korea to suffer from the Asian financial crisis. The third period is considered as an open macro-economy. The Bank of Korea adopted inflation targeting, the call rate and an increase in the exchange rate flexibility. The history of Korean monetary policy is a good illustration of the various roles of monetary policy tools with evolving economic conditions. Until recently, South Korea has shown astonishing GDP growth by allowing its government to interfere significantly with the control of the bank reserve ratio, and money supply. Since its experience of economic growth has been shown to be different from other developed countries, it can be a good case study to investigate the role of money in the conduct of monetary policy. This can also be a useful guide for other developing countries.

2.3.2 Definition of Money

Firstly I define what money is. The term money can be understood in terms of its three uses in the economy (Jevons, 1898): a medium of exchange, a unit of account and a store of value.

First, it is used as a medium of exchange or means of payment. Money is needed because of trading costs and frictions along with transactions at different times in a variety of markets. Money satisfies the so called double coincidence of wants by reducing the effort to seek individuals who wish to exchange one particular item for another.

Second, it is a unit of account. Money is used as the standard for designating the prices of goods in the economy. A unit of account means that money performs as the measuring unit for prices. Prices of goods are defined in terms of the monetary unit.

Third, it has a store of value role. Money is used as a means of postponing the pleasure of consuming goods until a later time. We obtain the value when a good is consumed for our needs and wants. We can store the value from consuming goods by holding money.

Money has several components such as cash and deposits with the banking system. Note and coin reserves held for commercial banks at the central bank is generally referred to as a monetary base or narrow money. Broad money includes demand deposits at banks, building societies and time deposits.

2.3.3 Monetary Policy Instruments

There are direct and indirect ways of controlling the money supply by central banks. Central banks control the money supply directly through reserve requirements. This requires banks and other depository institutions to hold in reserve and not let out. A decrease in the reserve requirements enables banks to lend out, which can expand the supply. One of the indirect ways to control the money supply can be through the setting of interest rates. Central banks print the exact amount of money to meet the interest rates. Currency board is another monetary policy tool, used by central banks which are required to keep a fixed exchange rate with a foreign currency.

Others are unconventional monetary policies such as quantitative easing and steering market expectations through forward guidance. In particular, the recent financial crisis led monetary authorities in developed economies to undertake quantitative easing. Central banks generally print money in order to inject into an economy through purchasing different types of assets and bonds. It is adopted when conventional monetary policies fail to stimulate the economy. For example, the Federal Reserve printed money to purchase long-term bonds. Then, the price of a bond will go up while the yield goes down, as there is a negative relationship between the price of a bond and its yield. When all types of long-term interest rates in sectors such as housing and machinery decrease, the long term spending will gear up which helps in boosting the economy. QE tries to depress mainly long-term interest rates and target the quantity of money to be supplied to the economy. Another approach in the unconventional monetary policy is forward guidance that enables central banks to influence market expectations on future interest rate (Eggertsson and Woodford, 2003). When there is zero lower bound on interest rates, central banks can use forward guidance to show its intention to keep the interest rate at the current level for a certain period in the future. Forward guidance infers a will to affect future inflation rates (Dale and Talbot, 2010).

2.3.4 The Role of Money in Monetary Policy : Monetarism

Fisher (1911) first developed the quantity theory of money which is a basic theoretical description for the relationship between money and prices. This is also known as the equation of exchange and an identity that relates total aggregate demand to the output. The equation of exchange can be written as:

$$M_t \times V_t = P_t \times Q_t \qquad (2.1)$$

where M_t is the money supply, V_t represents the velocity of circulation of money, P_t is the price level and Q_t is the real value of output. The velocity of circulation is the number of times that a unit of currency is spent on goods and services in a given period of time. Given a particular value of the money supply, the velocity can be calculated. If the velocity of circulation of money is stable over time [9], the money supply will determine the nominal spending. In other words, the growth rate of the money supply can help policy makers to predict the short-to medium term outlook for output and inflation.

This quantity theory of money directly links to Monetarism. The growth rate of the money is highly related to the economic activity, including changes in prices and income.

$$M_t = k_t Y_t = k_t \left(P_t y_t \right) \tag{2.2}$$

where M_t is the nominal money stock, k_t represents the people's desired ratio of money holdings to nominal income, and Y_t is nominal income. Nominal income Y_t is the product of P_t prices and y_t real income. k_t implies the behavioural relationship between the nominal money stock, nominal income and prices [10].

In the basic theory of monetarism, it is assumed that the real outputs may be influenced by the rate of productivity growth or capital stock but not by monetary variables. If k_t and the real output are treated as constants, changes in the money growth will be equal to changes in the price level. Monetarists believe that inflation is a monetary phenomenon and a consequence of monetary policy controlled by the money supply through changes in the monetary base. This stems from the quantity theory, which explains that constant increases or decreases in the prices occur along with the growth rate of money adjusted for long-term output and velocity trends. In terms of this theory, the role of monetary aggregates in the

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[9] The velocity is related to transactions technologies in a long term. If there is a growth in using credit cards, this will allow a money stock to support more transaction which leads to a higher level of spending and velocity. If transactions technologies develop gradually over time, velocity will be more likely stable and predictable.

[10] The equation (2.2) can be viewed as the money demand function if M_t is the nominal stock of money balances demanded by people. If money balances demanded is equal to the money supply and k_t is constant, Y_t can be predicted given the amount of M_t.

formulation of monetary policy is important. For instance, the Federal Reserve in the US put emphasis on the role of money when Chairman Volcker tried to overcome the great inflation in 1979.

In terms of the relationship between money and inflation, a rise in the growth rate of the money supply followed by a rise in the inflation rate leads to a decline in the return on non-nominal-interest-bearing money. Hence the real money demand decreases and people tend to avoid holding money and to re-allocate their asset holdings to real assets. This change in money demand can have an impact on nominal interest rates on loanable funds so that real interest rates can be shifted because of the combined changes in the inflation rates and the nominal interest rates. This also may lead to changes in expenditure on consumer goods and physical capital [11].

Several empirical assessments found that money has an impact on prices and outputs. Stock and Watson (1989) concluded that money helps to predict the fluctuations in output and Altimari (2001) found that money is also the leading indicator in the Euro area. In this paper, the broad monetary aggregate appears to be a leading indicator for price development. Trecroci and Vega (2000) found that money helps to predict future inflation using the Conen/Vega money demand framework.

As noted by Aiyagari *et al.* (1998), the quantity of money can influence the size of transactions costs in the goods and services markets and in the financial markets. The money supply can impact on outputs through enhancing the balance sheets at banks. The base money moves many months before the broader and credit based measure of the money supply. For instance, changes in the monetary base lead to changes in deposits, which affect the amount

[11] Mundell (1963), Cargill and Meyer (1977), Levi and Makin (1979) and Fried and Howitt (1983).

of banking lending. In this view, the central bank can control the size of the monetary base at will and this has an impact on bank's lending and hence influences outputs.

2.3.5 Vanishing Money : <u>New Keynesianism</u>

The instability of the relationship between monetary aggregates and inflation or nominal income makes monetary targeting problematic. The instability of the money-inflation relationship has been found in Germany and Latin America (Estrella and Mishkin (1997); Mishkin and Savastano (2000)). The velocity of money has been shown empirically not to be stable and predictable for the money supply as the quantity of money states. This can be changed in terms of people's behaviour in their handling of money. During the 1980s and early 1990s, the belief on the relationship between money supply growth and the growth rate of inflation was broken because of the unpredictable drop in the US velocity. For instance, Basu and Dua (1996) found that there is a non-stationarity of the income velocity of circulation, which leads to an unstable money demand function. The weak relationship between money and nominal income infers that monetary targeting will not draw the desired outcome for inflation. Monetary targeting owing to the unstable relationship between monetary aggregates and inflation and nominal income makes it difficult to serve as the transparency of monetary policy. This eventually leads central banks to place less importance on the role of money in the conduct of monetary policy.

Because of the unexpected and large shift in velocity in the early 1980s, deregulation of the banking system and financial innovation, monetary aggregate as a policy tool lost their appeal to the policy makers. Inflation targeting has been the preferred way in monetary policy. The theoretical basis of inflation targeting is commonly known as New Keynesian Model (Clarida *et al.*, 1999). Using an alternative approach to overcome instability from the monetary approach, policy makers have controlled inflation through current and future short-term interest rates. Taylor (1993) found that the conduct of monetary policy can be well-explained by movements in the federal funds rate to deviations in inflation from the target rate and deviations in real output growth from potential output growth during the period 1987-1992.

Taylor (1993) developed a model in which the interest rate can be systematically determined by observing the output gaps and inflation gaps in order to diminish the fluctuations in aggregate economic activities. Kerr and King (1996) showed that optimal interest rate policy can be determined with reference to output gaps and inflation forecasts without reference to monetary aggregates. This trend of vanishing money in the formation of monetary policy has been in central bank practice. Nowadays most central banks do not pursue a strategy of monetary targeting. For instance, the U.S. Federal Reserve de-emphasised the role of money in the early 1990s.

In standard New Keynesian models, money has a role in different sequences for the policy rate, which leads to different paths for inflation and output. However, money has no role in future output and inflation which are conditional on interest rates (Ireland, 2004). Woodford (2003) argued that the equilibrium paths of output and inflation can be explained without reference to money. Most New Keynesian approaches ignored the role of money in the conduct of monetary policy and constructed the short-run dynamic model as transmitted through interest rates.

There are several features of a New Keynesian model (Kydland and Prescott,1982). First, it is a dynamic, stochastic, general equilibrium model. Economic agents are aware of this and behave accordingly. Uncertainty exists as some processes in the economy react to exogenous shocks. Second, it is monopolistic competition. Prices are determined by private economic agents to maximize their objectives. Third, there are nominal rigidities. There are constraints for some firms on the frequency with which they can adjust goods and services' prices. Firms may pay some costs of adjusting those prices. Prices are sticky as firms only change prices after a random interval of time. Fourth, there is non-neutrality of monetary policy in the short-run. Because of nominal rigidities, changes in short-term nominal interest rates are not along with one-for–one changes in expected inflation, which lead to variations in real interest rates. The latter causes changes in real quantities. However, in the long run, all wages and prices adjust themselves and the economy returns to its natural equilibrium.

The basic New Keynesian model is plified to a system of three equations (Goodhart, 2007). The central banks set the interest rate and supply any amount of money demanded by the market at a given interest rate. Hence shifts in money demand are perfectly fitted so that money has no effect on variables such as output and prices. In other words, in a traditional money demand equation, money does not play an important role. The standard New-Keynesian model is based on three equations.

The first equation is a dynamic IS equation linking the evolution of aggregate demand and the output gap to the nominal interest rate. Through this equation monetary policy can have an impact on aggregate spending in the economy:

$$\tilde{y} = y_t - y_t^n = f\left(E\tilde{y}, i - E\pi\right) + e_t^d \tag{2.3}$$

where $\tilde{y}$ is the output gap which is the deviation of actual output y_t from the natural or sustainable level of output y_t^n, i is the short-term nominal interest rate and the central bank's instrument, $E\tilde{y}$ is the expectations of output gap and e_t^d is the exogenous disturbances. This is from the Euler equation for consumption of a representative household.

The second equation is the New Keynesian Phillips curve relating inflation to the output gap. This is an aggregate supply equation which relates the current inflation to expected inflation and the output gap (the difference between actual output and potential output):

$$\pi_t = f\left(E\pi, \tilde{y}\right) + e_t^s \qquad (2.4)$$

where π_t is the inflation rate between period $t-1$ and t, $E\pi$ is the expectations of inflation conditional on information available at time t and e_t^s is the error term. This equation comes from the optimal pricing decision by monopolistically competitive firms with sticky prices.

The third equation is a monetary-policy rule for setting the nominal interest rate, which is the Taylor type reaction function. The short-term interest rates are set by policy makers to minimise fluctuations in output:

$$i_t = b_1\pi_t + b_2\tilde{y} + e_t^p \qquad (2.5)$$

where $b_1 > 1$, $b_2 \geq 0$, and e_t^p is the monetary policy shock. This Taylor rule comes from the optimal reaction function of a monetary authority with a quadratic loss function in output gap and inflation.

In order to derive equations (2.4) and (2.5), Woodford (2003) assumed that monetary frictions are negligible or a cashless limit environment is provided in this framework so that the levels of output and inflation are independent of the real money balances in the model.

This three-equation-model which monetary authorities use today, determines inflation and output without regard to the money.

Through equations (2.3) to (2.5), the demand for money function, the following conventional LM equation can be obtained:

$$m_t = f\left(y, i, \pi\right) + e_t^m \qquad (2.6)$$

where m_t is the money balances, and e_t^m is another error term which can affect an aggregate demand equation. This error term is from the combination of government consumptions and preference shocks which affect the dynamic IS equation. The money demand is determined via equation (2.6) meaning that the central bank prints money up to the point that satisfies this demand. In this case, the money stock is a dependent and endogenous variable and if this demand money function fits perfectly, then you can obtain all the information from output, inflation and interest rates and you do not need to know the movement of money. Money supply is a passive endogenous variable which follows the interest rate. Money itself is a unit of account in this model and the central bank prints the exact amount of money to meet the interest rates.

Several pieces of empirical research [12] are also in general agreement with this limited role for money in predicting output. Rudebusch and Svensson (2002) used a small structural model of the U.S. data and concluded that nominal money does not affect output and inflation. Ireland (2004) demonstrated a micro-founded model where the impact of real money balances appears in the Phillips curve and IS curve. Then he estimated the model using a maximum likelihood model with the US quarterly data and showed that the real money balances do not have a significant role in the aggregate demand and the aggregate supply. Meyer (2001) proposed that money plays no role in either the macro model, or the conduct of monetary policy.

[12] Estrella and Mishkin (1997), Gerlach and Svensson (2003).

2.3.6 The Recent Issues

The New Keynesian model has been an issue in that it fails to explain common trends in inflation and money growth. Lucas (2007) was concerned about the disappearance of money in monetary policy and argued for a cross-check in policy formulation.

"New-Keynesian models define monetary policy in terms of a choice of money market rate and so make direct contact with central banking practice. Money supply measures play no role in the estimation, testing or policy simulation of these models. A role for money in the long run is sometimes verbally acknowledged, but the models themselves are formulated in terms of deviations from trends that are themselves determined somewhere off stage. It seems likely that these models could be reformulated to give a unified account of trends, including trends in monetary aggregates, and deviations about trend but so far they have not been. This remains an unresolved issue on the frontier of macroeconomic theory. Until it is resolved, monetary information should continue to be used as a kind of add-on or cross-check." (Lucas, 2007, p. 168)

There are several studies which raise the issue of the possibility that money may have a crucial role for output and prices. Nelson (2003) argued that money can be an important cross-check for economic and financial indicators of inflationary pressures. For instance, in the standard New Keynesian model, the output gap can be measured imperfectly by identifying the inflationary pressure since the sustainable output is not directly observable. Hence money supply growth may be informative to the extent of its role as a medium of exchange. Leeper and Zha (2001) concluded that vanishing money in the monetary policy is not empirically innocuous using a vector autoregression (VAR) analysis. Leeper and Roush (2003) also concluded that allowing the policy controlled interest rate to respond to money improves the identification of monetary policy shocks and helps to solve the liquidity and price puzzles.

In addition, Reynard (2006) discovered a proportional relationship between inflation and money growth using the U.S. and euro-area data when considering the equilibrium velocity movements because of inflation regime changes. Favara and Giordani (2009) estimated the effects of shocks on monetary aggregates employing VAR which can be identified by restrictions with regard to New Keynesian monetary models. They found out that shocks to monetary aggregates have a substantial and persistent impact on prices and output. Moreover, there is a unit relationship between money growth and inflation at low frequencies in Europe, U.K., the U.S. and Japan (Assenmancher-Wesche and Gerlach, 2007). Castelnuovo (2008) demonstrated that a money demand shock has a significantly positive impact on output using VAR-based impulse responses. Bhattarai (2008) found that a 1% increase in money growth leads to a 0.6% increase in output growth.

2.3.7 Limitations of Existing Studies

Inflation targeting does not reference money. There are several reasons why vanishing money may induce distortions in the interpretation of the role of money.

In terms of the standard New Keynesian model, money has little correlation with inflation and real variables at business cycle frequencies. However, in some countries such as Japan, the correlation between M2 and output since 1980 is 0.10 when cycles of 6 to 24 quarters are considered, but rises up to 0.90 when cycles of 24 to 44 quarters are employed (Canova and Menz, 2009).

The monetary policy through interest rates accommodates the demand-side shocks to desired money holdings. If central banks only assume that all monetary shocks come from demand-side, then the behaviour of the monetary base does not provide any information. However, it is not clear that all shocks to money are only demand-side. In reality, the fluctuation of output or inflation can be due to various shocks from money demand, supply, transient or permanent ones. For instance, one might say that the bulk of money in the form of commercial bank liabilities can perform very differently over a given period of time. A financial innovation can impact on money demand. Financial innovation allows people to use credit cards for a wider range of transactions. Dotsey (1984) demonstrated that increases in credit card use cause decreases in money demand in the U.S. This sudden decrease in money demand, which is caused by driving down the interest rate can affect output.

However, there can be shocks from money supply. If there is a supply shock to money, there are several financial or non-financial factors which are affected. When banks provide more loans to a wider group of households and firms on easier terms, it will feed back into the IS curve. Shifts in the banks' willingness to extend loans will have the effect of shifting the constraints which impact on the economy. Not only bank activities but also non-financial factors such as trade balances or consumption can be affected in response to the money supply shock. In addition, the money stock data may be published earlier. Hence, it can be an early indicator for output, so empirically the money stock can be a crucial indicator for the forecasting of output.

All in all, it is questionable as to whether monetary growth is consistent with the current paths of output, inflation and interests rates. However, at least in some policy makers' minds such as those who are running the Bank of Japan, Federal Reserve and European Central Bank, money supply matters for both inflation fluctuations and output. In addition, Goodhart (2007) also argued that money has considerable explanatory power as an indicator of inflation variation and future output, which contradicts the behaviour of money balances in the standard New Keynesian Model. In the next section, I will examine empirically whether this theoretical prediction is supported by the South Korean data using the VAR approach.

2.4 Methodology, Identification and Data

2.4.1 Methodology and Identification

This methodology section introduces how data can be estimated by recursive and non-recursive VAR methodologies, including explaining its identification and Granger-causality test.

2.4.1.1 VAR

To test whether money supply influences output, prices, and short-term interest rates, a Granger-causality analysis is performed. A simple Granger-causality analysis may not cover simultaneity effects (Granger, 1980). Money supply may Granger-cause output, while output may also Granger-cause money supply. In order to overcome this problem, Granger-causality in a Vector Autoregressive Model is performed. VAR is a vector version of the AR model. It can also include two or more variables into one vector as it is a vector equation. A $p-th$ order vector autoregressive model, can be shown as:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \dots + A_p Y_{t-p} + \Phi D_t + e_t \tag{2.7}$$

where $Y_t = \left[y_{1t}, \dots, y_{kt} \right]'$ is a set of variables in a $(k \times 1)$ vector, A_j is a $k \times k$ matrix of autoregressive coefficients for $j = 1, 2, 3, \dots, p$, and Φ is a $k \times d$ matrix of coefficients on deterministic terms in a $d \times 1$ vector D_1. The vector $e_t \equiv \left[e_t, ..., e_{kt}\right]'$ is from a k-dimensional white noise process.

$E\left[e_t\right] = 0, E\left[e_t e_t'\right] = \Omega$ and $E\left[e_t e_t'\right] = 0$ for $s \neq t$, with Ω a $(k \times k)$ symmetric positive definite matrix.

This implies that there is no serial correlation among these disturbances but contemporaneous correlation is allowed.

Harvey (1990) mentioned that if the order p is set, each equation in the model can be estimated by ordinary least squares (OLS), which estimations are consistent and asymptotically efficient. In other words, based on the sample $Y_1, Y_2, ..., Y_T$, and setting the first p observations $Y_{1-p}, Y_{2-p}, ..., Y_0$, the k equation of the VAR can be performed separately by OLS. With regard to the assumption that the ε_t are Gaussian white noise, the simple OLS estimator is the same as the full information maximum likelihood (FIML) estimator (Hamilton, 1994). Hence the OLS estimator of $A \equiv \left[A_1, ..., A_p\right]$ is asymptotically normally distributed.

VAR provides a number of advantages compared with univariate time series models or estimation of a structural model (Brook, 2008). First, the forecasts created by VAR often provide better information than traditional structural models. As Sims (1980) argued, large scale structural models can lead to misguided results owing to their out-of–sample forecast accuracy. Second, VAR is more flexible than univariate AR models as it allows more variables with not only own lags but also with combinations of white noise terms. Third, there is no need to distinguish which variables are endogenous or exogenous.

In comparison to other model classes, VAR model also has several drawbacks and limitations. One of the major drawbacks is that there are so many parameters. If there are n variables and each variable contains k lags in each equation, $\left(n+kn^2\right)$ parameters should be examined. For instance, if $n=4$ and $k=3$ there will be 52 parameters to estimate. For a relatively small sample size, degrees of freedom will rapidly be chewed up. Sometime, there are several parameters which rarely differ from zero. Arranging any lag lengths is not reasonable as it can harm the estimates and may lead to a misleading outcome concerning causality if variables have different lag structures (Ahking and Miller, 1985). To overcome this limitation, Hsiao (1981) suggested that Akaike's (1969) Final Prediction Error (FPE) criterion can help to estimate a univariate AR and sequentially adding lags and variables. However, there are two disadvantages to the FPE-criterion approach [13]. An alternative approach to selecting the appropriate VAR lag length can be an information criterion which does not require such normality assumptions concerning the distribution of errors.

The Granger-causality in general does not provide the information regarding the sign of the overall effect or how long these effects require to take place. Hence, as links between the equations distort interpretation of each coefficient, Sims (1980) suggested estimating a VAR model by analysing the reactions from different shocks over time in the system - such information will be provided by examinations of the VAR's impulse responses and variance decompositions.

Impulse Reponses trace out the responsiveness of the dependent variables in the VAR to shock to the error terms. So unit shock is applied to the error for each variable from each question and its effects on the VAR system over the allocated period are noted. For example if there are 3 variables in a system, a total of 9 impulse responses could be created. The way

[13] See Strum *et.al.* (1999).

that this is performed in practice is by converting the VAR in to a Vector Moving Average (VMA). If the condition of the system is stable, the shock should gradually die away.

In order to transform the original VAR into a model, the SVAR approach suggests you should start from the structural form model. Equation (2.7) can be written as:

$$K(L)Y_t = \varepsilon_t$$

$$K(L) = \varepsilon K + \sum_{i=1}^{k} A_i L^i \tag{2.8}$$

where K is an $n \times n$ non singular matrix.

The contemporaneous relations can be directly explained in K. The Cholesky factorization of the matrix Ω is used, which generates an orthogolanised reduced form for our error terms e. The lower triangular Cholesky matrix, K, imposes on restrictions such that orthogonal innovations to variable of vector Y_t, only based on the previous member of the vector:

$$K_i = -K\Gamma_i$$

$$Ke_t = \varepsilon_t$$

$$E\left(Ke_t e_t' K'\right) = K\Sigma K' = E\left(K\varepsilon_t \varepsilon_t' K'\right) = I \tag{2.9}$$

where Σ is s symmetric matrix.

This orthogonalisation of the variables helps us to observe the effect that an increase in one of the variables has on other variables in the system individually. For the statistical reliability, impulse responses along with a 95% confidence interval is employed, which is based on asymptotic Gaussian Approximations of the distribution of the responses.

However, for computing impulse responses and variance decompositions, the order of the variable is crucial as the error terms are likely to be correlated across the equation. Hence, the notion of observing the effect of the shocks separately leads to a misrepresentation of the system dynamics. Its solution to this difficulty is to orthogonalise the innovations based on economic theory. It is also of no consequence that the higher the magnitude of the correlation coefficient between error terms, the more the variable ordering will be important. In case the residuals are almost uncorrelated, the ordering of the variables is immaterial (Lutkepohl, 1991).

2.4.2 Data Description

The following empirical analysis in this chapter employs quarterly data from South Korea, covering the period from 1981:01 to 2012:04 for the benchmark model [14] and from 1986:01 to 2012:4 for the extended models [15]. The choice of the start year, 1981 and 1986 is due to the data availability. Based on the theoretical implications, the following time series data has been utilised in the test as summarised in Table 2.5.

All variables except interest rates, exchange rates, inflation and prices indices are in real terms [16] and the variables are log transformed.

[14] The benchmark model includes output, prices, the short-term interest rate, the monetary base and commodity prices.

[15] The extended model is the bench mark model plus financial variables or non-financial variables. Financial variables are banking lending, exchange rates, long-term interest rates and stock prices. Non-financial variables are exports, imports, investment, and government consumption.

[16] Nominal per capita GDP at $GDP1981 \times \frac{P2005}{P1981}$.

Table 2.5 Description of Variables and Data Sources

Variable	Data	Data Source	Symbol
Money Supply	M0, M1 and M2	Bank of Korea	*M*
Output	Gross Domestic Output	IMF International financial Statistics	*Y*
Prices	GDP Deflator & Consumer Price Index	IMF International financial Statistics	*P*
Short-term Interest Rates	3 Moths Interest Rates	Datastream	*R*
Commodity Prices	Korean Commodity Index	Datastream	*CP*
Bank Lending	Loans of CBs and SBs	Bank of Korea	*BL*
Exchange Rates	US Dollar to Korean Won	OECD	*ER*
Lon-term Interest Rates	10-year Bond Yield	IMF International Financial Statistics	*LR*
Stock Prices	KOSPI	Reuters	*SP*
Export	Exports of Goods & Services	Bank of Korea	*EP*
Import	Imports of Goods & Services	Bank of Korea	*IP*
Investment	Gross Fixed Capital Formation	IMF International Financial Statistics	*IV*
Government Spending	Government Final Consumption Expenditure	Datastream	*GP*

Note: Money supply is denoted by M_0, M_1, and M_2. M_0 is the monetary base, M_1 includes M_0 plus demand deposits and M_2 includes M_1 plus short-term time deposits in banks and 24-hour money market funds.

As Nelson and Plosser (1982) stated, most macroeconomic data show the stochastic trends, which can be lead to a spurious regression. Hence before running any regression, a stationarity test is necessary to distinguish between stationary series and non-stationary series. I adopt the Augmented Dickey Fuller Test (ADF).

Table 2.6 Unit Root Test: Augmented Dickey Fuller Test

Variable	Symbol	Lag	t-statistics	Prob
Money Supply	$M0$	4	-1.767177	0.3952
	$M1$	2	-3.314579	0.0163**
	$M2$	4	-2.949631	0.0432**
Output	Y	0	-4.083240	0.0015***
Prices	P	4	-2.637487	0.0883*
Short-term Interest Rates	R	1	-1.598376	0.4804
Commodity Prices	CP	2	0.378990	0.9813
Bank Lending	BL	6	-0.676611	0.8470
Exchange Rates	ER	1	-2.484604	0.1221
Lon-term Interest Rates	LR	0	0.129796	0.9666
Stock Prices	SP	0	-2.542147	0.1085
Export	EP	0	-9.348593	0.0000***
Import	IP	0	-1.177608	0.6821
Investment	IV	0	-2.450446	-2.450446
Government Spending	GC	0	-3.576824	0.0078***

Note: */**/*** indicate the 10%/5%/1% significance level.

For instance, the null hypothesis for testing a unit root test is $H_0 : y_t \sim I(1)$, and alternative hypotheses under each testing approach is $H_1 : y_t \sim I(0)$. $I(1)$ indicates that y_t is integrated of order one which has a unit root and $I(0)$ shows that y_t is stationary. Using test statistics and a p-value the existence of the unit root can be examined. While monetary base data is non-stationary, M1 and M2 data series are stationary at the 5 % significance level. Output and prices are stationary at the 1 % and 10 % significance level respectively. Excluding export and government spending, all variables are non-stationary meaning that they have a unit root. Johansen's maximum likelihood method test for co-integration relationship is conducted among non-stationary data. Co-integration defines that a two or more times series is co-integrated if they have the same common stochastic drift. In other words, it is to exist between non-stationary time series if they possess the same order of integration and a linear combination of these series is stationary. Both the trace statistics and maximal eigenvalue statistics unanimously confirm that there is no co-integrating relationship at the 5% significant. Non-stationary variables are in first difference in the model.

2.5 Results

In this section, I have explored the effects of a money supply shock on the dynamics of output, prices, the short-term interest rate and commodity prices using recursive VAR, non-recursive VAR and Granger-causality test in South Korea. Moreover, I have provided new empirical evidence on the transmission mechanism by adding financial variables (banking lending, exchange rates, long-term interest rates and stock prices) or non-financial variables (exports, imports, investment, and government consumption) into the benchmark model.

2.5.1 Basic Identification Scheme

In order to examine whether money is relevant for output and inflation determination, the benchmark model includes output, prices, the short-term interest rate, the monetary base and commodity prices. This is a preliminary evaluation of the impact of a shock to the monetary base on the macroeconomic (output and prices) and financial variables (the short term interest rate and commodity prices).

2.5.1.1 Two Structures: Recursive VAR and Non-Recursive VAR

Two types of the VAR model are examined to assess the effect of money. The first specification is based on a recursive identification scheme and the second one follows a non-recursive VAR scheme. The lag value of each model is set equal to four [17]. When variables are non-stationary and have unit roots, they should be examined in first differences to tackle the potential problem of the non-standard distribution taken by the F-test (Sims *et al.*, 1990). In the absence of co-integration among some non-stationary variables[18], stationary VAR models with the log-differenced series are estimated. In the equation (2.7), stacking the variables at each date into the 5×1 vector:

$$X_t = [Y_t, P_t, R_t, M_t, CP_t]' \tag{2.10}$$

where Y_t is output, P_t is prices, R_t is the short-term interests, M_t is the monetary base and CP_t is commodity prices. As Sims (1992) mentioned, a different selection of ordering leads to different recursive structures of VAR. He argued that the earlier listed variable in the VAR impacts the later listed variables, whilst the opposite has no effect. Hence the solution to this problem involves ordering exogenous variables first and endogenous variables thereafter. I shall order contemporaneously exogenous variables first so that output and prices are assumed to be contemporaneously exogenous to the monetary policy instruments, the short-term interest rate and monetary base. The commodity prices are regarded as an information variable which responds instantly to all of the shocks so that it is ordered last. [19] This ordering implies that the central bank sets the policy instrument, but the output and prices only respond to a policy change with one lag. For instance, owing to adjustment costs, firms

[17] The lag order ρ is selected by the Akaike information criterion (AIC) and the Schwarz information criterion (SIC).

[18] Please see Table 2.6 for the information of non-stationary variables.

[19] Christiano *et al*. (1996) also use the commodity price index as it is a leading indicator for inflation.

within the quarter do not change their prices and output in response to a monetary policy shock. In the recursive model, money is set after the interest rate as the identification imposes that money shocks have no effect on any other variable other than money itself and commodity price. The implications from equations (2.2) to (2.6) underlie this ordering of variables for VAR analysis. In this VAR model, money has no role. According to the classical or the neo-classical models, money is just numeraire commodity in most of the dynamic general equilibrium models meaning that it does not have any impact on output and employment (Patinkin, 1987). Monetarists, including Friedman (1952), considered the major role of money as to stabilize prices, leaving the role of efficient allocation of resources to the relative price system. In addition, money is endogenous to the Taylor rule in the New Keynesian macroeconomic models. However, in the non-recursive VAR, in order to allow the money supply to enter into the monetary policy rule, I shall identify a short-term interest rate shock and a money supply shock without imposing the restriction that the interest rate does not respond to monetary base within the period. In contrast to inflation targeting, the behaviour of monetary aggregates is considered to be relevant for the analysis of optimal monetary policy.

The recursive VAR can be shown based on the following Cholesky decomposition:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{bmatrix} \begin{bmatrix} u_t^Y \\ u_t^P \\ u_t^R \\ u_t^M \\ u_t^{CP} \end{bmatrix} = \begin{bmatrix} e_t^Y \\ e_t^P \\ e_t^R \\ e_t^M \\ e_t^{CP} \end{bmatrix} \tag{2.11}$$

where a demonstrates the contemporaneous relations among 5 variables (output Y, prices P, interest rates R, money supply M and commodity prices CP). u_t is the mutually correlated structural shocks and e_t is the corresponding vector of reduced-form residuals. The structural shocks are defined by the standard Cholesky decomposition. Cholesky decomposition orthogonalise the disturbances and thereby obtain structurally interpretable impulse response functions. Sims (1980)'s approach uses a Cholesky decomposition of the variance covariance matrix of the model's shocks. This enables the moving average representation to be performed based on orthogonalised innovation. Cholesky's decompositions are much faster and accurate than the eigenvector or eigenvalue decomposition, which is about a factor of 10 faster (Gonnet and Scholl, 2009). u_t can be identified from the estimates of e_t , and the variance/covariance matrix Σ (Enders,2009,p.294). This ordering reflects the central bank's reaction function.

The third row in (2.11) can be written as the vector of equation from (2.8):

$$a_{31}u_t^Y + a_{32}u_t^P + u_t^R = e_t^R \tag{2.12}$$

This states that unexpected movements in interest rates e_t^R within a quarter can be due to one of three factors: the response to structural shocks to output, captured by $a_{31}u_t^Y$, and the response to structural shocks to prices captured by $a_{32}u_t^P$, and to structural shocks to interest rates, captured by u_t^R . In other words, the forecast error of interest rates is affected by its own structural innovation and the structural variables in output and prices.

And the fourth row in (2.11) is:

$$a_{41}u_t^Y + a_{42}u_t^P + a_{43}u_t^R + u_t^M = e_t^M \tag{2.13}$$

It reflects that monetary base responds to output, prices and the interest rate. But since the money is ordered in a fourth row of the system, a money shock has no effect on any other variable except the commodity prices within the period. This is because the interest rate is set by the central bank based on the current innovations to output and prices and the money supply accommodates this. This ordering takes into account the role of money in the New Keynesian model.

In the first model identification scheme, the short-term interest rate does not react to the monetary base within the period. However, it can be incorrect since Leeper and Zha (2001) suggest that the interest rate which responds contemporaneously to money reflects a better identification of a monetary policy shock than the one which just reflects output and inflation. In order to overcome this issue, a non-recursive VAR scheme can be adopted since it allows more general contemporaneous interactions among variables than the recursive VAR model. The structural VAR approach is based on Sim(1980)s' approach but identifies the impulse responses by imposing restrictions on the covariance matrix of the structural shocks. Bernanke (1986) and Blanchard and Watson (1986) developed this approach by imposing a set of prior restrictions on the contemporaneous effects of shocks. Compared to the unrestricted VAR approach, this non-recursive VAR attempts to provide some economic theory or rational behind the covariance restrictions used, and thus intends to avoid the use of arbitrary identifying restrictions (Garratt *et al*., 1998). Timing assumptions about the interaction between money and interest rates can be used for the formulation of a non-recursive VAR, which are easy to implement. In the recursive VAR model, a variable affects the other within the period but not the other way around. However, the non-recursive VAR enables us to develop our interest in mutual interaction within the period. Therefore, so as to allow the money supply to enter into the monetary policy rule, I shall identify a short-term interest rate shock and a money supply shock without imposing the restriction that the interest rate does not respond to monetary base within the period. This non-recursive VAR model helps us to observe a monetary policy shock imposing the systematic feedback between the main macroeconomic variables and monetary policy variables. For this purpose, I have closely followed Favara and Giordani (2009)'s non-recursive scheme so that the non-recursive VAR (Model 2) is as follows:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & a_{34} & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{bmatrix} \begin{bmatrix} u_t^Y \\ u_t^P \\ u_t^R \\ u_t^M \\ u_t^{CP} \end{bmatrix} = \begin{bmatrix} e_t^Y \\ e_t^P \\ e_t^R \\ e_t^M \\ e_t^{CP} \end{bmatrix} \quad (2.14)$$

The first two rows in (2.14) show unexpected movements in interest rates e_t^R within a quarter indicating the sluggish real sector. Output and Prices are assumed to be contemporaneously exogenous to other variables. They respond to interest rates and money supply and commodity prices with a lag. The third row represents the monetary policy and this can be written as the vector of equations from (2.8):

$$a_{31}u_t^Y + a_{32}u_t^P + u_t^R + a_{34}u_t^M = e_t^R \quad (2.15)$$

Compared to equation (2.12), $a_{34}u_t^M$ can be affected by structural shocks to money captured by $a_{32}u_t^M$. In this monetary policy rule, the central bank tries to adjust the interest rate in response to changes in money supply. The fourth row in (2.14) shows that the monetary base reacts contemporaneously to output, prices and the short-term interest rate.

Figure 2.4 displays the estimated impulse responses to an unexpected interest rate shock (Figure 2.4.A) and money supply shock (Figure 2.4.B) in a recursive VAR. Figure 2.5 is from a non-recursive VAR as the matrix (2.14) is not diagonal. Figure 2.4.A represents the impulse response functions of one standard deviation shock to the money supply in the system. Using the software programme EViews, standard error bands which are dashed red lines are constructed to represent the statistical significance of the impulse response functions. The solid lines display the point estimates of impulse response functions, and the dotted lines are two-standard-error bands over 20 quarters which are computed by the Monte Carlo simulation. The impulse response function is statistically significant at the 95 % confidence level when both standard error bands are simultaneously above or below zero on the y-axis.

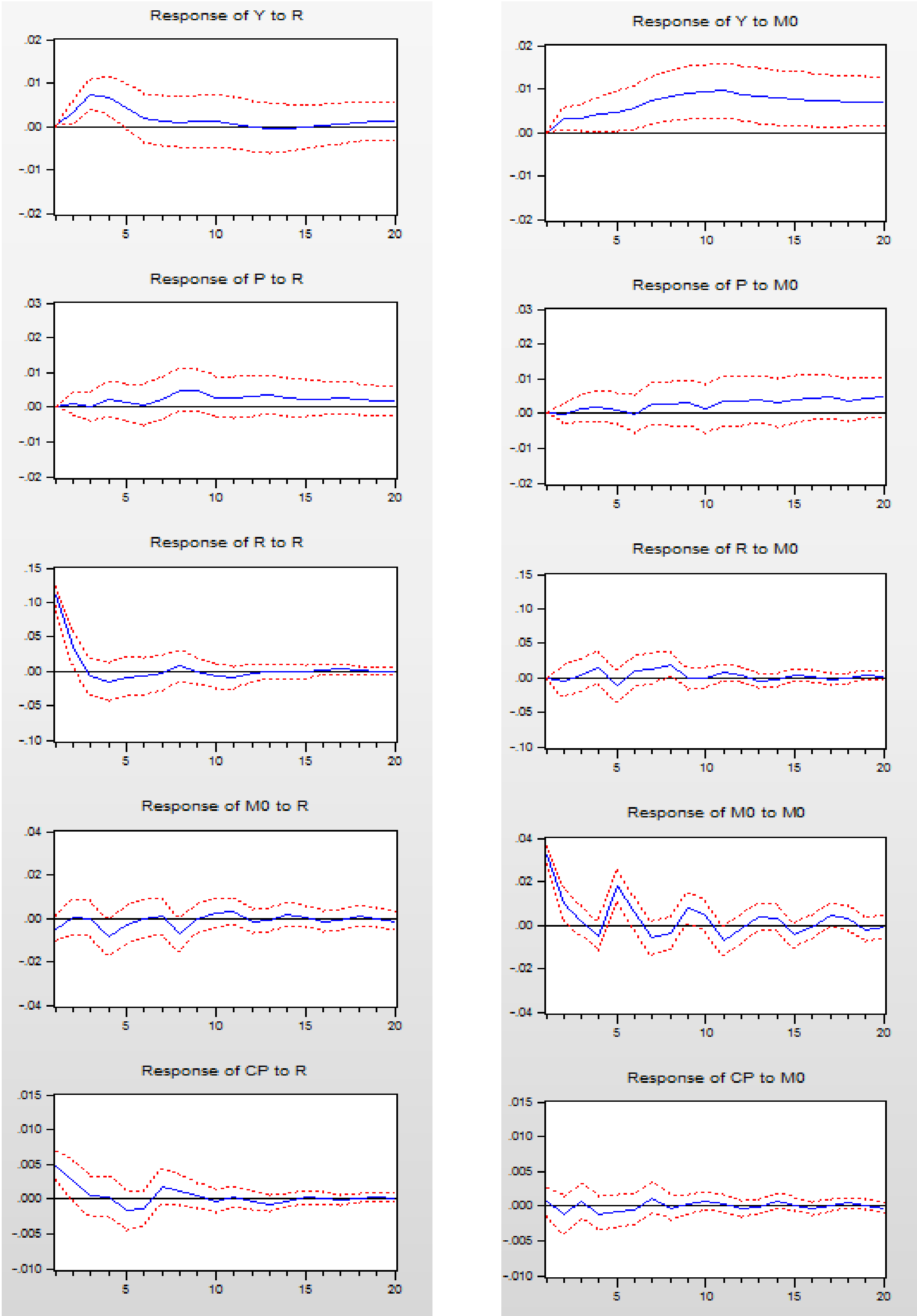
Contrary to the New Keynesian model, the response of output by money supply is significantly different from zero from 6 quarters. In Figure 2.4.B, one standard deviation in monetary base is followed by an increase in the real GDP. The effect on output steadily increases over time after 6 quarters and reached 0.01% at 10 quarters.

In other words, a 1% rise in money supply stimulates output by 0.01% after 10 quarters. This can confirm that output adjustment is sluggish. This result is in line with the research of Leeper and Zha (2001) that the economy responds to a money shock gradually. It is also interesting to note that the positive effect on real GDP of a money shock appears to be very persistent. This result would seem to suggest that the money supply is a potentially useful instrument in output growth. Prices also respond positively to a money supply shock but the results are insignificant.

In Figure 2.4.A, the positive interest rate shock increases the output for up to 5 quarters and the results are insignificant afterwards. Firstly output is increased by 0.008% at 3 quarters and goes back to 0. A response of prices to the interest rate shock is positive but insignificant. The impulse responses of Model 2.5.B, a non-recursive VAR, are similar to those of an identified recursive VAR except the responses of the short-term interest rate which are only significant between 1 quarter and 4 quarters.

Figure 2.4 Impulse Response to Short-term Interest Rates and Monetary Base: Recursive VAR

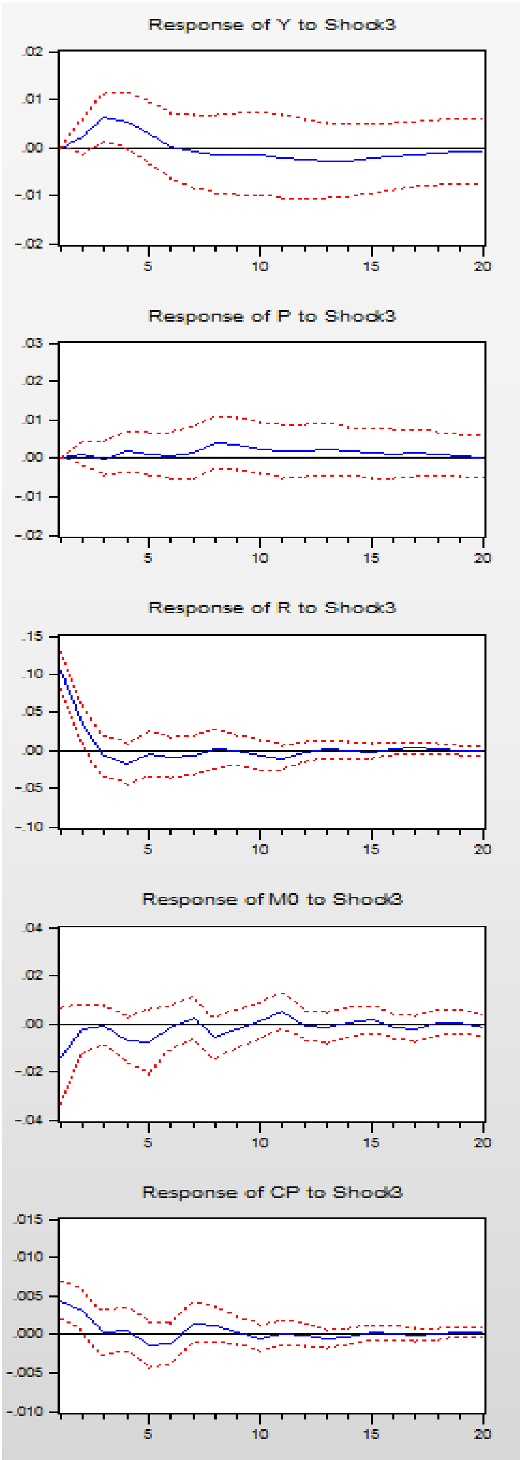
(2.4.A : Shock to R) (2.4.B : Shock to $M0$)



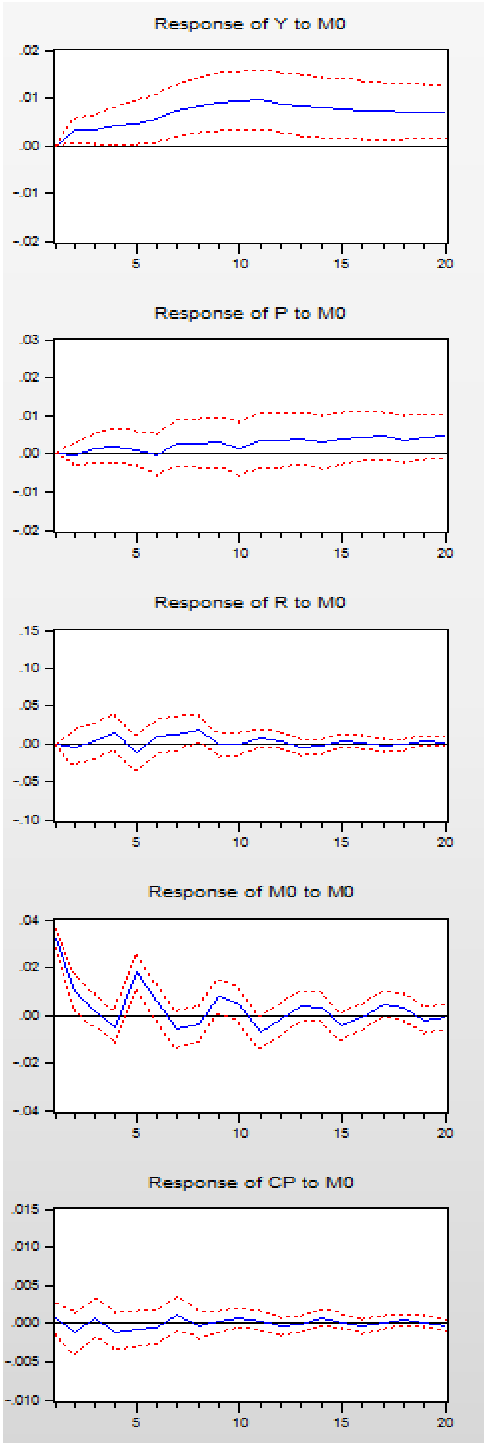
Note: The boxes in each column demonstrate the responses of the VAR variables to a one standard deviation shock to the interest rate R and the monetary base $M0$ yielded by the recursive VAR. The 95% error bands were computed with Monte Carlo simulations. The lag value of each model is set equal to four.

Figure 2.5 Impulse Response to Short-term Interest Rates and Monetary Base: Non-Recursive

(2.5.A : Shock to R)



(2.5.B : Shock to $M0$)



Note: The boxes in each column demonstrate the responses of the VAR variables to a one standard deviation shock to to the interest rate R and the monetary base yielded $M0$ by the non-recursive VAR. The 95% error bands were computed with Monte Carlo simulations. The lag value of each model is set equal to four.

It is interesting to observe the positive relationship between interest rates and output in the short term. This finding does not provide a straight forward explanation. However, it could reflect Tobin's effect that works via inflation. Mundell (1963) explained that an increase in the money growth leads to an increase in the nominal interest rate and velocity of money. According to the Mundell-Tobin effect (1965), the nominal interest rates will rise when there is higher inflation. It refers to the idea that higher inflation reduces the demand for money and attracts people to interest-bearing assets. In other words, because of inflation, the public would hold a greater amount of other assets instead of money balances so that the nominal interest rates rise less than one for one with inflation. The Tobin effect also explains that an increase in inflation also leads to an increase in the capital stock and economic growth. The results clearly show that the monetary base plays a crucial role in output.

Next, the variance decomposition is estimated for output in the VAR over a period of twenty years. That is the proportion of forecast error variance of output owing to its own, or others, to one standard deviation shock. By 6 quarters, the impact of interest rates on output is larger than the impact of money supply on output in the recursive VAR while the impact of money supply on output is larger than the impact of interest rates on output in the non-recursive VAR. The contribution of unexpected shocks to money supply gradually increases over time. The decomposition of output in Table 2.7 shows that after three years since the occurrence of the impulse, around 32 % of the change is explained by the impulses of the monetary base and around 8% by the impulses of the interest rates. Therefore, the long-term variance of the output is one third explained by the change of monetary base. In other words, the money supply significantly impacts on the movement of output.

This table seems to suggest that output variation is explained similarly by M0 in both recursive and non-recursive VARs. It is worth looking at a comparison of recursive and non-recursive settings in Variance Decomposition. Up to 12 quarters, money explains more of the output variation in the non-recursive VAR. It can be interpreted that when the central bank tries to adjust the interest rate in response to changes in money supply, money has a greater role in terms of output variation than when the central bank does not reflect the movement of money in the formation of its policy.

Table 2.7 Variance Decomposition: Output

Period	Variance Decomposition of			
	Recursive VAR		Non-Recursive VAR	
	R	$M0$	R	$M0$
2	3.884497	3.732637	0.701131	6.129974
4	18.27643	6.075982	7.999957	14.34085
6	15.20380	10.17692	5.775090	17.15999
8	11.44415	18.09979	6.037812	22.84069
10	9.445715	26.36550	7.042246	28.92972
12	8.121190	32.56080	7.700568	32.64677
14	7.321463	36.25228	7.736360	34.87874
16	6.718379	38.83456	7.451057	37.02627
18	6.255727	40.46729	7.125096	38.60727
20	5.893597	41.55867	6.855562	39.82988

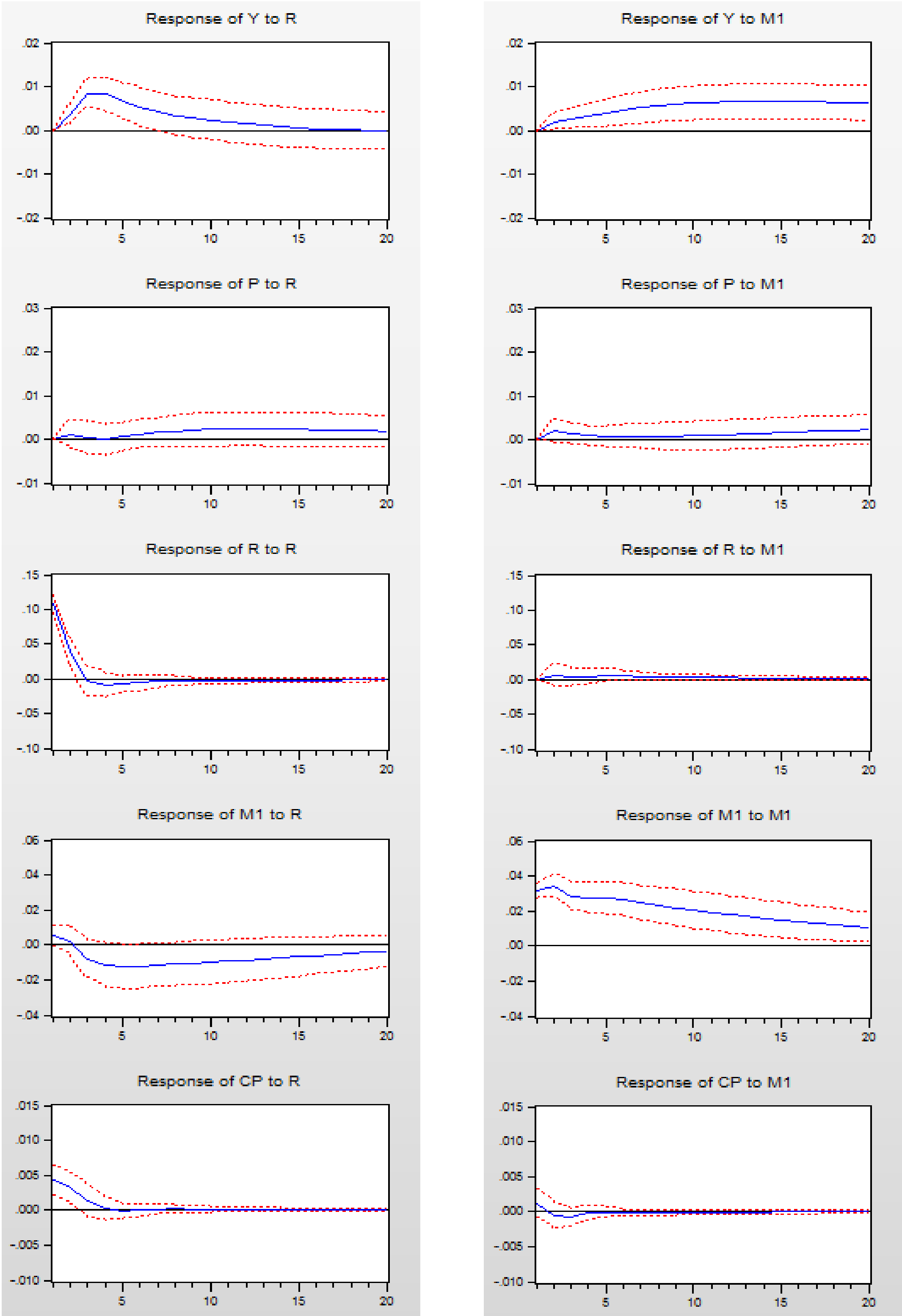
Note: A short-term interest rate is denoted by R and Money supply is M_0

2.5.1.1.1 Robustness : Alternative Variable Specifications

The results have been checked for robustness to replace some variables with alternative ones such as M1 and M2. In Figure 2.6, I use M1 rather than M0 and in Figure 2.7, I replace M2. The lag value of each model is set equal to two and six in Figures 2.6 and 2.7. In Figure, 2.6, a money supply shock, M1 has a positive impact on output and a shock to interest rate also has a positive effect on output. Compared to monetary base shock, the response of output to M1 reacts immediately and gradually increases.

Figure 2.6 Impulse Response to M1

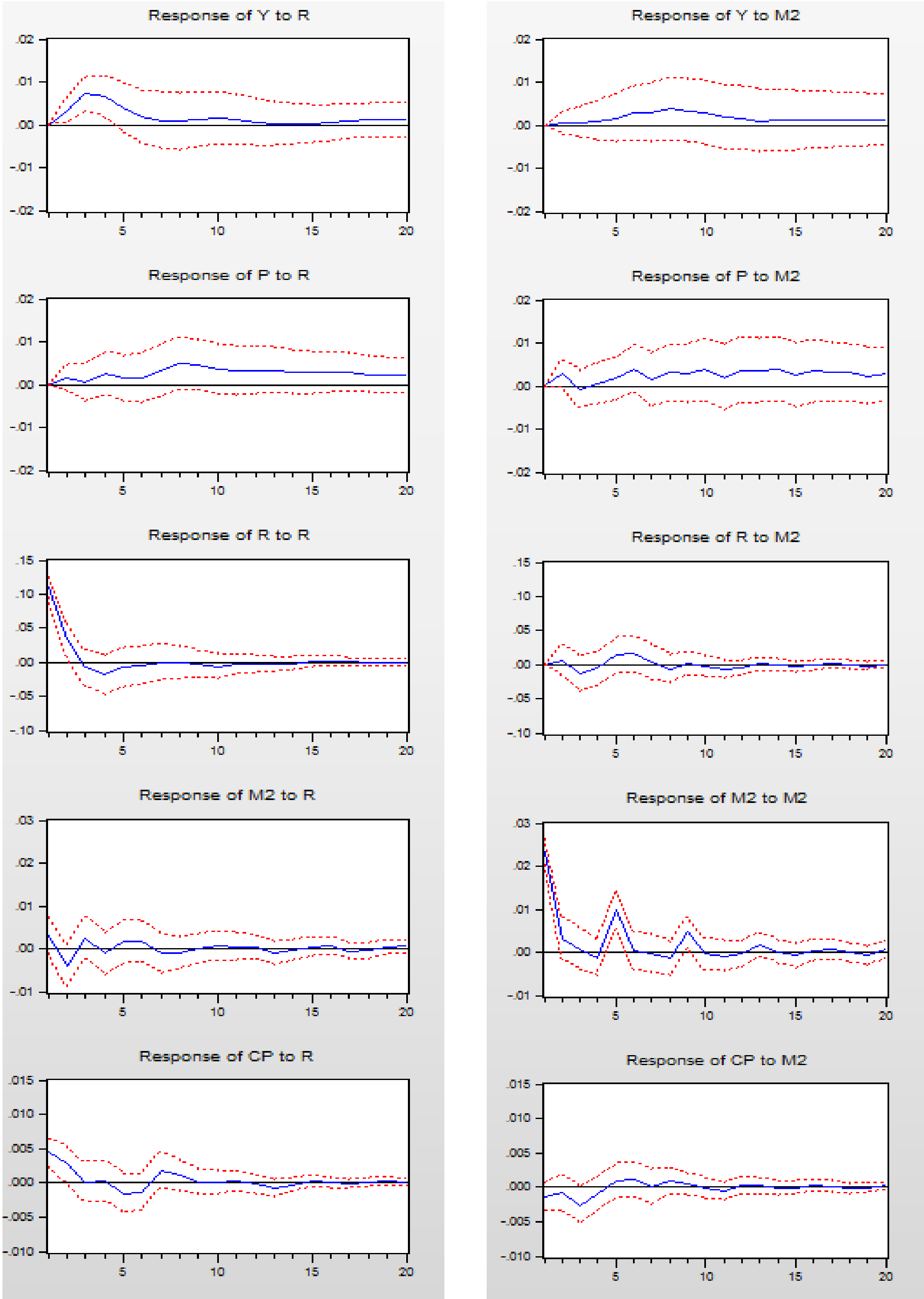
(2.6.A : Shock to R)　　　　　　(2.6.B : Shock to $M1$)



Note: The boxes in each column demonstrate the responses of the VAR variables to a one standard deviation shock to the interest rate R and the monetary base $M1$ yielded by the recursive VAR. The 95% error bands were computed with Monte Carlo simulations. The lag value of each model is set equal to two.

Figure 2.7 Impulse Response to M2

(2.7.A : Shock to R)　　　　(2.7.B : Shock to $M2$)



Note: The boxes in each column demonstrate the responses of the VAR variables to a one standard deviation shock to the interest rate R and the monetary base $M2$ yielded by the recursive VAR. The 95% error bands were computed with Monte Carlo simulations. The lag value of each model is set equal to six.

A 1% rise in M1 stimulates output by 0.007% at 10 quarters while 1% in M0 stimulates output by 0.01%. However, if we use M1, a broader monetary aggregate than M0, the result is more significantly different from 0 over the period. In most cases, the responses of all variables to M1 are similar to ones to M0. In Figure 2.6, the responses of the outputs to a M2 shock are positive but are insignificant which means that the choice of a monetary aggregate is crucial for the results.

The effect of the supply of broad money is not larger than the effect of money base. The responses of all variables to M0 are more significant than M1 and M2. It may be due to the degree of the development in the financial system in South Korea. The supply of broad money in a financially developed economy is determined by transactions between the non-bank private sector and the banking sector. For instance, paying out dividends will create money and the issuance of banking long-term debt or equity will reduce money since asset managers buy the instruments from their deposits. As the financial system in South Korea was not developed as much as in other developed countries until the late 2000s, results using monetary base should be given more credit. In addition, Cheng and Lai (1997) found that government spending Granger-cause money supply. This implies that, in the process of the national economic development programme, printing money financed productive public investments. In other words, money seems to play an independent role for output dynamics. However, the relationship between money supply and prices is ambiguous.

2.5.2 Extended System

In the previous section, I estimated a 5-variable-VAR model to observe the effect of money supply and discovered that there is a positive response of output to the money shock. However, it is uncertain how, within this money approach, monetary policy impulses are transmitted to the output level. This can also raise the question of the transmission mechanism through which the money supply affects the output. This section examines various views on the transmission mechanism, and discusses the resulting money supply. The finding in this section will offer a perspective that will help us better understand how money affects key financial and non-financial variables such as bank lending and government consumption. For instance, this offers a useful insight into how money supply works, by allowing us to trace out the money supply transmission mechanism from the initial increase in financial sector money holdings to the impact on output. In order to find out the transmission mechanism, I estimate several 6-variable-VAR models, each of which includes one of the financial market variables (banking lending, exchange rates, long-term interest rates and stock prices) and non-financial variables (exports, imports, investment, and government consumption) into the benchmark model.

2.5.2.1 Financial Variables

One of the primary purposes of the Bank of Korea (BOK) is the pursuit of financial stability. Following the revision of the BOK Act in 2011, financial stability has become more important when conducting its monetary policy. The central bank needs to pay attention to the key services which the financial markets provide to the real economy. For instance, financial stability matters because the payment system was preserved during the Asian financial crisis but only at a massive cost to the taxpayer in South Korea. In addition, Willem (2007) stated in his FT blog that central banks should play a key role in financial market.

"Liquidity is a public good. It can be managed privately (by hoarding inherently liquid assets), but it would be socially inefficient for private banks and other financial institutions to hold liquid assets on their balance sheets in amounts sufficient to tide them over when

markets become disorderly. They are meant to intermediate short maturity liabilities into long maturity assets and (normally) liquid liabilities into illiquid assets. Since central banks can create unquestioned liquidity at the drop of a hat, in any amount and at zero cost, they should be the liquidity providers of last resort both as lender of last resort and as market maker of last resort..." (Willem, 2007)

Therefore, I observe how money supply works through the transmission mechanism in the financial sector, which leads to an impact on output.

In the equation (2.7), stacking the variables at each date into the 6×1 vector:

$$X_t = [Y_t, P_t, R_t, M_t, CP_t, F_t]' \tag{2.16}$$

F_t is the financial variable. This will be the bank lending BL, Index of stock prices SP, Long-term interest rates (the yield on 10 year) government bonds LR, and the exchange rate ER. I add them one-by-one to the benchmark model. The recursive VAR will be as follow:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 \end{bmatrix} \begin{bmatrix} u_t^Y \\ u_t^P \\ u_t^R \\ u_t^M \\ u_t^{CP} \\ u_t^F \end{bmatrix} = \begin{bmatrix} e_t^Y \\ e_t^P \\ e_t^R \\ e_t^M \\ e_t^{CP} \\ e_t^F \end{bmatrix} \tag{2.17}$$

where a demonstrates the contemporaneous relations among 6 variables (output Y, prices P, interest rates R, money supply M, commodity prices CP and financial variable F) [20].

The additional variable in the benchmark model is ordered after the money supply variable. It reflects the fact demonstrates there is a contemporaneous effect of money supply on each

[20] The comparison of structural shocks is in Appendix 2.A.

financial variable while the money supply does not respond contemporaneously to it. The non-recursive VAR forms as:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & a_{34} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 \end{bmatrix} \begin{bmatrix} u_t^Y \\ u_t^P \\ u_t^R \\ u_t^M \\ u_t^{CP} \\ u_t^F \end{bmatrix} = \begin{bmatrix} e_t^Y \\ e_t^P \\ e_t^R \\ e_t^M \\ e_t^{CP} \\ e_t^F \end{bmatrix} \tag{2.18}$$

I identify a short-term interest rate shock and a money supply shock without imposing the restriction that the interest rate does not respond to monetary base within the given period. All the financial variables react immediately to changes in all the other variables. The interest rate responds contemporaneously to money. Money supply will be not changed in response to financial markets at the same period. The comparison of structural shocks of variables is in Appendix 2.A.

Our bench mark results regarding output remains mostly unaffected and similar conclusions are produced if each financial variable is included in the VAR. In these 6-variable-VAR models the results in non-recursive VAR are similar to ones in recursive VAR. A money supply shock still leads to a positive response of output. I now examine how financial variables which are potentially useful predictors of inflation and output respond to a money supply shock.

(1) Bank Lending

As shown in the first column of Figure 2.8, a money supply shock to banking lending increases by 0.02 % by 7 quarters in South Korea. This may have occurred due to the money view, by which the central bank controls the quantity of money by manipulating banks' reserves. In other words, when the monetary base increases through the easy supply of money, the central bank generates new bank reserves[21], this will allow the banks to lend more to the public. Therefore, businesses and households, who depend on bank lending, increase their purchasing of durable goods and purchases of capital for investment so that output is also affected in a positive way.

(2) Exchange Rate

The second column of Figure 2.8 shows the impulse response of nominal exchange rates. The exchange rate rises markedly in response to the money supply shock. The nominal exchange rate immediately depreciates by about 0.02% on money supply's impact and moves back to 0 by the third quarter. When the authority decides to print money or sell bonds, the Korean currency depreciates because the supply of money is higher than its demand. The exchange rate is defined by the relative price of domestic and foreign money, which is based heavily on the domestic and foreign monetary situation. In theory, this result assumes that an unanticipated increase in the money supply will lead to a decrease in the exchange rate and increases in output by enhancing international competitiveness in the short run. The response of output of money in this extended model also demonstrates that there is no appreciable differences compared to the benchmark results.

(3) Long-term Interest Rate

In the third column of Figure 2.8, I report the results of impulse responses concerning the long-term interest rate to a money supply shock. Once again, there are virtually no

[21] These are commercial banks' holdings of deposits at the central bank and currency that are physically held in a strong room, known as a bank vault.

differences in output when compared to the benchmark results. However, a shock to a money supply causes the long term government bond to decrease the rate but it is not significant.

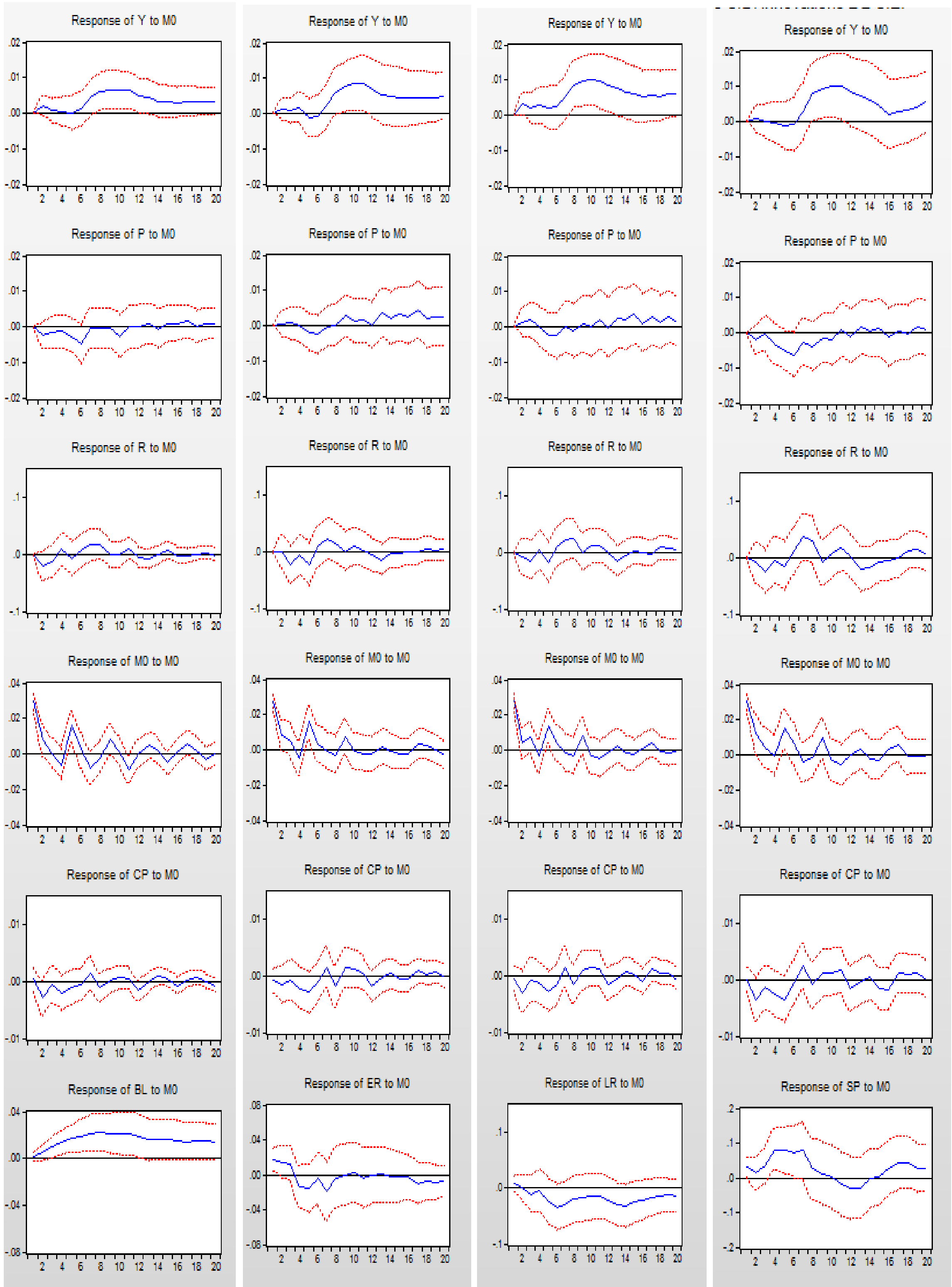
(4) Stock Prices

In the last column of Figure 2.8, a money supply shock increases stock prices by 0.09% by the third quarter and decreases after the seventh quarter. This may be the result of the portfolio-rebalancing effect. This effect comes from the assumption that there are several assets that are not perfect substitutes. For instance, money and short-term securities are imperfect substitutes as the interest rates are different. Then the additional money supply will make investors change their portfolios. This is in line with Honda *et al.* (2007). Additional money from a central bank leads investors to reduce an interest-bearing asset component in their portfolios and invest more on an equity component as well as a foreign asset component. This portfolio rebalancing will lead to an increase in stock prices, which helps to stimulate economic activity.

Next, I conduct the variance decomposition analysis of each financial variable except long term interest rates the results of which are insignificant. The results are reported in Table 2.8. The value indicates the percentage of the variance from 2 to 20 quarters-ahead forecast errors that are accounted for by money shocks. Money shocks account for a considerable part of the volatility of bank lending and stock prices. The forecast error variances of bank lending and stock prices are 27% and 20% of the 20 quarters-ahead respectively. On the other hand, money shocks account for only 5% of the 20 quarters-ahead-forecast error variance in exchange rates.

Figure 2.8 Effects of M0 on Financial Variables : Model 1. Recursive VAR

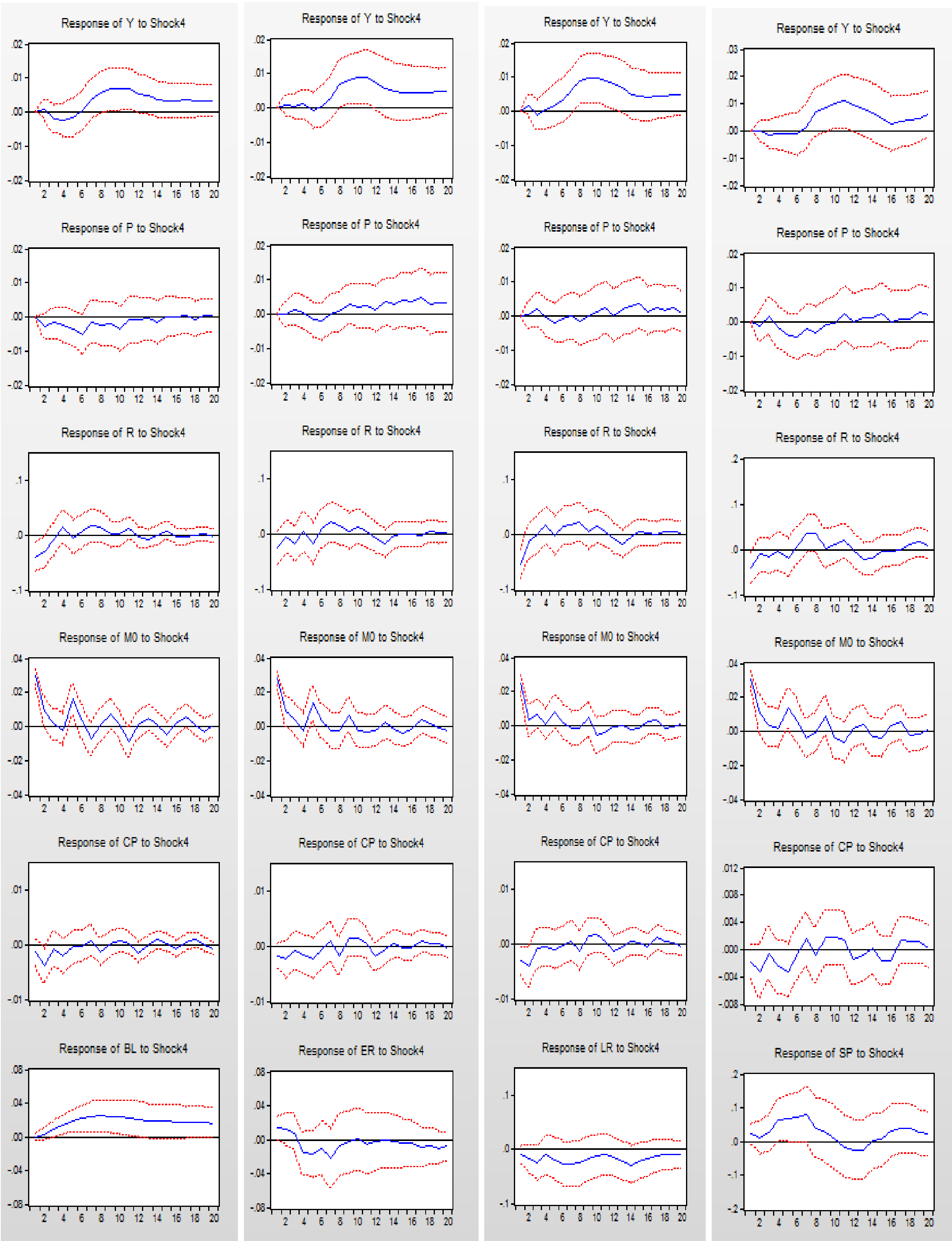
(a: Bank Lending) (b: Exchange Rates) (c:Long-term Interest Rates) (d: Stock Prices)



Note: The boxes in each column demonstrate the responses of the VAR variables to a one standard deviation shock to the monetary base yielded by the recursive VAR (Model 1). The 95% error bands were computed with Monte Carlo simulations. The lag values of each model are set equal to six, eight, eight and nine in figure a,b,c,and d.

Figure 2.9 Effects of M0 on Financial Variables : Model 2. Non-Recursive VAR

(a: Bank Lending) (b: Exchange Rates) (c: Long-term Interest Rates) (d: Stock Prices)



Note: The boxes in each column demonstrate the responses of the VAR variables to a one standard deviation shock to the monetary base yielded by the non-recursive VAR (Model 2). The 95% error bands were computed with Monte Carlo simulations. The lag values of each model are set equal to six, eight, eight and nine in Figure a,b,c,and d.

Table 2.8 Variance Decomposition: Bank Lending, Exchange Rates and Stock prices

Period	Variance Decomposition of BL	
	Recursive VAR	**Non-Recursive VAR**
2	1.588417	0.441342
4	9.085408	8.554121
6	14.70583	16.72056
8	20.25326	24.13070
10	23.09995	28.06512
12	25.31681	30.58749
14	25.79434	31.56055
16	26.28236	32.49410
18	26.55507	33.26358
20	27.02541	34.11643
	Variance Decomposition of ER	
2	6.360224	4.547841
4	7.751407	4.714915
6	7.343016	4.968847
8	7.030101	6.039852
10	7.219749	5.607582
12	5.958335	5.683782
14	6.750441	5.642339
16	6.389318	5.703668
18	6.111671	6.115166
20	5.958446	6.561977
	Variance Decomposition of SP	
2	3.370370	1.810925
4	14.16541	8.842411
6	20.16802	15.84397
8	20.94396	18.44076
10	18.62918	16.70354
12	18.58516	16.48786
14	18.78841	16.63207
16	18.61652	16.56594
18	20.04466	17.56060
20	20.51678	17.78472

Note: Banking lending is denoted by BL, an exchange rate ER is and a stock price index is SP.

Summarising these results, a money supply shock significantly increases bank lending, slightly depreciates the Korean currency (Won), and raises the stock prices in the short-term, three of which would stimulate the economy. In other words, the money supply does play an important role in the transmission mechanism through the bank-lending channel, the exchange rate channel and the stock market.

2.5.2.2 Non-Financial Variables

Injecting money into the economy may affect the spending and investment behaviour of individuals, firms and government. For instance, when interest rates increase, it encourages people to save more, rather than to spend more. Changes in the amount of money in the economy affect the demand for goods and services. Therefore, we observe how money supply works through the transmission mechanism in the non-financial sector, where it has an impact on output.

Next I assess the dynamic response of each non-financial variable to a money supply shock. equation (2.7) as rewritten as below:

$$X_t = [Y_t, P_t, R_t, M_t, CP_t, NF_t]' \tag{2.19}$$

NF_t is the non-financial variable. This will be the exports, imports, investment and government consumption. I add them one-by-one to the benchmark model. The recursive VAR is as follow:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 \end{bmatrix} \begin{bmatrix} u_t^Y \\ u_t^P \\ u_t^R \\ u_t^M \\ u_t^{CP} \\ u_t^{NF} \end{bmatrix} = \begin{bmatrix} e_t^Y \\ e_t^P \\ e_t^R \\ e_t^M \\ e_t^{CP} \\ e_t^{NF} \end{bmatrix} \tag{2.20}$$

The structure of non-recursive VAR is same as one with financial variables:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & a_{34} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 \end{bmatrix} \begin{bmatrix} u_t^Y \\ u_t^P \\ u_t^R \\ u_t^M \\ u_t^{CP} \\ u_t^{NF} \end{bmatrix} = \begin{bmatrix} e_t^Y \\ e_t^P \\ e_t^R \\ e_t^M \\ e_t^{CP} \\ e_t^{NF} \end{bmatrix} \tag{2.21}$$

When I include non-financial variables, it does not produce any significant change in the benchmark model. It still shows a positive response of output to a money shock.

The impulse responses in the first columns of the Figure 2.10 suggest that there is an increase immediately and decrease in exports afterwards but the result in exports is not significantly different from zero. In Figure 2.10.b Imports increase up to 0.04 % after a shock to money. In the previous section, a money supply shocks leads to a depreciation in Korean currency (Won). In general, a depreciation in exchange rates makes exports more competitive and imports more expensive. However, as the South Korean economy is heavily dependent on energy imports and other technological component imports, an increase in money leads to a higher spending on foreign products and services for an investment.

(1) Investment

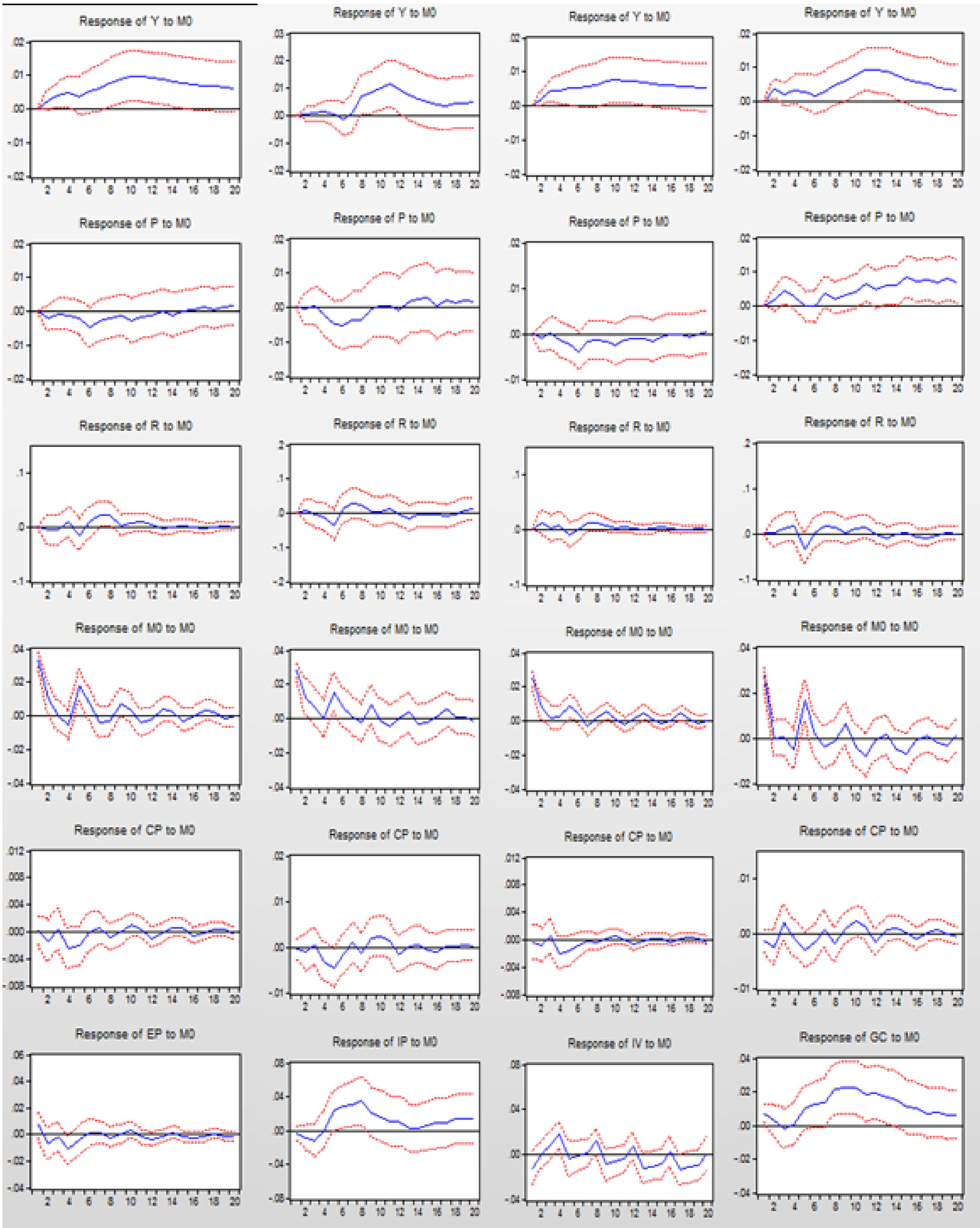
The third column of Figure 2.10 shows the impulse response of investment. The money supply shock increases the investment at 3 quarters. In the bench mark model, the response of nominal interest rates to the money shock is positive. Using the Mundell-Tobin effect, injecting money in the economy raises the short-term interest rate and decreases the real interest rate. The lower real interest rate induces people to borrow more money to finance further spending. In other words, an increase in money leads to an increase in investment since the firms can get funding with a lower cost from financial institutions.

(2) Government Consumption

The last column of Figure 2.10 represents the impulse responses of government consumption. In response to a money supply shock, government consumption is increased. It is because the money supply can increase the inflation tax which is a part of government revenue so that it can help fund government spending. Macroeconomics, particularly the Keynesian school of thought, argues that public spending accelerates economic growth. Hence, government spending is regarded as an exogenous force that changes aggregate output. Landau (1983) and Ghali (1998) illustrate that a positive relationship between government expenditure and economic growth can be found, using either standard regression forms or error-correction regressions. In these 6-variable-VAR models, the results in non-recursive VAR are similar to ones in recursive VAR.Next, I conduct the variance decomposition analysis of each financial variable except exports, the results of which are insignificant. Table 2.9 displays the percentage of the variance from 2 to 20 quarters-ahead of forecasted errors that are accounted for by money shocks.

Figure 2.10 Effects of M0 on Non-Financial Variables: Recursive VAR

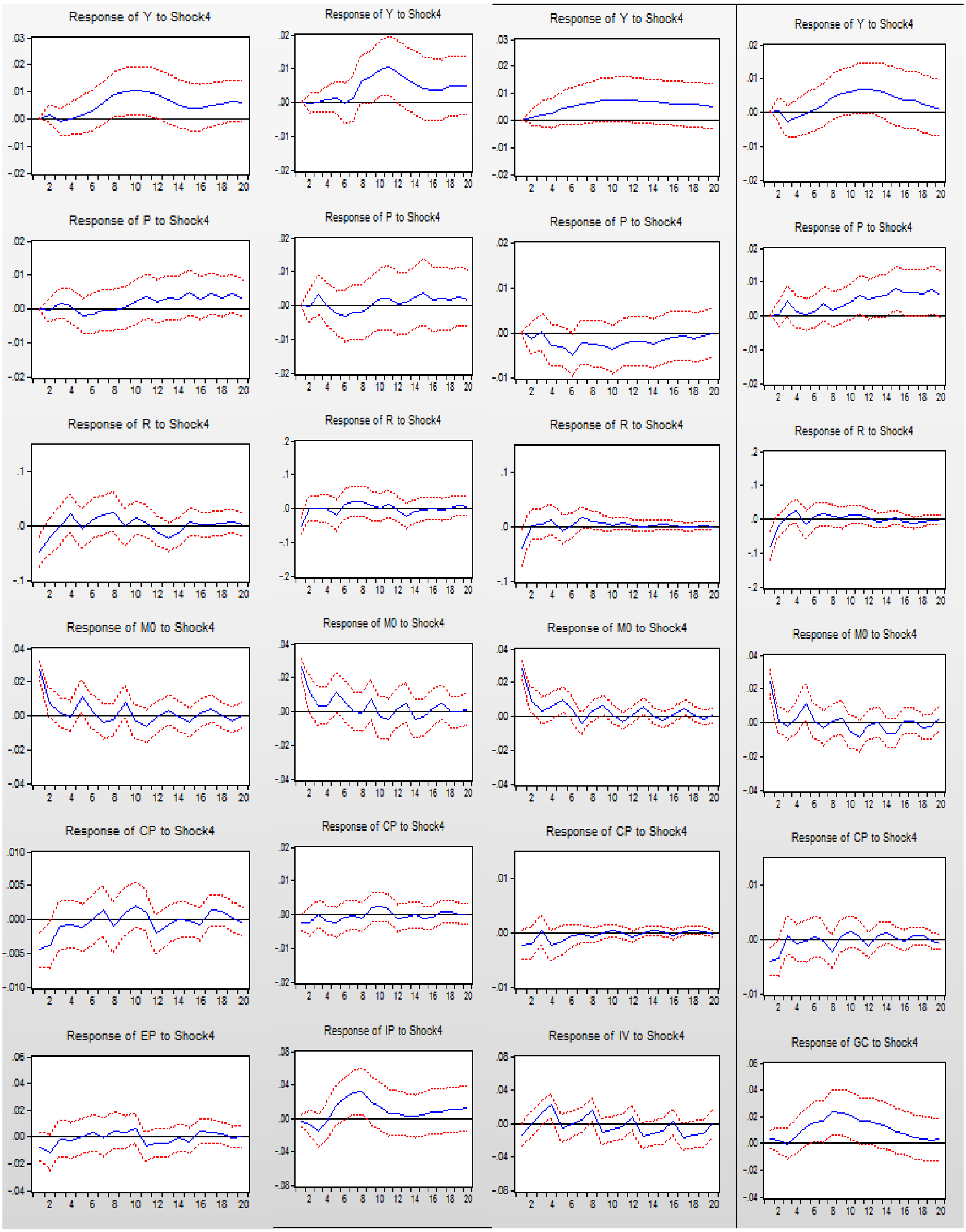
(a: Exports) **(b: Imports)** **(c: Investment)** **(d: Government Consumption)**



Note: The boxes in each column demonstrate the responses of the VAR variables to a one standard deviation shock to the monetary base yielded by the recursive VAR. The 95% error bands were computed with Monte Carlo simulations. The lag values of each model are set equal to five, four, four and five in Figure a,b,c,and d.

Figure 2.11 Effects of M0 on Non-Financial Variables : Non-Recursive VAR

(a: Export) (b: Import) (c: Investment) (d: Government Consumption)



Note: The boxes in each column demonstrate the responses of the VAR variables to a one standard deviation shock to the monetary base yielded by the non-recursive VAR (Model 2). The 95% error bands were computed with Monte Carlo simulations. The lag values of each model are set equal to five, four, four and five in Figure a,b,c,and d.

Table 2.9 Variance Decomposition: Imports, Investments and Government Consumption: M0

Period	Variance Decomposition of IP	
	Recursive VAR	Non-Recursive VAR
2	2.550840	1.437129
4	3.528265	4.404597
6	16.12614	11.14468
8	29.80602	24.74487
10	32.58218	27.01027
12	32.36392	25.92323
14	28.56212	22.87810
16	25.26634	20.21043
18	24.40620	19.28137
20	24.92282	19.39380
	Variance Decomposition of IV	
2	3.879018	3.870832
4	11.65696	13.39913
6	8.221293	9.421206
8	9.278954	11.08571
10	8.934252	10.12937
12	8.781950	9.797655
14	9.835324	10.78245
16	9.790434	10.60439
18	11.03502	11.99504
20	11.10723	12.03657
	Variance Decomposition of GC	
2	2.838357	0.607301
4	1.734725	1.202510
6	6.736839	9.448282
8	15.88419	21.05659
10	27.04334	30.41780
12	32.31120	33.44959
14	35.47811	34.84633
16	35.41596	33.82731
18	34.68915	32.35079
20	34.13294	17.78472

Note: Import is denoted by IP and investment is IV and government consumption is GC .

Money shocks account for a considerable part of the volatility of imports and government consumption. The forecasted error variances of imports and government consumption are 27% and 34% of the 20 quarters-ahead respectively. On the other hand, money shocks account for only 11% of the 20 quarters-ahead-forecast error variance in investment.

All in all, the inclusion of non-financial variables does not affect the overall picture of the benchmark model. A money supply shock impacts on the outputs through exports and imports, government consumption and investment. Even the magnitude of the changes is a bit different; the overall picture provided by the recursive and non-recursive VAR models is indeed similar.

2.5.2.3 Robustness

2.5.2.3.1 Granger/Block-Erogeneity Test

The null hypothesis of the tests is that the money supply does not Granger-cause each variable. For the financial variables, the results are reported in Table 2.10 The null hypothesis that the money supply does not Granger-cause banking lending can be rejected at the 5 % significance level suggesting that there is a Granger-causality from the money supply to banking lending. Money supply does Granger-cause stock price. In addition, the money supply has a statistically significant impact on exchange rates. I observe the bi-directional relationship between money supply and exchange rates. Table 2.11 displays the Granger-causality tests for the non-financial variables. I can find the bi-directional relationship between government consumption and money supply as well as between investment and money supply. Government consumption, imports, and investment Granger-cause money supply. Hence, the results of the Granger-causality test reassure the effect of money supply on financial variables and non-financial variables.

2.5.2.3.2 Alternative Variable Specifications

I employ alternative measures of money as in 2.5.1.1.1. Figure 2.12 shows the results when I replace M1 in the system adding financial variables. Figure 2.13 shows the results when we replace M1 in the system adding non-financial variables. The responses of exchange rates are quite similar to those obtained when narrower aggregates are used. However, the results of banking lending, long-term interest rates and stock prices are not significantly different from zero.

Table 2.10 Granger-causality Test : Financial Variables

Null Hypothesis	*F*	*P*
BL		
Banking Lending does not Granger-cause Money supply	7.232060	0.2999
Money supply does not Granger-cause Banking Lending	13.85276	0.0313**
ER		
Exchange Rates do not Granger-cause Money supply	17.17099	0.0284**
Money supply does not Granger-cause Exchange Rate	18.40896	0.0184**
LR		
Long-term Interest Rates do not Granger-cause Money supply	13.01012	0.1115
Money supply does not Granger-cause Long-term Interest Rate	10.34940	0.2414
SP		
Stock Prices do not Granger-cause Money supply	9.466195	0.3954
Money supply does not Granger-cause Stock Price	15.42191	0.0800*

Notes: One (two, three) stars indicate statistical significance at a level 10% (5%, 1%). F indicates Chi-square and P is probability.

Table 2.11 Granger-causality Test: Non-Financial Variables

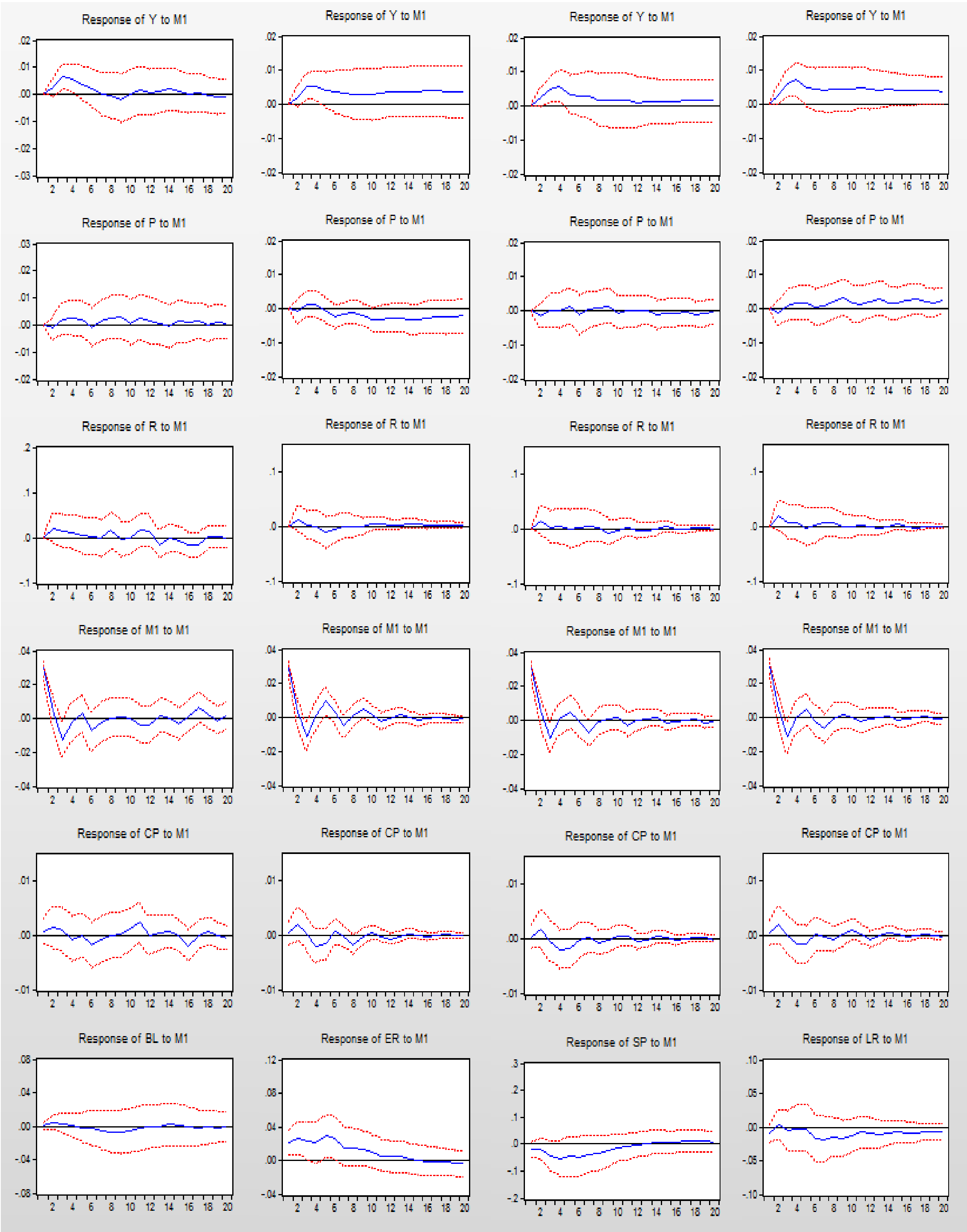
Null Hypothesis	*F*	*P*
	EP	
Exports do not Granger-cause Money supply	11.09695	0.1963
Money supply does not Granger-cause Exports	12.16717	0.1439
	IP	
Imports do not Granger-cause Money supply	16.23908	0.0621*
Money supply does not Granger-cause Imports	27.26426	0.0013***
	IV	
Investment does not Granger-cause Money supply	28.63056	0.0000***
Money supply does not Granger-cause Investment	11.36153	0.0228**
	GC	
Government Consumption does not Granger-cause Money supply	53.08200	0.0000***
Money supply does not Granger-cause Government Consumption	21.23218	0.0034***

Notes: One (two, three) stars indicate statistical significance at a level 10% (5%, 1%). F indicates F-statistics and P is probability.

As shown in Figure 2.13, exports increase immediately and imports sharply decrease and increase after the second quarter but it is not significant. It can be linked to the exchange rates since money supply shock causes the exchange rate depreciation, which helps exports. The investment is also increasing with respect to a money shock.

Figure 2.12 Effects of M1 on Financial Variables: Recursive VAR

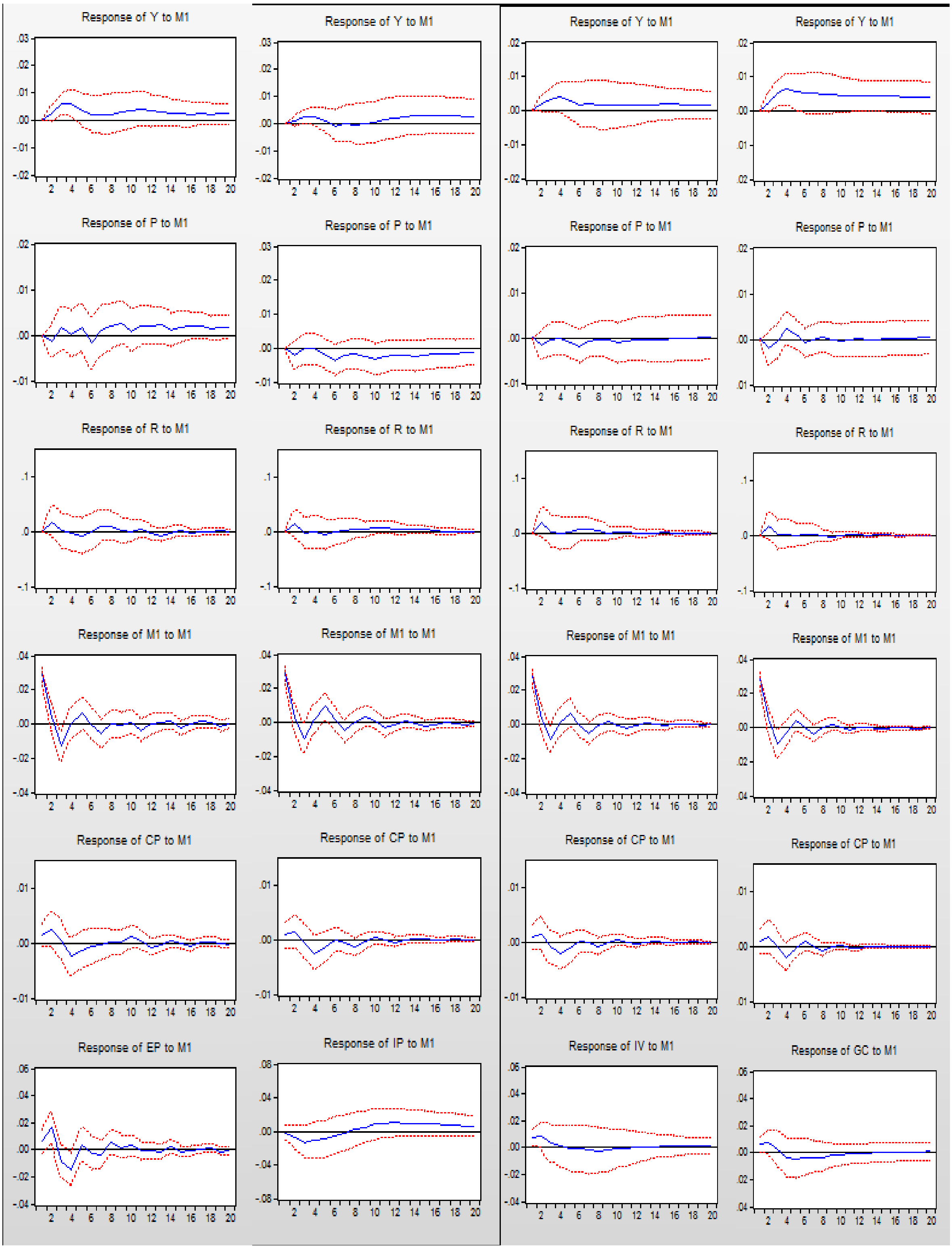
(a: Bank Lending) (b: Exchange Rates) (c:Long-term Interest Rates) (d: Stock Prices)



Note: The boxes in each column demonstrate the responses of the VAR variables to a one standard deviation shock to the monetary base yielded by the recursive VAR (Model 1). The 95% error bands were computed with Monte Carlo simulations. The lag values of each model are set equal to eight, four, five and five in Figure a,b,c,and d.

Figure 2.13 Effects of M1 on Non-Financial Variables: Recursive VAR

(a: Exports) (b: Imports) (c: Investment) (d: Government Consumption)



Note: The boxes in each column demonstrate the responses of the VAR variables to a one standard deviation shock to the monetary base yielded by the recursive VAR (Model 1). The 95% error bands were computed with Monte Carlo simulations. The lag values of each model are set equal to five, six, four and three in Figure a,b,c,and d.

2.6 Conclusion

Many macroeconomists and policy makers have argued whether the injection of money into the economy is effective. New Keynesian models state that monetary policy is set based on a choice of the market rate. In order to test this theoretical prediction, a wide range of empirical tests defining the role of money growth have been conducted. Mainly, I relied on two different VAR approaches, recursive and non-recursive structures, to construct several models of South Korea. This chapter investigated the macroeconomic and financial effects of monetary base shocks in South Korea. In order to observe the role of money, two main empirical tests are conducted: (1) a preliminary assessment about the effect of the money supply shock on output and prices (2) tests to find transmission channels through which a money supply affects the output level.

In the bench mark model, the behaviour of output, prices, commodity prices and short-term interest rates derived from the impulse response functions can be explained by the transmission of a money supply. The results in the benchmark model demonstrated that a positive shock to money leads to a rise in the output. This contradicts the behaviour of money balances in Woodford (2003)'s New Keynesian Model. A clear-cut prediction of new Keynesian models of monetary policy is decisively rejected by this research. However, there is no significant relationship between interest rates and money. Moreover, the response of output to the interest rate shock is positive. Since there is a positive response of output to money supply shock, money should be an important crosscheck in South Korea. This is in line with Nelson (2003) and Leeper and Zha (2001) who examined the role of money in the conduct of monetary policy in the US.

The positive impact of money supply's shock on output in South Korea through various transmission channels can be observed. By introducing further variables in the models, I could check the effects of a monetary base on South Korean macroeconomic development. The findings help policy makers to better understand how money affects key financial and non-financial variables. They should access the accurate timing and effects of their policies so that an understanding of the transmission mechanisms through which monetary policy impacts on the economy can be gained (Mishkin, 1996). In terms of the transmission mechanism, I look at the financial and the non-financial factors. Most results are supported by findings in ECB (2010) and Bank of England (2012). In South Korea, money supply shock has a sportive impact on the aggregate output through bank lending, exchange rates, stock prices, exports, imports, investment and government consumption channels.

The positive money supply shock stimulates real economic activity through banking lending. In the impulse response function analysis, a money supply shock raises bank lending as well as the output level. With the easy money, the central bank increases new bank reserves, which leads to an increase in banking lending. Therefore, firms and households can obtain more funding for their spending and investment. The nominal exchange rates depreciate once there is a money supply shock. In theory, if the monetary authority decides to create more money which leads to a decrease in real interest rates, the home country currency depreciates as the supply of money is higher than its demand. In addition, a money supply shock increases stock prices as a result of the portfolio-rebalancing effect. When the central bank creates more money, investors try to eliminate an interest-bearing asset component in their portfolio and increase an equity component. In terms of the financial transmission, a money shock in South Korea stimulates economic activity through the banking lending, exchange rates and stock market. The shock also impacts on non-financial variables. Even a money shock leads to depreciation in exchange rates, which I expect to stimulate exports. However, the results suggest a negligible role of exports as the results are not significant. It does not react significantly to the money shock indicating limited scope for a monetary base expansion to impact trade. However, when a shock to M1 employed instead of M0, a money shock has a significant impact on exports. I also observe the temporary increase in investment and there is a positive response of government consumption to a money supply shock. The money supply generates inflation tax meaning higher government revenue. The government can make more public investments since a money supply helps fund the spending. Hence, a money supply shock has a positive impact on the aggregate output through government spending.

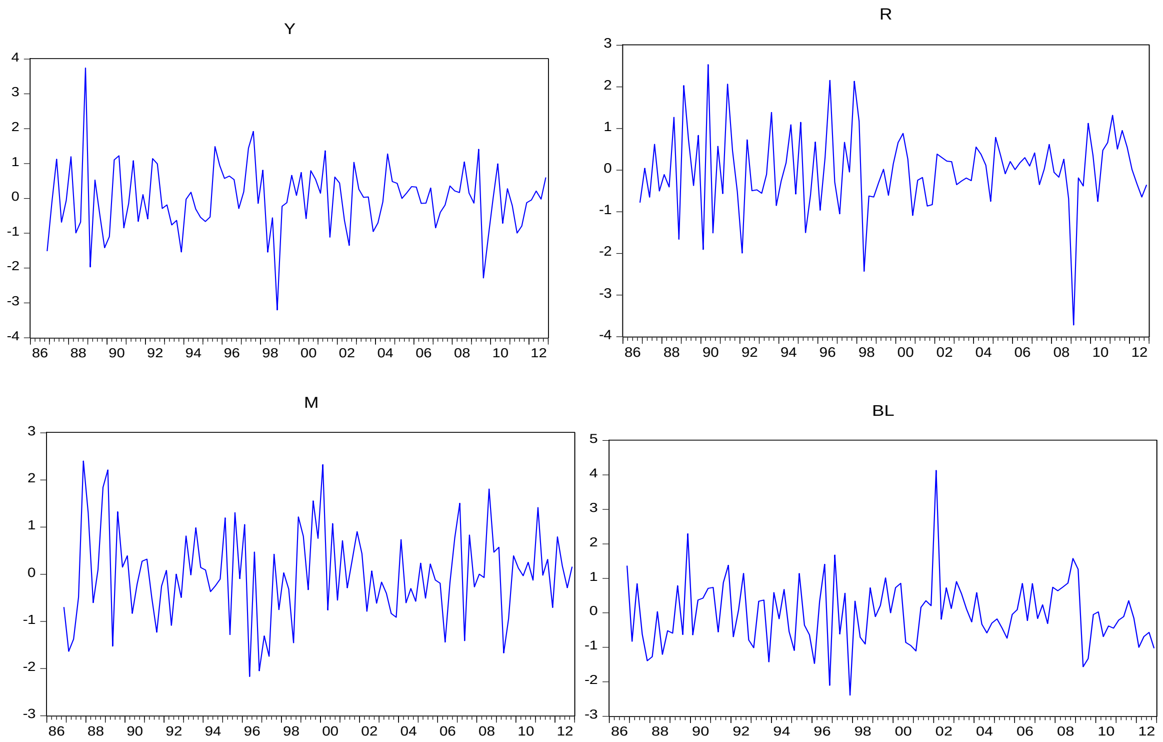
A guiding principle in this chapter has been the use of different tests of the model in order to provide more concrete information on the results. This has led to model examination with the following dimensions: (1) the choice of broad money and (2) different econometric estimation techniques. Using the Granger-causality test, I have also found that evidence of the role of money is robust. In the Granger-causality test, the money supply shock Granger-causes the output, bank lending, exchange rates, stock prices, exports, imports, investment and government consumption. Hence, while the money supply can impact on output in the short run, ignoring money in monetary policy, which central banks generally do today, may be wrong. Our contribution to the current literature also hinges on the finding that the shock to monetary aggregates plays a crucial role in explaining output movements in South Korea. I suggest that the optimal model-based interest rate policy should do a cross-check since monetary aggregates can play a useful role in output level. However, several extensions and applications are left for future research. This chapter does not provide an alternative theoretical framework that could account for this finding. My hope is that further theoretical and empirical research will examine a more detailed assessment of the particular transmission channels following a money supply shock.

Appendix 2

Appendix 2.A Comparison of Structural Shocks

Using restrictions as reported in equation (2.18), structural shocks are retrieved. Four orthogonalised residuals by using Historical Decomposition in EViews are presented in Figure 2.A.1.

Figure 2.A.1 Structural Shocks of Variables



Note: Y=Output, R=Short-term interest rate, M=M0, and BL=Banking Lending.

There were negative structural shocks in output, short-term interest rates, monetary base and bank lending that can be observed in 2009. When Bank of Korea launched Quantitative Easing in late 2010, there was a positive shock in money, negative shocks in interest and a positive shock in bank lending and output. This implies that Quantitative Easing was effective in the short-term as central bank injected money into the economy and lowered interest rate, which boost aggregate demand and output respectively.

Appendix 2.B Commands in EViews

1. Equation (2.14)

Endogenous variable list:

@e1 for Y residuals

@e2 for P residuals

@e3 for R residuals

@e4 for M0 residuals

@e5 for CP residuals

Short-run:

@e1 = C(1)*@u1

@e2 = C(2)*@e1 + C(3)*@u2

@e3 = C(4)*@e1 + C(5)*@e2 + C(6)*@u3+C(7)*@e3

@e4 = C(8)*@e1 + C(9)*@e2 + C(10)*@e3 + C(11)*@u4

@e5 = C(12)*@e1 + C(13)*@e2 + C(14)*@e3 + C(15)*@e4 + C(16)*@u5

2. Equation (2.18)

Endogenous variable list:

@e1 for Y residuals

@e2 for P residuals

@e3 for R residuals

@e4 for M0 residuals

@e5 for CP residuals

@e6 F for residuals

Short-run:

@e1 = C(1)*@u1

@e2 = C(2)*@e1 + C(3)*@u2

@e3 = C(4)*@e1 + C(5)*@e2 + C(6)*@u3+C(7)*@e3

@e4 = C(8)*@e1 + C(9)*@e2 + C(10)*@e3 + C(11)*@u4

@e5 = C(12)*@e1 + C(13)*@e2 + C(14)*@e3 + C(15)*@e4 + C(16)*@u5

@e6 = C(17)*@e1 + C(18)*@e2 + C(19)*@e3 + C(20)*@e4 + C(21)*@e5 + C(22)*@u6

Chapter 3

Money Growth, Seigniorage and Public Education Expenditure:

an Estimated DSGE Model of the US Economy

Abstract

To help explain the effect of money supply growth and seigniorage on output growth, this chapter develops the cash-in-advance and human capital based endogenous growth model. Using the Bayesian maximum likelihood method, I apply the model to the US data and assess the role of money supply shock to the US economy. In the short run, the higher money supply growth causes higher seigniorage. Since the seigniorage revenue is spent productively by the government in areas such as education, a positive money growth has a growth-enhancing effect in spite of an adverse-effect from the inflation tax.

3.1 Introduction

The relationship between money supply and economic growth has been receiving a great deal of attention in the field of monetary economics. Economists differ on the effect of money supply in terms of inflation on economic growth. Shi (1999) explained that the money supply growth leads to higher inflation, which induces households to shift consumption from market goods to leisure. Furthermore, inflation reduces an individual's real money balance so that it causes a negative wealth effect which decreases while capital accumulates. On the other hand, Gillman (2005) presented the view that there is a positive relationship between inflation and growth from a positive Tobin (1965) effect. Although these papers are informative about how inflation caused by the money supply growth impacts on the economic growth, there are few studies which have explored the growth enhancing effects of seigniorage revenue.

Seigniorage is the revenue accruing to government and the central bank from the monopoly which they have on money supply. The profit made by the monetary authority from printing money is the difference between the face value of the money and the cost to produce it. One may think that, if seigniorage revenue is spent productively, it may have some growth-enhancing effects. There is a substantial body of literature documenting the link between public spending and growth. Barro's model (1990) found that public spending on infrastructure financed by income taxation alone has a positive impact on economic growth. Ascharuer (1989) argued that public spending induces excess aggregate demand pressures and stimulates the production. Basu (2001) demonstrated that public infrastructural investment which is financed by seigniorage revenue has a positive externality on the private sector's production. This view holds that not only public infrastructural investment, but also government education spending impacts on economic growth. Since the work of Lucas (1988), human capital accumulation has been seen as an engine for long-run growth, where public education expenditures directly influence human capital accumulation hence affecting long run growth [22].

Hardly any effort has been made in the recent literature to analyse the growth effects of money growth when the government resorts to inflation to finance its growth related public spending. In particularly, research which focuses on public expenditure on education financed by seigniorage is relatively less common.

In order to obtain more evidence on the association between GDP growth and seigniorage [23], the business cycle component of each variable is observed using quarterly US data. The cycle is decomposed into two different bands of frequency, the business cycle frequency with the periodicity of 6 to 32 quarters, and low frequency with the periodicity of 32 to 100 quarters. Two different frequencies are deployed by using the Christiano and Fitzgerald (2003) method of symmetric type band pass frequency filter. The data ranges from the period of 1960:01 to 2007:04 from OECD and U.S. Bureau of Economic Analysis. The choice to end the period of date accumulation in 2007 is made to avoid some possible structural changes in the macro aggregates because of the financial crises, which the stationary log-linearised model will not be able to reproduce.

Figures 3.1 and 3.2 plot GDP growth and seigniorage using a band bass filter with 6 to 32 quarters and low frequency of 32 to 100 quarters respectively. In both Figures, using business cycle frequency and low frequency demonstrate the positive relationship between seigniorage and GDP growth. This is confirmed by conducting the correlation test and values are shown in Table 3.1. The seigniorage-GDP growth correlation coefficients are 0.16 (business cycle frequency) and 0.34 (low frequency) respectively which are statistically significant at the 5% and the 1 % level.

[22] Eckstein and Zilcha (1994), Cassou and Lansing (2001) and Blankeanu (2005).
[23] Seigniorage is computed as the change in the monetary base as a share of real GDP.

Figure 3.1 GDP growth and Seigniorage: Business Cycle Frequency

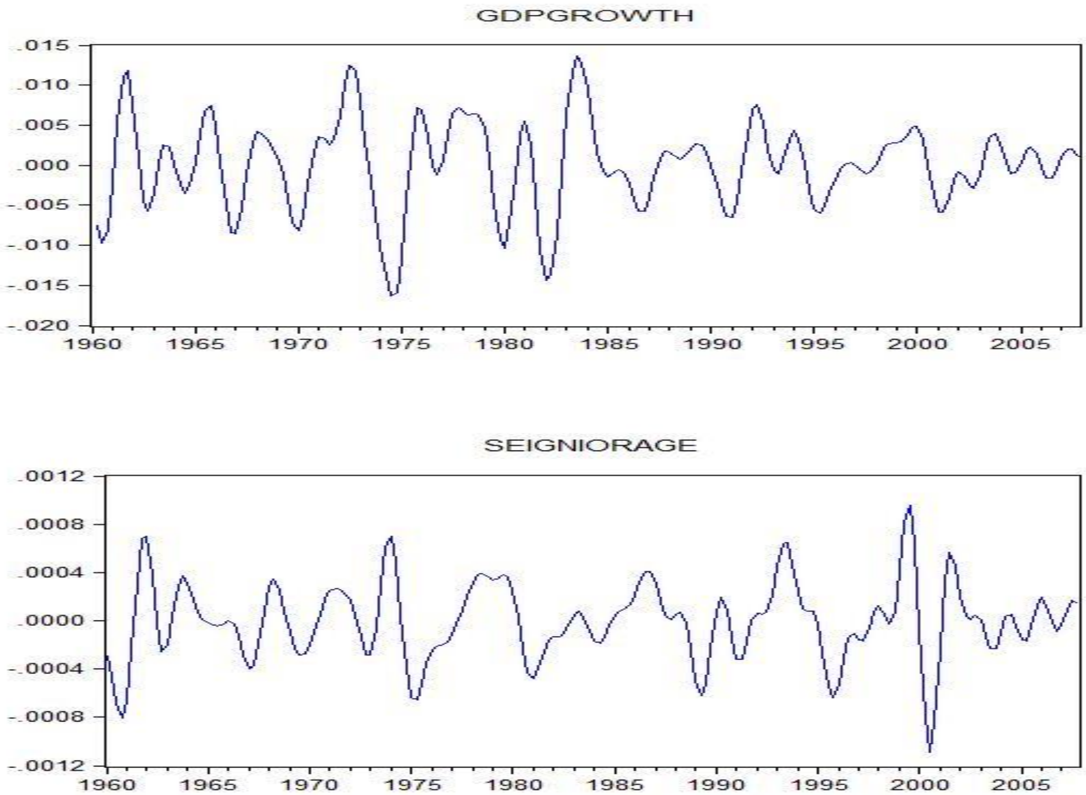


Figure 3.2 GDP growth and Seigniorage: Low Frequency

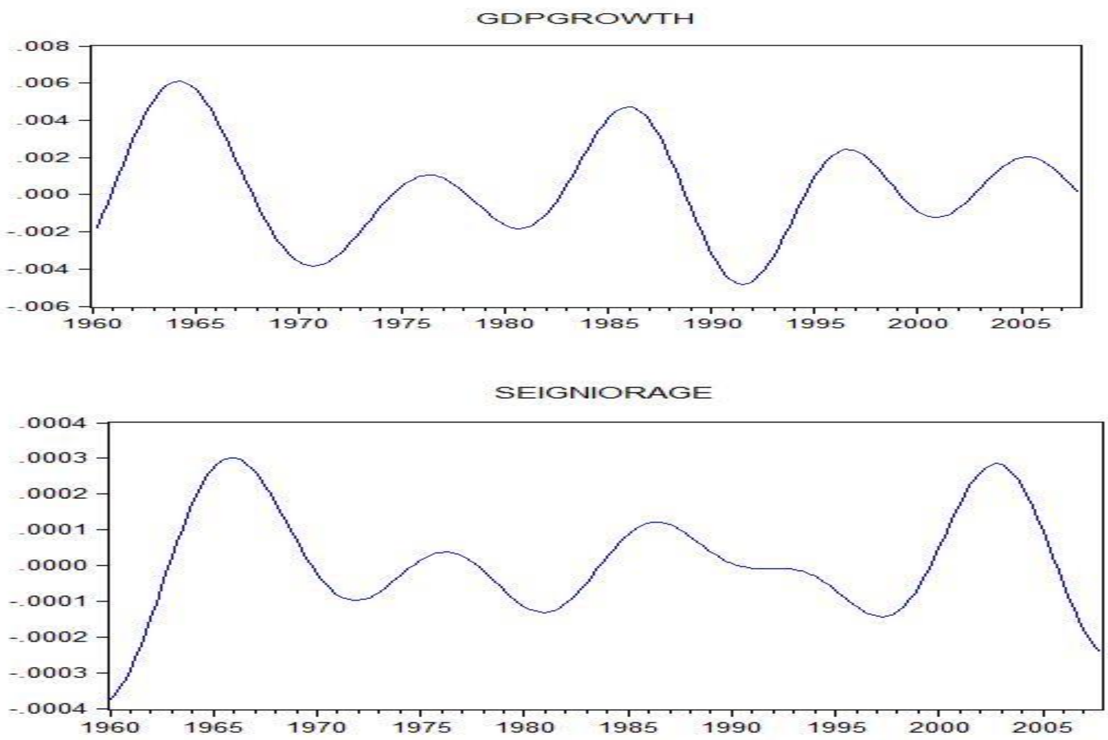


Table 3.1 Correlation between GDP growth and Seigniorage

	Business Cycle Frequency	Low Frequency
GDP growth - Seigniorage	0.162871 (0.0244) **	0.338579 (0.0000) ***

Note: P-values are given in parentheses, */**/*** indicate the 10%/5%/1% significance level. GDP growth is measured as logarithmic first differences. Sample rage: 1960:01 – 2007:04

In addition, I also found out that, using yearly US data, that public spending on education [24] has a positive relationship with GDP growth and seigniorage. The correlation coefficients of public spending on education - GDP growth and public spending on education-seigniorage are 0.0302 and 0.1067 respectively at the 10% significance level.

Given these preliminary findings, the main interest in this chapter is how seigniorage in terms of money supply growth impacts on the output growth. In the next five sections, the chapter addresses the following questions:

(1) What is the relationship between money growth and seigniorage?

(2) What are the effects of money growth on seigniorage and output growth in the short-term?

(3) Will the government spending on public education financed by seigniorage impact on output growth?

(4) Are there any benefits or costs for households from seigniorage?

In this chapter, I hope to contribute to answer these questions by developing a cash-in-advance (hereafter referred to as CIA) model and estimating the money shock to the economy with the US data, using Bayesian techniques.

[24] The data is taken from Table 9-9 of the historical tables provided by White House Office of Management and Budget. It is only available yearly from 1962 to 2012. Public spending on education is conducted as a share of US government consumption and investment.

These are four different questions and each implies a distinct sense in which seigniorage can affect the economy. Hence I describe a model economy that can explain these sorts of questions. The model in this chapter closely follows Basu *et al.* (2012) which discussed a DSGE model with cash-in-advance constraint, using calibrated parameters. Money is introduced into the model using a cash-in-advance constraint. The model in this chapter assumes that households need to hold cash to purchase consumption goods [25]. It features three types of economic agents, namely households, firms, and the government. I also employ human capital investment that endogenises the balanced growth path equilibrium growth rate (Lucas, 1988). The CIA model is employed by considering an economy where the government revenue is collected by printing money and tax income. The revenue is then spent by the government on public education which might enhance the productivity in the human capital. The government uses the seigniorage as a way of financing public spending on education which could positively impact on growth. The human capital stock here rises as each household sector produces more human capital.

The results of some simulations of the baseline model under various assumptions about the behaviour of the monetary growth rate will be presented. I firstly examine theoretically how injections of money, operating through a cash-in-advance constraint and government spending, alter the conclusions derived from the economy. This model is an experimental tool to observe the effect of money growth on macroeconomic variables. I attempt to estimate the effects of money supply on the economy using a likelihood-based Bayesian estimation.

In order to examine the role of money shock in the short run, I follow Smets and Wouters (2003, 2007). This full information approach fits the model in a way which deals with all the variation in the data, and not just the dynamic effects of a money shock. Using Bayesian estimation I also find the posterior distributions of parameters, which are more informative

[25] Leisure and investment in our model are credit goods.

than just point estimates. The US quarterly data from 1960 to 2007 as observable variables is employed. Combining the likelihood function with prior distributions for the parameters of the model, a Bayesian approach helps us to form the posterior density function. Prior knowledge can often be obtained from economic theory or empirical findings in microeconomic studies. A Bayesian estimate can now be a bridge between the calibration method and maximum likelihood estimation in order to obtain the posterior distribution of the structural parameters. This can be obtained through the Monte-Carlo Markov-Chain (MCMC) sample methods.

I find that a monetary DSGE model incorporating a fiscal policy fits the data well and delivers sensible structural parameter estimates. Impulse responses show that a money supply shock has a short-term positive impact on seigniorage and output growth while it has a negative impact on the physical capital to human capital ratio.

This paper contributes to a theoretical explanation of seemingly conflicting seigniorage effects on government spending and consumption, within an economy that is estimated realistically in relation to the US data. If the government spends this seigniorage revenue productively on education, money growth will have a growth-enhancing effect. However, owing to the inflation tax, there is a distortionary effect from money growth on the output growth.

The remainder of the chapter is organised as follows. Section 2 reviews the literature on seigniorage and government spending. Section 3 sets up a CIA model and describes how seigniorage impacts on the output growth. Section 4 explains the Bayesian estimation methodology and provides data and information. In section 5, I present the empirical results in the short run. Section 6 contains concluding observations.

3.2 Literature Review

Understanding the factors that drive good economic performance in the long-term has been a major interest in economics. In the standard neoclassical growth model, steady state growth is purely defined by the exogenous level of technological progress and the growth rate of labour supply. It is often unable to explain the effect of government policies on economic growth. This traditional view contrasts with those on recent development in terms of economic growth theory. In this section, the conceptual issues that must be addressed when estimating the growth effects of changes to seigniorage are reviewed. In addition, different aspects of the existing theoretical and empirical literature are reflected as they relate to the different growth effects of seigniorage and government spending.

3.2.1 Seigniorage

The term seigniorage goes back to the early middle ages, when the sovereigns of many countries financed their consumption from profits via the coinage of money. In other words, seigniorage is the revenue obtained by the monetary authority through money creation (Cukierman, 1992). This is the difference between the costs of production and the face value of a coin and a currency note, which is the monopoly profit of monetary authority. Seigniorage has often been considered interchangeably as the total profit from money creation and maintenance. The theoretical analysis can be simplified by assuming that there is no cost for money creation. Following Willem (2007), two different definitions of the revenue by the state through the money creation are defined in this section. They are monetary seigniorage and opportunity cost seigniorage.

The most common measure of seigniorage is monetary seigniorage, which defines the increment of the monetary base over a period of time (Fischer, 1982). The monetary base is the sum of the currency in the economy and the reserves which commercial banks hold at the central bank. If the monetary base contracts, the monetary authority suffers a loss.

Monetary seigniorage s_M is the change in nominal base money outstanding ΔM, deflated by the price level P:

$$s_{1,t} = \frac{\Delta M_t}{P_t} \tag{3.1}$$

The concept of monetary seigniorage has been widely measured and employed by monetary economists since the data to calculate this measure is easily available.

Monetary seigniorage (3.1) can be expressed in a way which is related to the steady state of this economy as inflation tax, which is the decline in the real value of money due to inflation. This is the loss of the purchasing power of the money holder (Cooley and Hansen, 1989) which can be expressed as follows:

$$s_{1,t} = \frac{\Delta M_t}{P_t} = \frac{\Delta M_t}{M_t}\frac{M_t}{P_t} = \frac{\Delta P_t}{P_t}\frac{M_t}{P_t} = \pi_t \frac{M_t}{P_t} \tag{3.2}$$

where the rate of inflation rate is $\pi_t = \frac{\Delta P_t}{P_t}$.

In this sense, π_t can be considered as the inflation tax rate and $\frac{M_t}{P_t}$ is treated as the tax base.

Numerous empirical studies [26] have argued that inflation commonly occurs as the result of the need to increase the seigniorage in order to finance a high public deficit. Printing money

[26] Sargent and Wallace (1981), Van Wijnbergen (1989) and Easterly and Schmidt-Hebel (1996).

causes the money holder to pay inflation tax, which can be regarded as a beneficial consequence of the seigniorage (Kiguel and Neumeyer, 1995). In other words, inflation tax reduces the real value of the entire stock of money, reduces debt burden for the government, and thereby transfers resources from the bondholders and, the private sector to the public sector. Inflation tax reduces the real value of financial stocks so that it leads to a welfare cost effect (Cooley and Hansen, 1989). The real financial loss is the same as the loss of the money holder's purchasing power. Seigniorage often results in inflation, which causes financial loss.

Many economists [27] examine seigniorage revenue as a source of income for the state. Aghevli (1977) analysed the situation demonstrating that, in developing countries, public expenditure can be financed by inflation tax because of the inefficiency of the tax system. On examining forty selected developing countries, Tahsin (2003) demonstrated that economies with high levels of public expenditure and taxation also have higher inflation tax. The higher seigniorage often leads to a higher inflation. Based on monetarist theory, an increase in the money base will lead to a higher monetary inflation. The rise in inflation decreases real money balances by increasing the nominal interest rates, which affects the readjustment of cash among individuals. This raises the stock prices and leads to a decrease in private consumption (Gurbuz *et al.*, 2009).

Another concept is opportunity cost seigniorage which explains seigniorage as the total opportunity costs of money holders. This can be expressed as:

$$s_{2,t} = \frac{i_t M_t}{P_t} \tag{3.3}$$

where M_t is the money base at t, i_t is the nominal rate of return on assets, and P_t is the price. This represents how much additional real income individuals can obtain if they have interest-

[27] Bailey (1956), Cagan (1956), Friedman (1971), and Phelps (1973).

earning assets instead of non-interest-earning money. This approach is identified by the interest income that people voluntarily forego by holding money instead of earning assets. However, this approach has conceptual problems when it is employed for empirical studies of seigniorage. For instance, the structure of the monetary authority's portfolio is different from the ones of the assets by investors so that opportunity cost seigniorage is not the same as the monetary authority's revenue from creating money. In addition, the choice of a true interest rate in the opportunity cost approach is hard to identify. Hence the monetary seigniorage is widely used for measuring the amount of seigniorage.

3.2.2 Government Spending and Economic Growth

Fiscal policy can affect both the level of the output and its growth rate [28]. The growth models in this literature analysed short-term growth effects when public expenditure increased and the outcomes were different in terms of the type of spending and finance channel. Government spending can have either a positive or negative effect on economic growth. It depends on categorising government expenditures as productive or unproductive and taxes as non-distortionary or distortionary regarding investment decisions. In other words, the composition of government expenditures which affect private sector investment or social welfare and the forms of taxation to finance the expenditures do matter in the analysis. In addition, the effect of public spending can be positive, zero or negative depending on the tax or consumption combinations used or the other fiscal variables when the theoretical models are extended to allow for the effects of surplus or deficits.

In the standard growth model, the level of total output is a function of factor inputs such as labour, capital and productivity. In the original neoclassical growth model introduced by

[28] Barro (1990), Futagami *et al*. (1993), Ghosh and Mourmouras (2002).

Solow (1956), there is no public sector and no room for examining the effects of fiscal policy on economic growth. The growth rate is determined by the technological level and population growth rate. Arrow and Kurz (1969) developed a neoclassical model with the addition of public capital by imposing a proportional income tax. Government spending could play a crucial role affecting the productivity of inputs as it can raise the marginal product of factor inputs in the firm's production function. For instance, when there are more public infrastructures, which may lower adjustment costs, it helps to boost the productivity. It can also lead to higher returns on private investment and higher stock of private capital. Following the work of Barro (1990), numerous endogenous growth models have been developed. The government obtains the revenue from the income tax to finance public expenditure which enters in the firm's production function. The long-term growth arises when the level of public spending is increased. Devarajan *et al.* (1996) expanded on Barro's model with different kinds of public consumption. They distinguished the spending between productive and non-productive expenditures and found the optimal composition of different kinds of consumption in terms of their relative elasticities.

The New Keynesian models differ from the simple growth models and consider some issues critical to the short-term growth effects of government spending[29]. They analysed consumption and investment responses by looking at the demand-side effects from credit-constrained consumers and price rigidities. In these models, government expenditure often does not enter into the firm's production function so that it does not affect the productivity of private inputs. However, the recent models include productive spending with time-to build requirements or implementation lags so that they become better predictions of the short-term effects of government spending.

[29] Beetsma and Jensen (2004) , Gali *et al*. (2007).

The models which categorised public spending according to growth have been developed (Agenor and Neanidis, 2006). They analysed some extensions of the Barro/Devarajan framework. They included infrastructure, education or health expenditure as factor inputs to private production as well as the combination of these expenditure types. For instance, the infrastructure spending is allowed to enter the production function for education. They found that there was a positive impact of public expenditure on economic growth.

The empirical findings on the effect of government consumption on the economic growth are diverse. Barro (1991) found the existence of a negative relationship between economic growth and government consumption using 98 countries over the period 1960 to 1985. Lee (1995) developed an endogenous growth model of open economy and found that government spending leads to slower growth. Gueseh (1997) also employed OLS estimation over the period 1960 to 1985 for 59 middle income developing countries to investigate the effects of government size on the economic growth. The yielding evidence indicated that a growth in government size has a negative impact on economic growth.

Contrary to finding a negative relationship between government consumption and economic growth, some literature proposes that the government can provide productive activities by implementing appropriate policies and eliminating unproductive ones [30]. Kelly (1997) argued that the rent-seeking concerns and the crowding-out concerns might have been overstated in existing studies. She observed 73 countries over the period 1970 to 1989 and found that public investment contributes to higher growth. Abdullah (2000) studied the relationship between government expenditure and economic growth and emphasised that size of government has a significant positive association with the growth of real GDP per capita. He explained that the government should increase its expenditures on infrastructure, social and

[30] Amsden (1989), Epstein and Gintis (1995), and Burton (1999).

economic activities to encourage the private sector to boost economic growth. In Ranjan and Sharma (2008)'s study, public expenditure is shown to have a positive effect on economic growth. They found the existence of co-integration among the variables between 1950 and 2007.

3.2.3 Public Education Spending and Economic Growth

Ever since Romer (1986) and Lucas (1988) emphasised the roles of human capital accumulation, a body of theoretical and empirical literature [31] has attempted to analyse the determinants of endogenous growth. These studies have emphasised the role of human capital in increasing the innovation capacity of the economy by improving new technologies and new ideas. Since education in particular, a major source of human capital, makes the labour more productive, it improves welfare and accelerates the economic growth. Investment in education helps to accumulate human capital, in a way which is comparable to physical capital, and that makes a magnificent contribution to economic growth (Loening, 2004). The effect of education on economic growth has been analysed based on cross-country estimates of gross enrolment rates of schooling. Temple (1999) and Self and Grabowski (2004) found that schooling and the growth rate of per capital GDP across countries have a positive relationship.

Sequiera and Martins (2008) have demonstrated that public spending on education reduces poverty and increases general welfare and economic growth. Numerous studies showed that there is a direct relationship between government spending on education and economic

[31] Barro and Sala-i-Martin (2004), Aghion and Howitt (1999), de la Fuente and Domenech (2001) and Temple (1999).

growth.[32] At the same time, government spending on education has an indirect impact on growth, whilst human capital is accumulated through private sector subsidies [33].

Blankenau *et al.* (2005) examined the expenditure-growth relationship in the framework of an endogenous growth model. They found that the effect of public education expenditure on growth may not be monotonic over the given period. The relationship depends on the tax structure, the level of production technologies and the level of government expenditures. In addition, higher education attainment reduces the income dispersion (O'Neill, 1995).

Michaelowa (2000) claimed that expenditure on education has an indirect effect on growth. For instance, public expenditures lead to better individual health, lower infant mortality and higher education attainment, which help to increase productivity in terms of increased earnings and more participation in the labour force. Sylwester (2000) examined the transition mechanism that can link economic growth and income inequality. He argued that government spending on education is positively related to future economic growth though the contemporaneous impact on economic growth is negative. Kamara *et al*. (2007) also proved that public expenditures on education are positively correlated to economic growth in African countries. Based on the micro level and macro level, public investment in education is very beneficial for society (Dahlin, 2005).

As governments invest in basic education in many countries, the accumulation of human capital can be highly related to public spending. In this sense, many studies have constructed theoretical models relating public spending on education to economic growth financed by income tax. Productive government spending on education has a direct impact on the

[32] Eckstein and Zilcha (1994), Kaganovich and Zilcha (1999), Cassou and Lansing (2001), and Blankenau and Simpson (2004).
[33] Zhang (1998), Milesi-Ferretti and Roubini (1998), and Bouzahzah *et al*. (2002).

accumulation of human capital, thereby affecting long-term economic growth. However, the study of public education spending financed by seigniorage is scarce.

The next section develops a model of growth which includes government expenditure on education and the seigniorage revenue in the budget constraints together, in an attempt to provide theoretical answers to the role of seigniorage. The starting point for our theoretical analysis is Lucas' (1988) endogenous two-sector growth model, which incorporates money in the utility function and public expenditures into the human-capital production function.

3.3 The Basic Framework

This section develops a cash-in-advance model, which incorporates three types of participations (households, firms and government) in the model. Then, the balanced growth and its implication will be discussed.

3.3.1 Household

The representative household is endowed with preference given by:

$$u\left(c_t, z_t\right) = \sum_{t=0}^{\infty} \beta^t \left[\ln\left(c_t\right) + \omega \ln\left(z_t\right)\right] \tag{3.4}$$

For $0 < \beta < 1$, where c_t is consumption, and z_t is hours that are devoted to leisure [34].

[34] $u(.)$ and $\Gamma(.)$ are bounded, monotonically increasing and strictly concave functions, with the parameter $\omega \geq 0$.

Following the work of Basu *et al*. (2012), time is allocated between leisure z_t, time spent in human capital accumulation l_{ht}, and work in goods production l_{gt}. This can be represented as follows:

$$1 = z_t + l_{gt} + l_{ht} \tag{3.5}$$

Hours supplied to the goods sector earn a nominal wage w_t.

This chapter adopts the cash-in-advance approach for introducing money into a general equilibrium framework. The CIA model captures the role of money as a medium of exchange while the money-in-the-Utility emphasises the role of money as a store of value. In the MIU approach, money provides transaction services, which means that holding money affects directly the utility of households (Sidrauski, 1967). Real money balances directly embedded real money balances in the utility function. In contrast, the CIA approach affects indirectly the utility of households as money is held to finance purchases (Lucas, 1982; Cooley and Hansen, 1989). The CIA model has some advantages over the MIU model as it presents the transaction role of money and *ad hoc* assumptions regarding cross partials of the utility function are not needed. This can help to provide a model of the environment where the cash is more liquid than non-money wealth in a convenient way (Svensson, 1985).

The cash-in-advance constraint[35] for agents in the goods market equals:

$$P_t c_t = M_t \tag{3.6}$$

---

[35] CIA constraint $P_t c_t = M_t$ reflects the classical quantity theory of money. This can be written as follow: $\frac{P_{t+1}}{P_t}\frac{c_{t+1}}{c_t} = \frac{M_{t+1}}{M_t} \Rightarrow (1+\gamma_t)(1+\pi_t) = (1+\mu_t) \Rightarrow \pi \approx \mu_t - \gamma_t$.
where P_t is the rate of output growth, π_t is the rate of inflation, and μ_t is the money growth. In the quantity theory of money, steady-state money growth rates move one-for one with steady-state inflation (McCallum and Nelson, 2010). This is implied in the steady state $\gamma_t = 0$ as $\pi_t = \mu_t$.

where M_t is money holding, and P_t is the aggregate price level. M_t is the nominal money balance which is chosen by the representative household in period t and will be carried into the next period $t+1$. The agent purchases the consumption goods with cash. The role of money in this model is identified as being that the transaction needs money so that it may be held for some time advance [36]. Income from the goods sector during period t will not be available for consumption purchase during period t in this cash-in-advance constraint. It is assumed that households receive the wage after they finish shopping in the goods market [37].

In choosing between savings, consumption, money holding, and hours supplied to the goods market, agents face the constraint:

$$P_t c_t + P_t i_t^k + M_{t+1} - M_t = P_t w_t l_{gt} h_t + P_t r_t k_t \tag{3.7}$$

where i_t^k is physical investment r_t is the real return on physical capital. The real wage w_t represents the return to hours measured in efficiency units $l_{gt}h_t$, where l_{gt} refers to hours supplied to final goods production and h_t is the stock of human capital. The revenues of the household are wages, and capital gains and expenses are investment in cash, $M_{t+1} - M_t$, physical investment $P_t i_t^k$, and consumption purchases $P_t c_t$. Physical capital is produce as follows:

$$k_{t+1} = \left(1 - \delta_g\right) k_t + i_t^k \tag{3.8}$$

where δ_g is the rate of depreciation of the capital stock and investment equals the next period's capital stock. As in the Lucasian two-sector growth model (1988), households also invest in human capital. Since human capital is specific to the individual and its technology is

[36] Consumption here is considered as cash good and investment as a credit good.
[37] The time line of CIA model is in Appendix 3.A.

one of constant returns, each agent can be treated as individually controlling her or his own human capital production technology [38]. Human capital accumulation in this model is:

$$h_{t+1} = (1-\delta_h)h_t + A_{Ht}(l_{ht}h_t)^{\nu} G_t^{1-\nu} \tag{3.9}$$

where l_{ht} is time input from the household to the reproduction of human capital, G_t is government spending on education, δ_h is the depreciation rate of human capital, and A_{Ht} is the technology level in human capital. G_t is publicly provided "quality" of education through financing primary, and secondary education. The general skills from primary and secondary schooling acquired later help to build up the human capital accumulation.

3.3.2 Firms

The initial step of our analysis is Lucas' (1988) endogenous two-sector growth model. I consider an economy in which there are two productive activities: market or physical output production and human capital production. The following physical production technology extends the approaches found in Lucas (1988), and Rebelo (1991), by including productive government spending. Following Barro (1990), I incorporate a sector of human capital production into the endogenous growth model where productive government spending is a factor of the human capital production technology. Each producer has access to the following firm production:

$$y_t = A_{Gt}k_t^a(l_{gt}h_t)^{1-a} \tag{3.10}$$

[38] As human capital can be in the absence of distortional taxes, human capital accumulation is Pareto efficient (Devereux and Love, 1995).

$A \in [0,\infty]$, $a \in [0,1]$

where y_t is output per worker, A_{Gt} is the exogenous TFP in the goods sector, k_t is capital per worker and a is the capital's share in output. $l_{gt}h_t$ can be identified as effective labour input depending on the worker's human capital and on his or her non-leisure time allocation decision, to be precise, how much time they want to devote to work in goods production. The firm production technology (3.10) displays constant return to scale (CRS) in two inputs together, and the return to its accumulation is diminishing, $a \in [0,1]$.

Profit maximisation simplifies to a series of static problems. Formally, the firm's problem is written as:

$$\underset{k_t, l_t^g h_t}{Max}\, \Pi = P_t y_t - P_t w_t l_{gt} h_t - P_t r_t k_t \tag{3.11}$$

where r_t is the real return on physical capital and w_t is the real wage which represents the return to hours measured in efficiency units $l_{gt}h_t$. Since y_t is constant-returns to scale and the economy is competitive, zero profits are earned in equilibrium. Firms in the final goods sector simply rent capital and employ labour to maximize profits at each point in time. As there is no depreciation, the real rate of return on capital is the same as its earnings per unit time. Therefore, the real interest rate at time t is:

$$r_t = aA_{Gt}k_t^{a-1}(l_{gt}h_t)^{1-a} \tag{3.12}$$

And labour's marginal product, the real wage, at time t is:

$$w_t = (1-a)A_{Gt}k_t^{a}\left(l_{gt}h_t\right)^{-a} \tag{3.13}$$

3.3.3 Government

Since the long-run implications of monetary and fiscal policies are considered, I ignore the possibility of government borrowing as in Sargent and Wallace (1981). In this model, government is financed by seigniorage which is revenue from printing money and tax revenue. The government revenue is:

$$G_t = s_t + \tau_t y_t \tag{3.14}$$

where s_t is seigniorage revenue and $\tau_t y_t$ is the tax revenue.

The real seigniorage equals the growth rate of the money stock times the quantity of real balances. The stock of money expands proportionately with factor μ_t. Seigniorage (3.14) can be rewritten as follow:

$$s_t = \frac{M_{t+1} - M_t}{P_t} = \mu_t \frac{M_t}{P_t} \tag{3.15}$$

where M_t is the money supply, P_t is the price level, and μ_t is the money growth rate. $\mu_t \frac{M_t}{P_t}$ is seigniorage, which is defined as the amount of real resources bought by the government by means of new base money creation following Cukierman *et al.* (1992). In terms of public finance, the identity (3.15) can be interpreted as an inflation tax with the tax rate μ_t and the tax base $\frac{M_t}{P_t}$. Government expenditures have to be financed by money creation and tax revenues. These revenues are fully spent by the government on education, which appears as an intermediate input in the human capital production function. In addition, the central bank sets the time path that the money supply equals the money demand. Therefore, the government budget constraint (3.14) can be alternatively be rewritten as:

$$\mu_t \frac{\bar{M}_t}{P_t} + \tau_t y_t = G_t \tag{3.16}$$

3.3.4 Exogenous Shocks

I assume the following stationary stochastic process for three shocks around the steady state:

$$A_{Gt} - \bar{A}_G = \rho_G \left(A_{Gt-1} - \bar{A}_G \right) + \varepsilon_t^G$$

$$A_{Ht} - \bar{A}_H = \rho_H \left(A_{Ht-1} - \bar{A}_H \right) + \varepsilon_t^H$$

$$\mu_t - \bar{\mu} = \rho_\mu \left(\mu_{t-1} - \bar{\mu} \right) + \varepsilon_t^\mu \tag{3.17}$$

where $\bar{A}_G$, $\bar{A}_H$ and $\bar{\mu}$ are the steady-state technology of the goods and human capital sectors and the steady state of the growth rate of money. Autocorrelation coefficients ρ_G, ρ_H and ρ_μ are positive fractions and $\varepsilon_t^G, \varepsilon_t^H$,and ε_t^μ are white noises with standard deviations σ_G, σ_H and σ_μ.

3.3.5 The Competitive Equilibrium

In this section, I present the optimality conditions that determine a competitive equilibrium and derive a special case which is an analytical solution to this model economy.

3.3.5.1 Definition

A competitive equilibrium requires that all markets clear. Given the initial h_0 and k_0, a competitive equilibrium of the model is a sequence of allocations $\{c_t, k_t, h_t, l_{gt}, l_{ht}, w_t, r_t, M_t, G_t\}$ that satisfy the following conditions:

(1) Given price P_t, the household maximises utility in equation (3.4) subject to the constraints in equations (3.6), (3.7), (3.8) and (3.9), with respect to $c_t, l_{gt}, l_{ht}, k_{t+1}, h_{t+1}$ and M_{t+1}. In other words, the maximisation problem faced by the representative agent is to choose consumption, a time allocation among leisure, market activity and education, stock of physical capital, human capital and cash balances;

(2) The goods producer maximises profit subject to the CRS production function constraint (3.10), giving conditions (3.12) and (3.13);

(3) Money demand and money supply equals in each period : $M_t^D = M_t^S$;

(4) The government's budget balances, meaning (3.16) holds;

(5) The goods market clearing of income equal to expenditure is given by equation. Namely, the goods market clears when output equals consumption, investment and government spending : $C_t + I_t + G_t = Y_t$;

3.3.5.2 Characterisation

The optimal plan of the household is solved by applying the Lagrangian method. I define the Lagrange multipliers associated with the flow budget constraint for the household (3.7) as λ_t, the human capital technology (3.9) as η_t and the cash-in-advance constraint on consumption (3.6) as ψ_t:

$$L^p = \sum_{t=0}^{\infty} \beta^t \left\{ u(c_t) + \omega \Gamma(z_t) \right\} + \sum_{t=0}^{\infty} \lambda_t \left[P_t w_t l_{gt} h_t + M_t + P_t r_t k_t - P_t c_t - P_t i_t^k - M_{t+1} \right]$$
$$+ \sum_{t=0}^{\infty} \eta_t \left[A_{Ht} (l_{ht} h_t)^{\nu} G_t^{1-\nu} + (1-\delta_h) h_t - h_{t+1} \right] + \sum_{t=0}^{\infty} \psi_t \left[M_t - P_t c_t \right]$$

The first-order conditions for this problem can be found in Appendix 3.C. The standard stochastic discount factor d_{t+1} encountering the household is:

$$d_{t+1} = \beta \left(\frac{u_{c_{t+2}} \dfrac{c_{t+2}}{c_{t+1}} \dfrac{1}{1+\mu_{t+2}}}{u_{c_{t+1}} \dfrac{c_{t+1}}{c_t} \dfrac{1}{1+\mu_{t+1}}} \right) \tag{3.18}$$

The first order conditions have the following interpretations. Since initial resources must be allocated among consumption, capital and money balances, each usage must generate the same marginal benefit at the steady-state. In terms of $\lambda_t P_t$, (3.C.8) becomes:

$$\lambda_t P = \lambda_{t+1} P_{t+1} \left[(1-\delta_g) + r_{t+1} \right] \tag{3.19}$$

where r_{t+1} is the real return on physical capital at time $t+1$. This is similar to a standard asset pricing equation and to a condition from problem which involves intertemporal optimisation (Walsh, 2003). In terms of today's utility, the marginal cost by reducing marginal utility of income slightly, λ_t, must be the same as the utility value of forwarding that marginal utility of income to one period, yielding a real return r at period $t+1$. In all, this is $\lambda_t P = \lambda_{t+1} P_{t+1}\left[\left(1-\delta_g\right)+r_{t+1}\right]$ along the optimal path.

In addition, the intertemporal optimality condition for the representative agents can be expressed as:

$$\lambda_t = \beta^{t+1}\frac{\left\{u\left(c_{t+1}\right)+\omega\Gamma\left(z_{t+1}\right)\right\}}{P_{t+1}} \tag{3.20}$$

The household's intertemporal optimality condition shows that marginal utility of income matches to the discounted marginal utility of consumption at period $t+1$.

The net inflation augmented real return capital gain at time t_{t+1} is:

$$\frac{P_{t+1}}{P_t}\left[\left(1-\delta_g\right)+r_{t+1}\right] = \frac{\psi_{t+1}}{\lambda_{t+1}}+1 \tag{3.21}$$

An expression for the net inflation augmented a real return rate, if money provides liquidity services $\left(\psi_{t+1}>0\right)$, the net inflation augmented real return is positive.

In order to derive the marginal utility of consumption, the net inflation augmented real return rate and the Lagrangian multipliers are considered. Equation (3.C.1) can be written as:

$$u_{ct} = \lambda_t P_t\left(1+\frac{\psi_t}{\lambda_t}\right) = \lambda_t P_{t+1}\left[\left(1-\delta_g\right)+r_{t+1}\right] \geq \lambda_t \tag{3.22}$$

As λ represents the marginal value of income, if the nominal return rate is positive, the marginal utility of consumption will be bigger than the marginal utility of income. Since the representative agents must hold money to finance consumption, the price of consumption is

$P_{t+1}\left[\left(1-\delta_g\right)+r_{t+1}\right]$. Therefore, the positive nominal return rate is treated as a tax on consumption in the CIA model.

When the positive nominal return rate exists, the CIA constraint holds with equality, which is $P_t c_t = M_t$. Hence, the consumption velocity of money is 1 $\left(\frac{P_t c_t}{M_t}=1\right)$.

This can be also implied:

$$\frac{c_{t+1}}{c_t}\frac{P_{t+1}}{P_t}=\frac{M_{t+1}}{M_t} \tag{3.23}$$

The relative price of human capital to physical capital can be expressed as $\frac{\eta_t}{\lambda_t P_t}$ [39], on an optimal growth path. The return rate on human capital is equal to the combination of the marginal product of human capital and the capital gain which is the change in the price of human capital , $\frac{\eta_t}{\lambda_t P_t}$. This can be expressed as:

$$\frac{\eta_t}{\lambda_t P_t}=\frac{h_t A_G\left(1-a\right)l_{gt}^{-a}\left(\frac{k_t}{h_t}\right)^a}{A_H \nu l_{ht}^{\nu-1}\left(\frac{G_t}{h_t}\right)^{1-\nu}} \tag{3.24}$$

The time length that is devoted to leisure z_t can be shown as:

$$z_t=\left(1+\frac{\psi_t}{\lambda_t}\right)\frac{\left(1-\omega\right)}{\omega}\frac{c_t}{h_t}\frac{1}{w_t} \tag{3.25}$$

[39] The flow budget constraint is re-expressed in real terms.

Since on an optimal growth path, $\frac{c_t}{h_t}$, w_t and z_t are constant over time, (3.25) shows that the ratio of Lagrangian multipliers, $\frac{\psi_t}{\lambda_t}$, should also be constant. In other words, this indicates that ψ_t and λ_t change at the same rate in the balanced-growth equilibrium as shown in equation (3.26):

$$\frac{\lambda_{t+1}}{\lambda_t} = \frac{\psi_{t+1}}{\psi_t} \tag{3.26}$$

The consumption to leisure trade-off can be shown by using equations (3.C.1), (3.C.2) and (3.C.6) as follow:

$$\frac{z_t}{c_t} = \frac{(1-\omega)(1+\mu_t)}{\beta\omega w_t h_t} \tag{3.27}$$

The left hand side is the marginal rate of substitution from goods towards leisure. The right hand side is money growth and the inverse of real wage. Increasing in money growth causes leisure to increase relative to consumption. The list of variables and parameters in CIA model can be found in Appendix 3.B.

3.3.5.3 The Balanced-Growth Equilibrium

In the balanced-growth equilibrium, physical capital and human capital grow at the same rate. Furthermore, the fraction of time devoted to leisure, z_t stays constant over time on the balanced-growth path. Given these conditions, it is easy to confirm that in the balanced-growth equilibrium, physical capital k_t and human capital h_t grows at the same rate as consumption c_t, output y_t, and real money balances $\frac{M_t}{P_t}$. Accordingly, the following holds:

$$\frac{k_{t+1}}{k_t}=\frac{h_{t+1}}{h_t}=\frac{c_{t+1}}{c_t}=\frac{y_{t+1}}{y_t}=\frac{M_{t+1}/P_{t+1}}{M_t/P_t}=1+\gamma \tag{3.28}$$

where $1+\gamma$ denotes the gross rate of balanced growth. Letting $1+\pi$ be the long run level of the gross rate of inflation, the previous equation (3.28) yields:

$$(1+\mu)=(1+\gamma)(1+\pi) \tag{3.29}$$

By use of (3.26), and (3.29), the common growth rate of ψ_t and λ_t can be written as:

$$\frac{\lambda_{t+1}}{\lambda_t}=\frac{\psi_{t+1}}{\psi_t}=\frac{1}{(1+\gamma)(1+\pi)}=\frac{1}{(1+\mu)} \tag{3.30}$$

From equations (23) and (30), the ratio of Lagrangian multipliers, $\frac{\psi_t}{\lambda_t}$ can be presented as:

$$\frac{\psi_t}{\lambda_t}=\mu_t \tag{3.31}$$

Now the balanced growth equation can be obtained in terms of the physical capital net return:

$$1+\gamma=\beta\left[\left(1-\delta_g\right)+MPK\right]=\beta\left[\left(1-\delta_g\right)+A_G\alpha l_{gt}^{1-a}\left(\frac{k_t}{h_t}\right)^{a-1}\right] \tag{3.32}$$

where MPK is the marginal product of capital. It can also be achieved based on the human capital net return:

$$1+\gamma=A_H\nu(1-z)\left(\frac{G}{l_h h}\right)^{1-\nu} \tag{3.33}$$

The balanced growth equation (3.33) implies how an increase in money growth impacts on growth. The effect of an increase in money growth on output growth can be both positive and negative since money growth has two opposing effects on the growth rate. In other words, money growth has a growth-enhancing effect as well as an adverse effect on the growth rate.

Consider what happens when the money growth rate increases. When the money growth rate μ_t increases, $(1-z)$ will decrease as $z_t = (1+\mu_t)\frac{(1-\omega)}{\omega}\frac{c_t}{h_t}\frac{1}{w_t}$. This leads to a substitution away from cash goods and towards credit goods. In this CIA model, inflation acts as a tax on the cash goods which distorts the consumption of cash goods relative to credit goods. This can be seen in equation (3.27), which shows the marginal rate of substitution from goods towards leisure. This distortion can in turn affect the labour/leisure choice so that it also impacts on time allocated to work. Substitution from cash goods towards leisure reduces human capital utilization rate of $(1-z)$ so that a lower return on both human and physical capital is obtained. Since government spending rises via increase in money growth rate, there is a direct growth-enhancing effect. Public education spending by financed seigniorage could play a crucial role by affecting the productivity of inputs in the firm production function as it can help to accumulate human capital.

In order to solve a dynamic stochastic general equilibrium model, a log-linear approximation of equilibrium conditions of the original non-linear model around the deterministic steady state should be conducted. After a log-linearisation, the responses of endogenous variables to the shocks can be examined in terms of the percent deviation from the values at the steady state.

All short run equations are reported in Appendix 3.C.2 and the process is controlled by the Dynare programme that is shown in Appendix 3.E.

3.4 Model Estimation

This section demonstrates how the solved baseline model can be estimated via the Bayesian approach and then how the prior densities are actually established.

3.4.1 Methodology

This methodology section explains how the solved models can be estimated by Bayesian approach, including explaining what are prior and posterior distributions via the Kalman filter to obtain the likelihood function, and adopting the Metropolis-Hastings algorithm to estimate the posterior function.

3.4.1.1 The Bayesian Inference

Bayesian inference starts from one simple idea, the Bayes' theorem. Schorfheide (2000) and Fernandez-Villaverde (2010) provide a clear and quite complete introduction to Bayesian estimation. In order to yield the posterior density, we can go directly to the data to get the information and apply Bayes' theorem with the prior information. Suppose that we have some data $Y^T \equiv \{Y_t\}_{t=1}^{T}$ which Y ranges from 1 to T for n variables, and we have a model, motivated by economic theory. The model is indexed by x, and it is a set of possible models M ($x \in M$). Our interests are the distributions for i parameters. Priors are defined by a density function of the form as below:

$$p\left(\theta_x \middle| x\right) \tag{3.34}$$

where θ_x is the parameters of a specific model x, $p(\theta)$ is a probability density function (PDF) which can be a gamma, beta, generalised beta, normal, shifted gamma, inverse gamma, or uniform function. A priority distribution shows pre-sample beliefs about the true value.

The likelihood function describes the probability that the model is assign to the observed data given its parameters:

$$p\left(Y^T|\theta_x, x\right) \equiv L\left(\theta_x \middle| Y^T, x\right) \tag{3.35}$$

This acts as the restriction that the model imposes on the observed data, either from equilibrium conditions or statistical considerations. We now have two building blocks, priors $p(\theta_x)$ and likelihood functions $p\left(Y^T|\theta_x\right)$. Remember our interest is the posterior density $p\left(\theta \middle| Y^T\right)$. We combine priors and likelihood functions by Bayes' rule to draw our interest:

$$p\left(\theta \middle| Y^T, x\right) = \frac{p\left(Y^T|\theta_x, x\right) p\left(\theta_x|x\right)}{p\left(Y^T|x\right)} \tag{3.36}$$

where $p\left(\theta \middle| Y^T, x\right) = p\left(\theta_1, \theta_2, \cdots, \theta_i|y\right)$ is the posterior density of i unknowns, and $p\left(Y^T|x\right)$ is the marginal likelihood. The observed data Y^T influences the posterior density only via the likelihood function, $p\left(Y^T|\theta_x, x\right)$.

The marginal density of the observed data conditional on the model, $p\left(Y^T|x\right)$ can be written as:

$$p\left(Y^T|x\right) = \int_{\Theta x} p\left(\theta_x; Y^T|x\right) d\theta_x \tag{3.37}$$

Given that the marginal density above is a normalising constant, the posterior kernel or the unnormalised posterior density is:

$$p\left(\theta_x \middle| Y^T, x\right) \propto p\left(Y^T \middle| \theta_x, x\right) p\left(\theta_x \middle| x\right) \equiv K\left(\theta_x \middle| Y^T, x\right) \tag{3.38}$$

With the help of the Kalman filter recursion, it is possible to derive the log-likelihood function. This helps us one step closer to find the posterior distribution of our parameters. The log posterior kernel can be shown as:

$$\ln K\left(\theta \middle| Y^T\right) = \ln L\left(\theta \middle| Y^T\right) + \ln p\left(\theta\right) \tag{3.39}$$

where the first term on the right side is now known values from Kalman filter recursion and the second term is the priors which are also known. We can now find the mode of the posterior distribution by maximising the log posterior kernel with respect to θ. Equation (3.38) shows that the posterior density of i unknowns $p\left(\theta \middle| Y^T, x\right)$ is different from the unnormalised posterior density $K\left(\theta_x \middle| Y^T, x\right)$ up to the constant. Therefore, we zero in on the posterior kernel through the posterior simulators such as the Markov Chain Monte Carlo (hereafter referred to as MCMC) methods instead of trying to explicitly compute the posterior distribution of $p\left(\theta \middle| Y^T, x\right)$.

Once the posterior density $p\left(\theta \middle| Y^T, x\right)$ is confirmed, the marginal posterior distribution of the parameters of interest can be obtained. For example, the marginal posterior distribution of θ_3 is derived by integrating the joint posterior distribution of i unknowns with respect to all except θ_3:

$$p\left(\theta_3 \middle| Y^T\right) = \int_{\theta_1}\int_{\theta_2}\cdots\int_{\theta i} p\left(\theta \middle| Y^T\right) d\theta_i \cdots d\theta_4 d\theta_2 d\theta_1 \tag{3.40}$$

The posterior mean can be easily calculated given the above marginal posterior distribution of θ_3:

$$E\left(\theta_3 \middle| Y^T\right) = \int \theta_3 p\left(\theta_3 \middle| Y^T\right) d\theta_3 \tag{3.41}$$

In addition, the posterior mean can be expressed as a convex combination of the prior mean and the maximum likelihood estimation:

$$E(\mu) = \frac{\left(\frac{1}{T}\right)^{-1} \hat{\mu}_{ML,T} + \sigma_{\mu}^{-2} \mu_0}{\left(\frac{1}{T}\right)^{-1} + \sigma_{\mu}^{-2}} \tag{3.42}$$

If we have no prior information $\sigma_{\mu}^{-2} \to \infty$, then $E(\mu) \to \hat{\mu}_{ML,T}$. And if we are sure the parameters of interest $\sigma_{\mu}^{-2} \to 0$, then $E(\mu) \to \mu_0$. In general, the circumstances are somewhere in the middle of these two extremes. Therefore, Bayesian estimation is an outcome from both calibration and maximum likelihood. In general, the calibrating models are based on priors and the maximum likelihood approaches are inherited through the estimation process with data. Bayes' rule is applied to these two building blocks.

It is important to mention here that the Bayesian estimation has several advantages and this is why I use it for my model.

First, as I mentioned, pre-sample information which works as a weight in the estimation is considerably useful. This process, unlike full information maximum likelihood, lets us use prior information to identify key structural parameters. It helps to avoid peaking at random areas where the likelihood peaks and it also helps with identifying parameters. There are often cases in which the problems of identification arise. It is caused by different values of structural parameters having the same joint distribution for observables. In general, it happens more when the posterior distribution is flat over a subspace of parameter values. However, the weighting of the maximum likelihood with priors helps to provide enough curvature in the posteriors to perform numerical maximisation even under this identification problem.

Second, Bayesian estimations handle mis-specified models (Monfort, 1996). Bayesians are trying to come up with a good description of the data. It focuses more on the normality of a lack of deification than on the identification problems. It can still continue to work without further complications or any new theory for a flat posterior. The answer may have an uncertainty; however, there is nothing conceptually different in terms of the inference process.

Third, the Bayesian estimation fits the solved DSGE model, compared to GMM estimation which is inherited from the particular equilibrium relationship. It employs all the cross-equation restrictions implied by the general equilibrium equations, which leads to a better estimation compared to the partial equilibrium approaches.

Fourth, Bayesian estimation compares the models based on fit. Posteriors can be useful to determine which model best fits the data. In addition, Bayesian estimation introduces shocks as observation errors in the structural equations, which explicitly explains model mis-specification.

Fifth, Compared to alternative methods based on large-sample approximation, MCMC methods offer a better description of the parameter uncertainty given in our small sample.

3.4.1.2 Steps

Bayesian inference on DSGE models can be applied by the Random Walk Metropolis Algorithm with the following steps (An and Schorfheide, 2007). This is the universal algorithm that produces Markov chains which correspond to the posterior distributions. In this Metropolis Hastings algorithm, we observe whether a new proposed value of the parameter increases the posterior or not. If it increases the posterior, we accept with probability 1 and if it does not increase the posterior, we accept with probability less than 1. In doing so, we travel not only the higher regions of the posterior but also the lower regions so that this avoids getting trapped in local maxima.

1. To estimate the kernel, $\ln K\left(\theta \middle| Y^T\right) = \ln L\left(\theta \middle| Y^T\right) + \ln p(\theta)$, use a Kalman filter algorithm to obtain the log-likelihood function conditioned on observed date, $\ln L\left(\theta \middle| Y^T\right)$.

2. Given $L\left(\theta \middle| Y^T\right)$ and $\ln p(\theta)$, we use a numerical optimisation process to find a posterior mode $\tilde{\theta}$ which maximises the log-kernel [40].

3. Draw θ^0 from a jumping distribution $\mathrm{N}\left(\tilde{\theta}, c\sum\left(\tilde{\theta}\right)\right)$ where c is a jumping scalar specified by the researcher and $\sum\left(\tilde{\theta}\right)$ is the inverse for the Hessian [41] computed at the posterior mode:

$$\sum\left(\tilde{\theta}\right) = \left[-\frac{\partial^2 \ln K\left(\theta \middle| Y^T\right)}{\partial\theta\,\partial\theta'}\bigg|_{\theta=\bar{\theta}} \right]^{-1} \tag{3.43}$$

We can draw θ^0 from directly specify a starting point.

[40] Since the kernel differs from the posterior distribution till the normalising constant, posterior mode from the kernel is similar with posterior mode from the posterior distributions.

[41] Covariance matrix calculated from the inverse of the negative of the second derivative of the log-kernel function (Kim and Nelson, 1999).

4. For $t = 1, \cdots, n_{sim}$ where n_{sim} is the number of simulations, obtain θ^* from a jumping distribution $\mathrm{N}\left(\theta^{t-1}, c\sum\left(\theta^{t-1}\right)\right)$. Compute the ratio of the densities:

$$r\left(\theta^{t-1}, \theta^* \middle| Y^T\right) = \frac{L\left(\theta^* \middle| Y^T\right) p\left(\theta^*\right)}{L\left(\theta^{t-1} \middle| Y^T\right) p\left(\theta^{t-1}\right)} \tag{3.44}$$

5. The jump from θ^{t-1} is accepted if $\theta^{(t)} = \theta^*$ and rejected if $\theta^{(t)} = \theta^{(t-1)}$:

$$\theta^t = \begin{cases} \theta^* : accept \\ \theta^{t-1} : reject \end{cases}$$

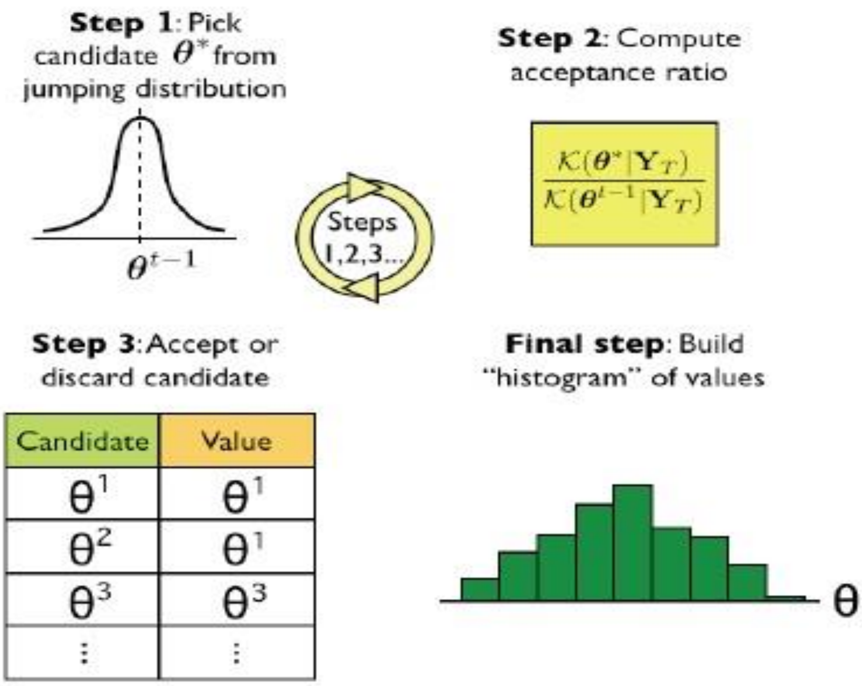
The important parameter in this process is the scale factor. If the scale factor is too small, the acceptance rate will be too high. This infers that the Markov Chain of parameters will perform slowly, which means the distribution will take longer to find the convergence with the posteriors as the Markov Chain may get stuck around a local maximum point. However, if the scale factor is too large, the acceptance rate will be low, meaning that the Markov Chain will spend more time in the tails of the posteriors. It is important for us not to give a lower or higher value of the posterior kernel and to make sure the appropriate acceptance rule let the search visit the entire domain of the posterior distribution. In this chapter, I set the optimal acceptance ratio around 25 % as suggested by Gelman *et al.* (2004).

6. When we perform the algorithm for a sufficient number of iterations, we can obtain inference. The posterior distribution of θ will be asymptotically normal (An and Schorfheide, 2007). The algorithm develops a Gaussian approximation around the posterior mode and adopts a scaled version of the asymptotic covariance matrix for the proposal distribution. Based on the collection of parameter drawn, we construct the marginal posterior density for each parameter. Finally we have an empirical

approximation of posterior means, modes, standard errors, and other objects of interests such as 95% highest posterior density intervals for parameters.

Figure 3.3 illustrates this process with Random Walk Metropolis Algorithm. In step 1, choose an appropriate candidate θ^* from a normal distribution and in step 2, compute the acceptance ratio by comparing the value of the posterior kernel for that candidate parameter to the value of the kernel from the mean of the drawing distribution. Then, decide whether to accept or reject your candidate parameter. If the acceptance ratio is less than one, go back to the candidate for the last period. After having several iterations, build a histogram of values which will be the posterior distribution.

Figure 3.3 Metropolis_Hastings Algorithm Process



(Source: Dynare User Guide)

3.4.2 Data and Prior Densities

3.4.2.1 Data

As there are three shocks in this model, physical capital technology shock, human capital technology shock and money shock, the maximum number of observable variables is three. When the rank of policy function matrix is less than the number of observables, there will be the stochastic singularity problem. In order to estimate the system for the US economy, I have used three macroeconomic observables at quarterly frequency. Following the previous study by Smet and Wouters (2007), this chapter includes real GDP, real government spending, and the GDP deflator. The real variables are obtained by deflating their nominal values using the GDP deflator. All data is from the Federal Reserves with the sample period being from 1960:01 to 2007:04. On one hand, my choice to begin at 1960 is due to data availability and to end at 2007 is to avoid some possible structural changes in the private sector or policy maker's behaviour due to the financial or euro crises. It is assumed that real GDP and real government spending are regarded as representative statistics for the real side and the nominal side of macroeconomics. In order to get stationary data, real variables are measured in logarithmic deviations from the linear trends. The inflation rate is obtained from the first difference in the log GDP deflator.

3.4.2.2 Prior Densities

As demonstrated in section 3.4.1, prior distributions perform a significant role in the Bayesian estimation of the DSGE model, since they help us to sharpen the inference. The choice of priors for the estimated parameters is set based on evidence from previous studies and the theoretical implications of the model. Also, an alternative source of prior information is the estimate of parameters from different countries (Fernandez-Villaverde, 2010). Most macroeconomic models assume that individuals are basically the same across countries. For example, if we have estimates from Germany that the discount factor in a DSGE model is around 0.99, it is reasonable to assume that the discount factor in the UK will be the same, if we employ the same model.

Some researchers prefer to select loose priors and others favour tighter priors that sharpen our inference and guide the posterior to plausible regions. In other words, priors reflect our beliefs about the validity of economic theories. When the evidence is weak or non-existent, we set more diffuse priors [42]. Setting a relatively high standard deviation for a density function imposes less informative priors and allows for the data to examine the parameter's location.

A few structural parameters are kept fixed in the Bayesian estimation process. Table 3.2 presents money growth rates and depreciation rates [43]. Money growth rate μ is obtained by AR (1) model fitting using M0 in the US. Its mean is 0.037 with a standard deviation of 0.01. The human capital and physical capital depreciate rates are set at 0.03 and 0.024 in line with Benk *et al*. (2009) and Basu *et al*. (2012).

Table 3.2 Fixed Parameters

Parameters	Descriptions	Value
μ	Money growth rate	0.037
ρ_μ	AR money shock	0.540
σ_μ	s.d. money growth shock	0.010
δ_g	Depreciation rate in human capital production	0.030
δ_h	Depreciation rate in physical capital production	0.024

[42] Del Negro and Schorfheide (2008) demonstrate an example which the effect of priors have on our inference.
[43] When using US money data for the Bayesian estimation, the value is extremely high. This is because it may have multiple peaks so that the Markov chain may have difficulty in moving around and may get stuck on one peak, which is not precise and correct. Since the US money growth has been relatively stable, the money growth in this estimation is fixed.

The table of steady-state values and assigned values of variables and parameters can be found in Appendix 3.D.

Table 3.3 Prior Distributions for Structural Parameters

Parameters	Descriptions	Density	Mean	S.D.
β	Discount factor	Beta	0.9900	0.1000
a	Capital's share in output	Beta	0.3600	0.0350
ω	Relative weight to leisure	Normal	1.8400	0.0250
$\bar{A}_G$	Steady-state physical technology growth rate	Normal	1.2000	0.1000
$\bar{A}_H$	Steady-state human capital technology growth rate	Normal	0.2100	0.1000
v	Capital's share in human capital production	Beta	0.8000	0.1000
τ	Tax Revenue (% GDP)	Beta	0.3000	0.0100
ρ_G	AR physical capital technology shock	Beta	0.5000	0.1000
ρ_H	AR human capital technology shock	Beta	0.5000	0.1000
σ_G	s.d. physical capital technology shock	Inv.Gamma	0.2500	Inf
σ_H	s.d. human capital technology shock	Inv.Gamma	0.2500	Inf

The prior's functional form is based on each parameter's characteristics. I draw priors for parameters from beta, normal and inverse gamma distributions [44]. I use the inverse gamma distribution when there are parameters which are assumed to be positive. Beta distortions are for fractions, which should be constrained between 0 and 1 and normal distributions are for non-bounded parameters (Guerron-Quintata and Nason, 2012). For instance, the priors on the standard deviations of the technology shocks are drawn from inverse gamma distributions. This distribution supports an open interval that is unbounded and not zero. This allows the technology shocks to have priors with 95 % probability intervals between zero and larger upper bounds. I adopt the same distributions and prior means from pre-existing studies, namely Smet and Wouters (2007) and Basu *et al.* (2012), and I have chosen fairly loose priors for all parameters.

Some researchers prefer to select loose priors and others favour tighter priors that sharpen our inference and guide the posterior to plausible regions. In other words, priors reflect our beliefs about the validity of economic theories. When the evidence is weak or non-existent, we set more diffuse priors. Setting a relatively high standard deviation for density functions imposes less informative priors and allow for the data to examine the parameter's location.

The prior distribution of the discount factor β has a beta distribution with a mean of 0.99 denoting that the annual real interest rate is 4% with a standard deviation of 0.1. The capital share in output a has a beta distribution with a mean of 0.36 and a standard deviation of 0.035 (Basu *et al.*, 2012). Following Angelopoulos *et al.* (2007), capital's share in human capital production has a beta distribution with a mean of 0.8 and a standard deviation of 0.1. It also indicates that the share in public education spending in human capital production is 0.2. The relative weight to leisure is set to 1.84. Based on the US data from 1990 to 2010, the mean of tax revenue is set to 0.30 and standard deviation to 0.01. The autoregressive

[44] See Del Negro and Schorfheide (2008) for more information.

coefficients in the shock processes have a beta distribution with a mean of 0.50 and a standard deviation of 0.1. The standard deviations of the technology shocks follow inverse gamma distributions with a mean of 0.25 and. This let them be infinite. Steady-state physical and human technology growth rates are followed by Smet and Wouter (2007).

3.5 Results

This section presents the posterior distribution for the main behavioural parameters. It uses random walk Metropolis-Hastings, to indicate how shocks, mainly monetary shocks, drive the fluctuation endogenous variables by using Bayesian impulse responses to analyse and provide a useful implication of seigniorage in the long run.

3.5.1 Target Variables : Actual and Model

Table 3.4 demonstrates the data for target variables (GDP growth, Rate of inflation, Rate of seigniorage, Leisure Hour and Government Spending) and the values of these variables in the steady state model. The yearly data, with the exception of leisure hour date, ranges from 1962 to 2007 in the US from the World Bank's development indicators. The average leisure data is taken from Basu *et al.* (2012).

The average data values for GDP growth are the same as the values in the steady state baseline model. The rates of seigniorage, leisure hours, and inflation in the calibrated model are close to the target values. However, the gap in the value of government spending between data and model is quite large.

Table 3.4 Values of the growth model target variables: actual and model

Target Variables (1961-2007)	Descriptions	Average Rate	Long-Run Steady State rate
γ	GDP growth	0.02	0.02
π	Rate of inflation	0.03	0.02
s	Rate of seigniorage	0.01	0.02
z	Leisure Hour	0.50	0.48
G/Y	Government Spending	0.16	0.32

3.5.2 Posterior Distribution

Once priors have been defined, I estimate the model by first computing the posterior mode, and the Hessian matrix via standard optimisation problems and by building the posterior densities. Using a random walk Metropolis-Hasting, 20,000 draws from the posterior distribution are conducted. The MCMC MH algorithm is started with an initial θ. This parameter vector is going through the Kalman filter routines presented in section 3.4.1.2 to obtain the log-likelihood function conditioned on an observed date, $\ln L\left(\theta \middle| Y^T\right)$. Then, initial θ is updated in terms of the MH random walk. This updated initial θ will be put into the Kalman filter to produce a second estimate of the likelihood of the linear approximate DSGE model. The MCMC MH algorithm will decide if the initial or updated θ and associated likelihood can be forward to the next step of the MCMC MH algorithm. Given this decision, the next step of the MCMC MH algorithm is to get a new proposed update of initial θ by the random walk law of motion and to produce an estimate of the likelihood at these estimates. This likelihood is compared to those obtained from the previous MH step using the MH decision rule to choose the likelihood. This process is repeated 20,000 times here to generate the posterior of the linear approximate DSGE model. Using this method the MH algorithm not only travels to the higher regions of the posterior but also towards the lower regions. This avoids it getting trapped in local maxima and gives a precise posterior. In MCMC MH algorithm, two parallel chains were used and all of the values passed all tests of convergence. In the Bayesian inference, the posterior distribution has important information regarding the location and uncertainty of the parameters.

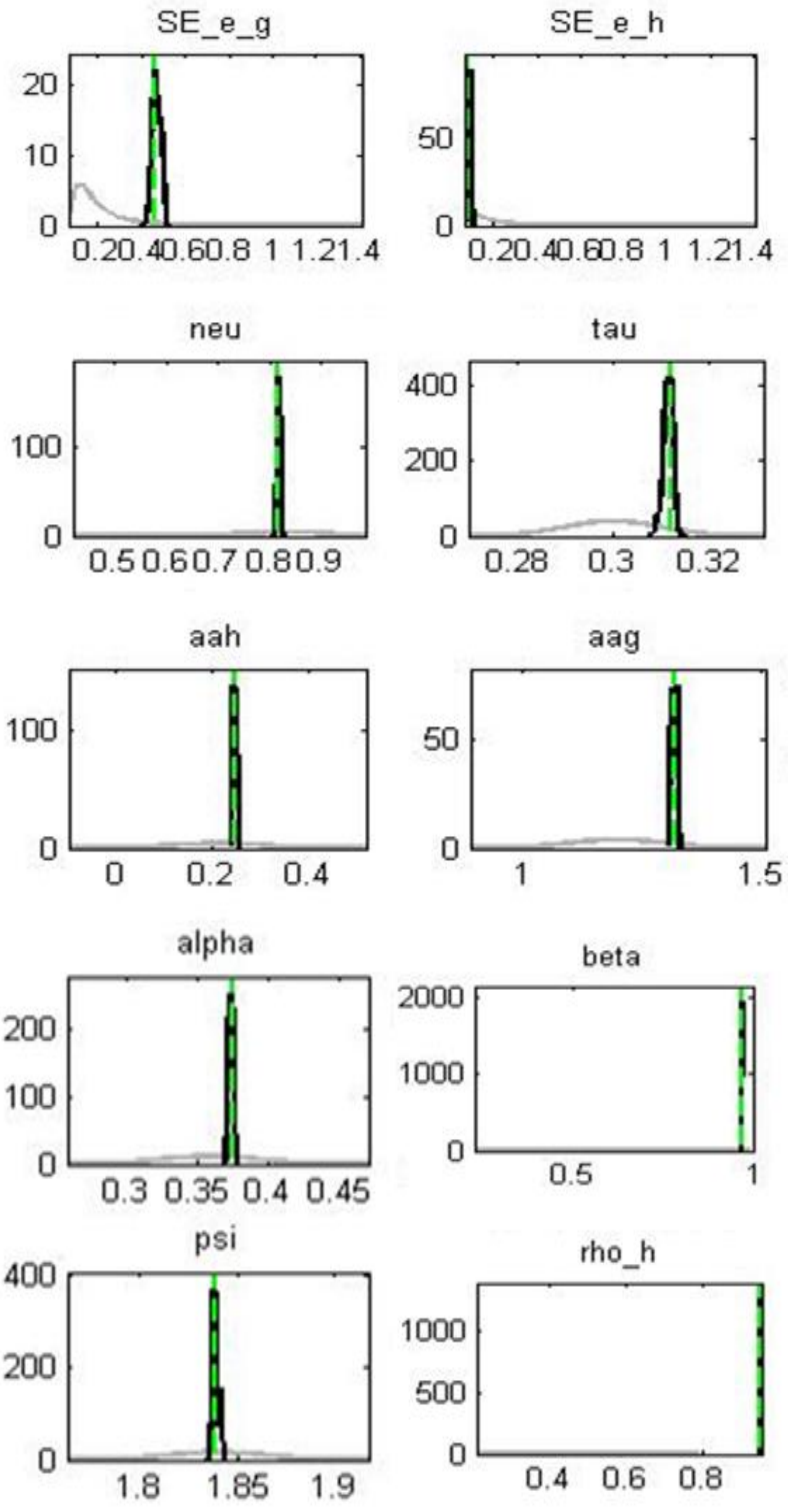
The posterior mean and the standard deviation of the 11 estimated parameters of the CIA baseline model are reported in Table 3.5. It presents a 95% highest posterior density interval for each structural parameter. For the lower and upper limits of 95 % highest posterior density interval, 2.5% and 97.5% percentiles are selected. Figure 3.4 also demonstrates the posterior distribution for the main behavioural parameters. A direct comparison of the full posterior and prior distributions of the parameters often provide valuable implications for how much data provides information for the parameters of interest. Overall, the posterior distributions are moderately close to the prior distributions. However, some parameters, such as the relative weight to leisure, seem to respond less well to the data. It may imply that the prior of this parameter is heavily data-based. As I used relatively tight priors for most values, it seems that identification is fairly strong. Most posterior standard deviations are smaller than those of prior standard errors as they contain the information from the data.

Table 3.5 Posterior Distributions for Structural Parameters

Parameters	Descriptions	Density	Mean	S.D.
β	Discount factor	Beta	0.9709 (0.9706,0.9713)	0.100
a	Capital's share in output	Beta	0.3734 (0.3712,0.3752)	0.035
ω	Relative weight to leisure	Beta	1.8390 (1.8375,1.8417)	0.025
$\bar{A}_G$	Steady-state physical technology growth rate	Normal	1.3185 (1.3116,1.3250)	0.100
$\bar{A}_H$	Steady-state human capital technology growth rate	Normal	0.2459 (0.2418,0.2502)	0.100
v	Effective labour share in human capital production	Beta	0.8178 (0.8145,0.8207)	0.100
τ	Steady-state tax rate	Beta	0.3115 (0.3104,0.3130)	0.010
ρ_G	AR physical capital technology shock	Beta	0.7583 (0.7539,0.7618)	0.100
ρ_H	AR human capital technology shock	Beta	0.9524 (0.9519,0.9529)	0.100
σ_G	s.d. physical capital technology shock	Inv.Gamma	0.4691 (0.4464,0.4985)	Inf
σ_H	s.d. human capital technology shock	Inv.Gamma	0.0871 (0.0803,0.0955)	Inf

Note: Posterior mean, standard deviations and 95% probability intervals in parentheses are based on the output of the Metropolis-Hastings Algorithm. Sample range: 1960:01 to 2007:04. Money growth μ is obtained by AR(1) model fitting using M0 in US. Its mean is 0.037 ,and ρ_μ is 0.54 with a standard deviation of 0.01.

Figure 3.4 Posterior Distributions for Structural Parameter



Note: SE_e_g = σ_G ,SE_e_h=σ_H , neu=ν , tau=τ , aah=$\bar{A}_H$, aag=$\bar{A}_G$, alpha=a , psi=ω , beta=β , rho_h=ρ_H

It is worth making a number of estimated parameters regarding the estimated process for the exogenous shock variables. The posterior mean of the discount factor is 0.97, which implies an annualised steady-state real interest rate of around 4%. The last two rows in the table show the estimated magnitudes of shocks and their standard deviations. Estimation of the shock process shows that the estimated standard deviations are larger than the existing papers. It reflects that these parameters are heavily based on the likelihood function.

3.5.3 Impulse Responses Analysis

Given the prior means of the estimated structural parameters in the baseline model, this section shows the responses to the three shocks: a positive physical capital technology shock, human capital technology shock and a money shock for the first ten years. The magnitude of the shocks is given by the posterior estimate of one standard deviation of the shock, in other words, the impulse responses to orthogonalised shocks to three parameters, $\bar{A}_G$, $\bar{A}_H$ and μ based on the log-linearisation of the full equations system. The full joint posterior distribution of structural parameters and shocks to produce the Bayesian uncertainty bounds of the impulse response functions are employed. Two different technology shocks in the goods and human capital investment sectors induce different effects on seigniorage and output growth while the monetary shock has a positive effect on seigniorage and output growth. The outcomes of the main economic variables to the uncertainty surrounding these structural shocks are discussed in this section.

3.5.3.1 Responses to a Positive Physical /Human Capital Technology Shock

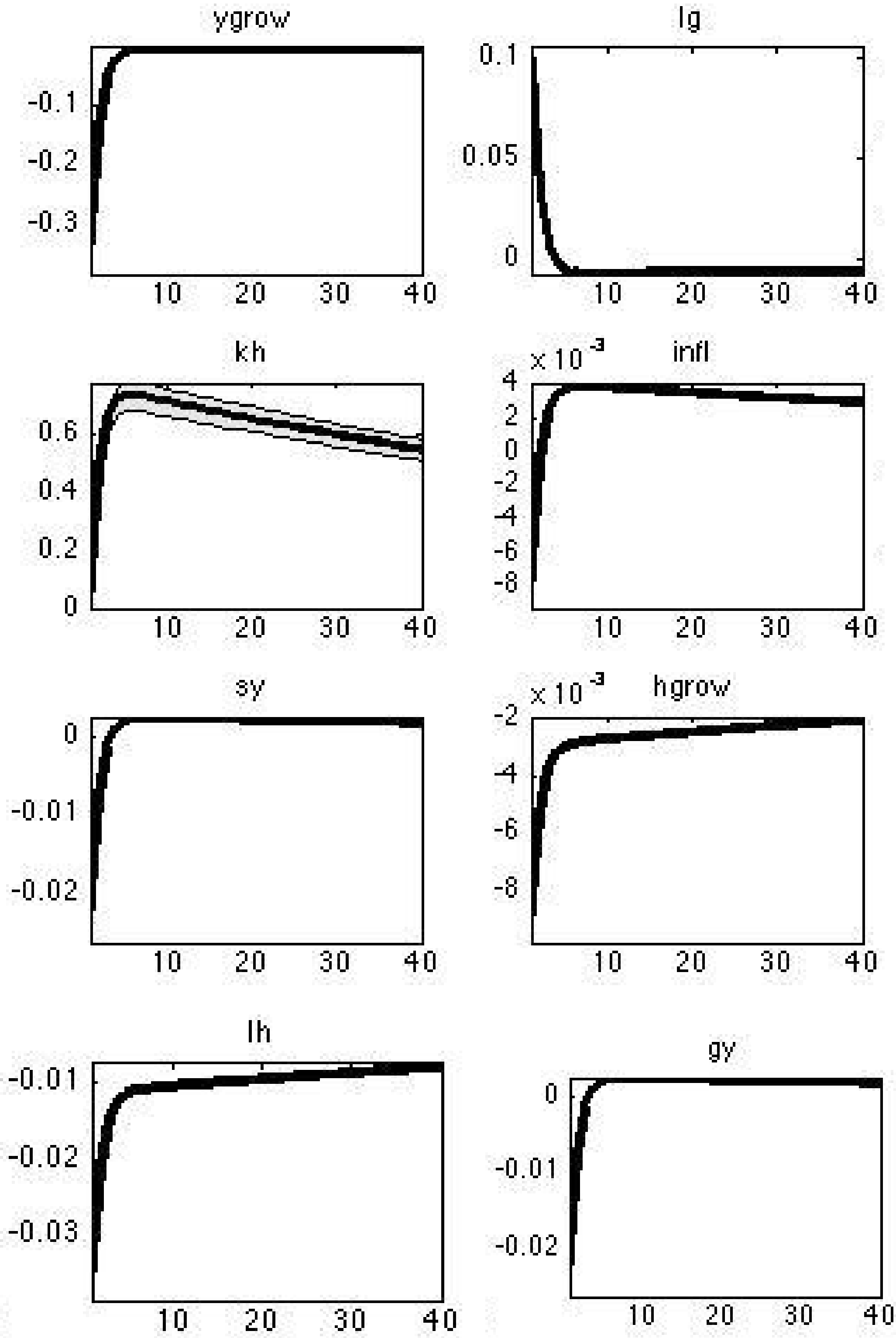
There are two productivity shocks in this model, namely: physical capital technology shock and human capital technology shocks. Figure 3.5 shows that a positive physical capital technology shock in the goods sector makes households substitute away from human capital investment time l_h and leisure z towards l_g working in the goods sector. This initial monetary shock raises the physical capital investment; hence it leads to a rise in the physical capital to human capital ratio $\frac{k}{h}$. The output growth fell because of a rise in the physical capital investment via diminishing marginal returns to capital (Basu *et al.*, 2012). The higher productivity raises the real wage and lowers the inflation rate. Secondly, since households prefer to spend time in physical capital investment rather than in leisure and in human capital investment, it decreases the growth of human capital. A positive productivity shock in the goods sector temporarily lowers the inflation rate and seigniorage rate. Since the revenue of government spending is decreasing, the reaction of government spending $\frac{g}{y}$ on a positive productivity shock is also negative. A fall in time spent in human capital production sector l_h and government investment in education leads to a lower growth of output.

Figure 3.6 shows that a positive technology shock in the human capital investment results in agents substituting time spent on leisure and labour in favour of investment in human capital investment. As the human capital investment rate goes up, there is a decline in the physical capital to human capital ratio $\frac{k}{h}$. Inflation rate declines as households spend less time on goods production which leads to a higher wage rate and lower relative price of output. However, when there is a positive human capital technology shock in the first five quarters, there is a prompt rise in seigniorage and government spending. Since there is more time invested in the human capital sector and more government spending in education, it leads to a rise in a growth of human capital as well as a growth of output.

3.5.3.2 Responses to a Money Shock

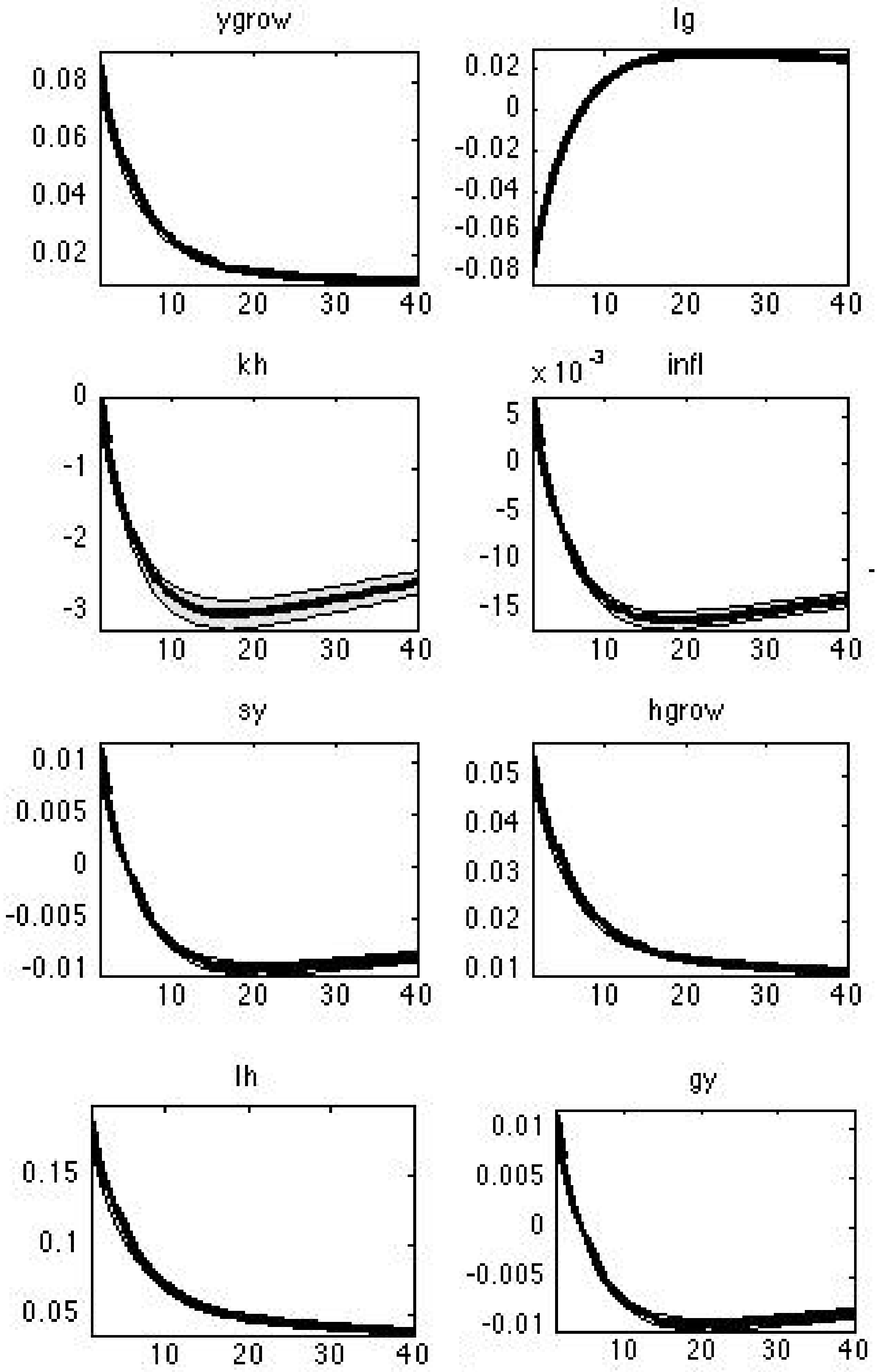
In Figure 3.7, a positive monetary shock leads to a positive impact on the inflation rate, thereby imposing substitution from goods to human capital investment and leisure since there is an inflation tax on the consumption of goods. The initial decrease in hours spent in good sectors l_g corresponds to the prompt decrease in the physical capital to human capital ratio $\frac{k}{h}$. However, a positive money shock raises the seigniorage which is one of the revenues of government spending. A positive monetary shock induces agents to switch time from goods production, which is subject to inflation tax, to leisure and human capital investment to which l_h instantly reacts positively. It also shows the positive relationship between the seigniorage and the government spending. As government spending $\frac{g}{y}$ goes up owing to the seigniorage and time to human capital investment l_h is up because of inflation tax, and there is a rise in output growth and human capital growth. Following Lucas (1988), the growth of human capital stocks leads to a growth of output. This confirms that the money injection has a positive effect on money growth through the public education spending financed by seigniorage.

Figure 3.5 Responses to a Positive Physical Capital Technology Shock



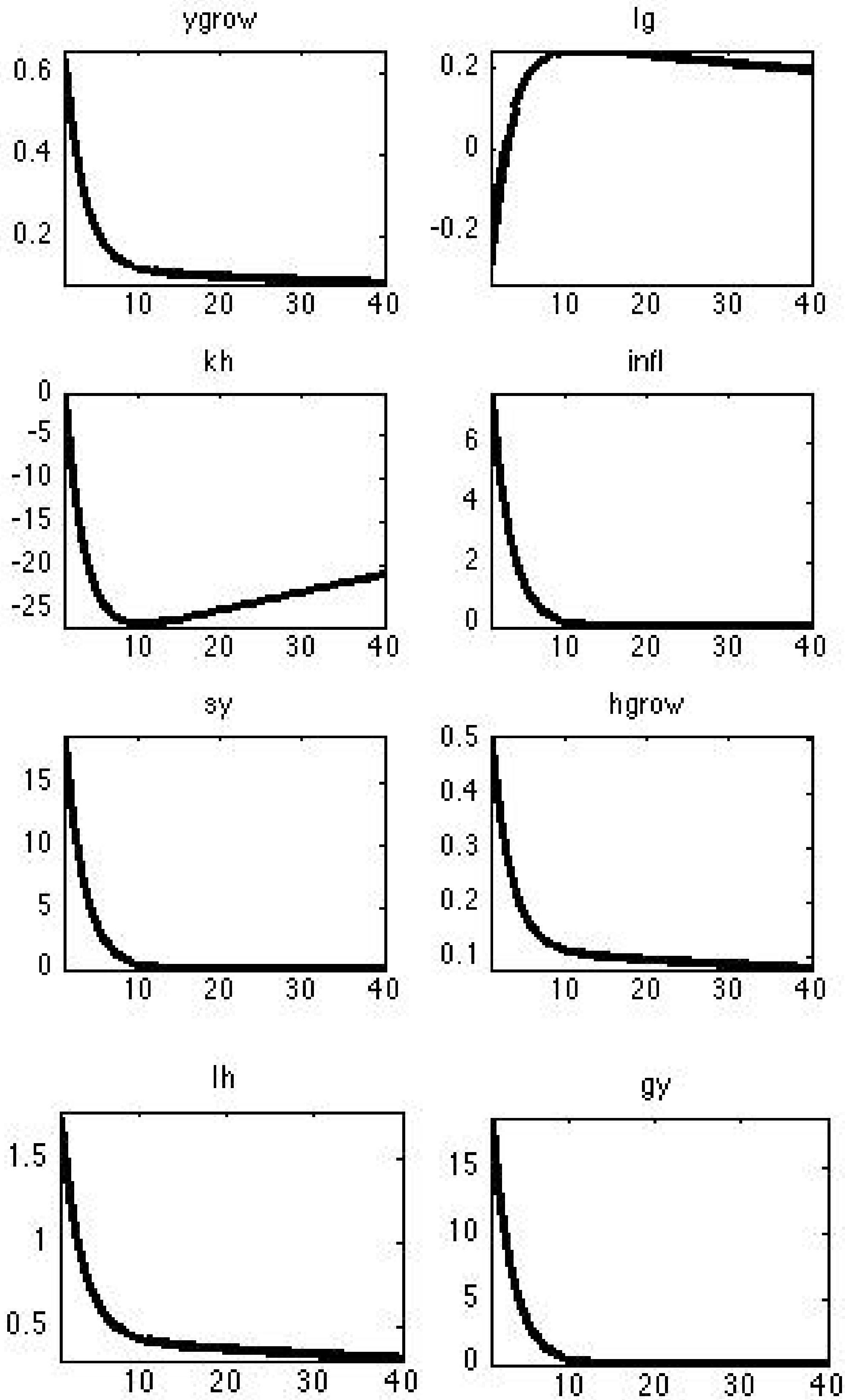
Note: ygrow=output growth , lg=time spent in goods production, kh=k/h, infl=inflation, sy=s/y seigniorage, hgrow=human capital growth, lh=time spent in human capital accumulation, gy=g/y government spending.

Figure 3.6 Responses to a Positive Human Capital Technology Shock



Note: ygrow=output growth , lg=time spent in goods production, kh=k/h, infl=inflation, sy=s/y seigniorage, hgrow=human capital growth, lh=time spent in human capital accumulation, gy=g/y government spending.

Figure 3.7 Responses to a Money Shock



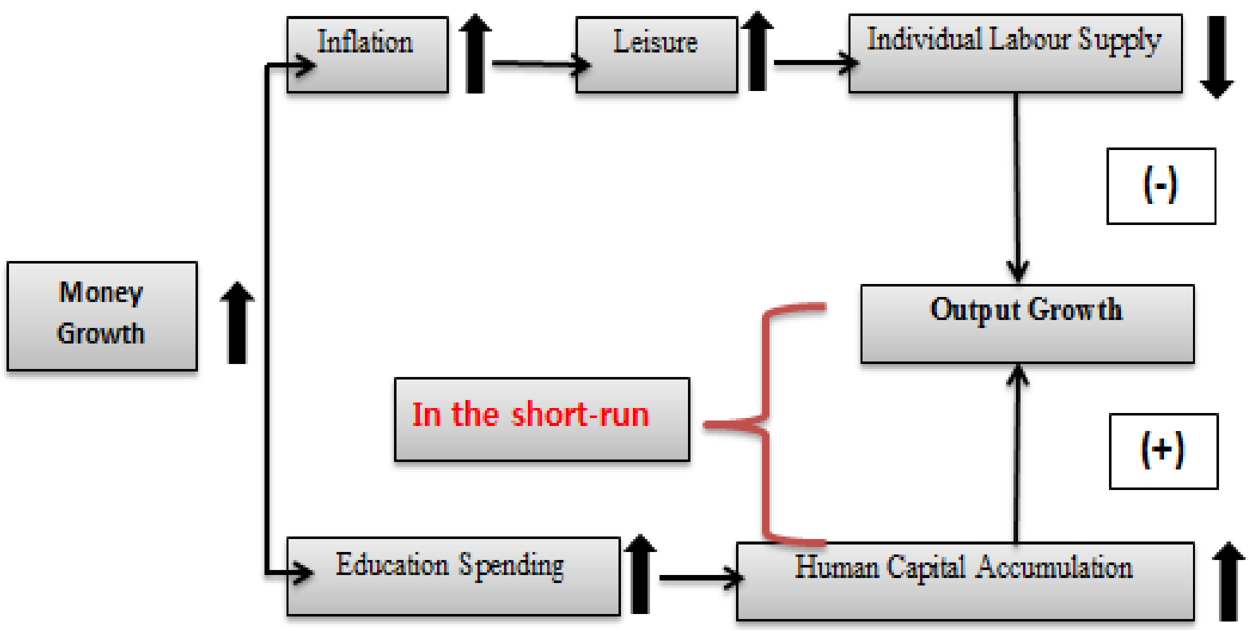
Note: ygrow=output growth , lg=time spent in goods production, kh=k/h, infl=inflation, sy=s/y seigniorage, hgrow=human capital growth, lh=time spent in human capital accumulation, gy=g/y government spending.

3.6 Conclusion

In this chapter, I have developed a model of money growth, seigniorage and output growth that has allowed us to examine the effects of money growth on seigniorage and long-term growth. I estimated the cash-in advance and human capital based endogenous growth model in which a government spends its revenue from seigniorage on public education. In the theoretical model, the money growth has two different effects on economic growth. A positive money growth leads to a higher seigniorage rate. Contrary to Basu *et al.* (2012), there is a positive effect of money growth on output growth since the government uses seigniorage as an input for productivity in human capital. The public education spending by financed seigniorage could play a crucial role by affecting the productivity of input in the firm's production function as it can help with the accumulation of human capital (Michaelowa(2000); Dahlin (2005)). On the other hand, the negative effects are from the inflation tax. Inflation, which acts as a tax on the cash goods, distorts the consumption of cash goods relative to credit goods (Gillman, 2005). Substitution from cash goods towards leisure reduces the employed time so that this significantly decreases the output growth rate. Similar to Basu (2001)'s work, there are two opposing effects from seigniorage to economic growth. While Basu (2001) found the relationship between reserve-augmented seigniorage and output growth, this chapter showed the linkage between seigniorage and output growth through the human capital channel. Seigniorage has a growth enhancing effect from human capital production through government spending on education. It also has a negative effect as it acts as a tax on the cash goods.

In order to define the role of money shock in a short run, the Bayesian estimation using US quarterly data from 1960:01 to 2007:04 is adopted. Combining the likelihood function with prior distributions for the parameters of the model, this helps to estimate the posterior density function for the parameters. In the short run, the impulse repose analysis provides that there is a positive movement in output when there is a money shock. A positive shock to money leads to the increase in output, seigniorage and government spending and a decrease in time spent in goods production in the short-term. The finding from our estimation reflects the benefits and costs of money supply that are owing to government spending on education. Positive money growth helps to increase seigniorage and government revenue, which can finance more government spending on education. Education in particular, which is a major source of human capital, makes labour more productive, therefore accelerating economic growth (Loaning, 2004). Cooley and Hansen (1989) examined the negative effect of seigniorage on output through a welfare cost effect. However, an implication of the finding in this chapter suggests that appropriate government education standing can help turn seigniorage into a more efficient engine of outgrowth. Overall, this is illustrated in Figure 3.8.

Figure 3.8 Effects of Money Growth on Output Growth in the Model



In the theoretical model, there is a clear positive relationship between money growth and government spending and a negative relationship between money growth and private consumption in the long-tern. However, in the short-term, money growth only has a positive impact on output growth. This is because a positive effect may be stronger than a negative effect in the short-term. Since a log-linearisation model in the Bayesian estimation is applied, this may be unable to catch the non-linear relationship between seigniorage and economic growth. This will be explored further in the next chapter.

Nevertheless, there are some limitations to this chapter. If money supply and seigniorage do not clearly demonstrate a major effect on the real economy, this must exist through channels which I have not explored here. I have confirmed the positive effect of money on growth in the short-term. It may have non-linearity in the short-term which I have not really explored because it is the log-linearised model. A full blown theoretical analysis of non-linearity in a DSGE growth framework is beyond the scope of the chapter but this can be a future line of research. This chapter has focused on only public education spending in the US economy, and it did not attempt to account for other important features such as public infrastructural investment. In future research, it would also be useful to extend the analysis to permit more realistic ones by employing financial sectors since seigniorage can be generated by imposing a reserve requirement on banks. In addition, I have left out other concepts of seigniorage. Seigniorage revenue can be caused through not only printing money but also issuing bonds. Hence estimating seigniorage through an open market operation on growth seems to be an interesting topic for future research.

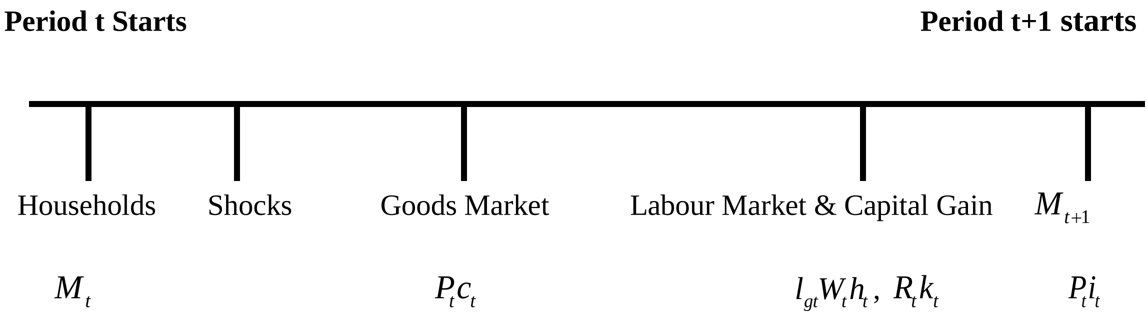
Appendix 3

Appendix 3.A Time Line of CIA Model

A simple version of the cash in advance is that, in discrete time, purchases in the goods market must be paid for with money which is held at the beginning of the period. In this model, a credit system is not considered. One of the comparative advantages of money over a credit system is that money may be more cumbersome to carry, but a credit system can be expensive as there is a need for record keeping. Moreover a credit system requires each individual's credit information but a money system does not need to hold such information. Therefore, since there is uncertainty about endowment and no financial system, money dominates a credit system in this model. The time line in this model is as follows:

1. Households start period t with money stock M_t which is carried from period $t-1$;
2. Three exogenous shocks, physical capital technology shock, human capital technology shock and monetary shock, occur. The injected money $\frac{M_{t+1}-M_t}{P_t}$ can be used for human capital accumulation;
3. The goods markets open and households purchase the consumption goods with money $P_t c_t$;
4. Households receive the wage and capital gain $l_{gt}W_t h_t + R_t k_t$;
5. All money holding M_{t+1} is carried by households to period $t+1$ while investment $P_t i_t$ in the economy is carried by firms to period $t+1$;

Figure 3.A Time Line of CIA Model



Appendix 3.B List of Variables and Parameters

Variables	Descriptions	Parameters	Descriptions
c	Consumption	β	Discount factor
z	Leisure	a	Capital's share in output
l_g	Time spent in goods production	ω	Relative weight to leisure
l_h	Time spent in human capital accumulation	$\bar{A}_G$	Steady-state physical technology growth rate
P	Aggregate price level	$\bar{A}_H$	Steady-state human capital technology
M	Nominal money balance	v	Capital's share in human capital production
i	Physical investment	τ	Tax revenue (% GDP)
r	Real return on physical capital	ρ_G	AR physical capital technology shock
h	Stock of human capital	ρ_H	AR human capital technology shock
w	Real wage	ρ_μ	AR money shock
k	Stock of physical capital	σ_G	s.d. physical capital technology shock
G	Government spending on education	σ_H	s.d. human capital technology shock
s	Seigniorage	σ_μ	s.d. money growth shock
y	Output	δ_g	Depreciation rate of the capital stock
d_{t+1}	Stochastic discount factor	δ_h	Depreciation rate of human capital
γ	Rate of output growth	μ	Money growth rate
π	Rate of inflation		

Appendix 3.C Summary of CIA Model

3.C.1 Solving CIA Model

The optimal plan of the household is solved by applying the Lagrangian method. I define the Lagrange multipliers associated with the flow budget constraint for the household which is also the marginal utility of nominal wealth (3.7) as λ_t, the human capital technology (3.9) as η_t and the cash-in-advance constraint on consumption (3.6) as ψ_t.

$$L^p = \sum_{t=0}^{\infty} \beta^t \left[\ln(c_t) + \omega \ln(z_t) \right] + \sum_{t=0}^{\infty} \lambda_t \left[P_t w_t l_{gt} h_t + M_{t+1} + P_t r_t k_t - P_t c_t - P_t i_t^k - M_t \right]$$

$$+ \sum_{t=0}^{\infty} \eta_t \left[A_{Ht} \left(l_{ht} h_t \right)^{\nu} G_t^{1-\nu} + \left(1-\delta_h\right) h_t - h_{t+1} \right] + \sum_{t=0}^{\infty} \psi_t \left[M_t - P_t c_t \right]$$

The first order conditions are:

$$\frac{\partial L^p}{\partial c_t} = \beta^t \frac{\omega}{c_t} - \lambda_t P_t - \psi_t P_t = 0 \tag{3.C.1}$$

$$\frac{\partial L^p}{\partial l_{gt}} = -\beta^t \frac{\omega}{z_t} + \lambda_t P_t w_t h_t = 0 \tag{3.C.2}$$

$$\frac{\partial L^p}{\partial l_{ht}} : -\beta^t \frac{\omega}{z_t} + \eta_t A_H \nu \left(l_{ht} h_t \right)^{\nu-1} G_t^{1-\nu} = 0 \tag{3.C.3}$$

$$\frac{\partial L^p}{\partial k_{t+1}} = -\lambda_t P_t + \lambda_{t+1} \left[\left(1-\delta_g\right) P_{t+1} + P_{t+1} r_{t+1} \right] = 0 \tag{3.C.4}$$

$$\frac{\partial L^p}{\partial h_{t+1}} = -\eta_t + \eta_{t+1} \left[\left(1-\delta_h\right) + A_H \nu l_{ht+1}^{\nu} G_{t+1}^{1-\nu} \left(h_{t+1} \right)^{\nu-1} \right] + \lambda_{t+1} l_{gt+1} P_{t+1} w_{t+1} = 0 \tag{3.C.5}$$

$$\frac{\partial L^p}{\partial M_{t+1}} = -\lambda_t + \lambda_{t+1} + \psi_{t+1} = 0 \tag{3.C.6}$$

$$\frac{\partial L^P}{\partial \psi_t} = M_t - P_t c_t = 0 \tag{3.C.7}$$

Using (3.C.1) and (3.C.6), λ_t is:

$$\lambda_t = \beta^{t+1} \frac{\left\{u\left(c_{t+1}\right) + \omega \Gamma\left(z_{t+1}\right)\right\}}{P_{t+1}} \tag{3.20}$$

Using (3.C.4) into (3.20):

$$\frac{u_{c_{t+1}}(c_{t+1}, z_{t+1})}{P_{t+1}} P_t = \beta \frac{u_{c_{t+2}}(c_{t+2}, z_{t+2})}{P_{t+2}} P_{t+1}\left[\left(1-\delta_g\right) + r_{t+1}\right] \tag{3.C.8}$$

By substituting (3.C.4) into (3.C.8), λ_t can be written as:

$$\lambda_t P_t = \lambda_{t+1} P_{t+1}\left[\left(1-\delta_g\right) + r_{t+1}\right] \tag{3.19}$$

where r_{t+1} is the real return on physical capital at time $t+1$.

In order to get (3.21), I employ equations (3.19) and (3.C.6):

$$\lambda_t P_t = \lambda_{t+1} P_{t+1}\left[\left(1-\delta_g\right) + r_{t+1}\right] = P_t\left(\lambda_{t+1} + \psi_{t+1}\right) \tag{3.C.9}$$

A binding cash in advance constraint (3.6) can be written as:

$$\frac{c_{t+1}}{c_t}\frac{P_{t+1}}{P_t} = \frac{M_{t+1}}{M_t} \tag{3.23}$$

Using (3.23) and (3.18):

$$\frac{\lambda_{t+1} P_{t+1}}{\lambda_t P_t} = d_{t+1} \tag{3.C.10}$$

Using (3.C.2) and (3.C.3):

$$\frac{\eta_t}{\lambda_t P_t} = \frac{h_t A_G (1-a) l_{gt}^{-a} \left(\frac{k_t}{h_t}\right)^a}{A_H \nu l_{ht}^{\nu-1} \left(\frac{G_t}{h_t}\right)^{1-\nu}} \tag{3.24}$$

(3.C.5) can be written as:

$$\frac{\eta_t}{\lambda_t P_t} = \frac{\eta_{t+1}}{\lambda_{t+1} P_{t+1}} \frac{\lambda_{t+1} P_{t+1}}{\lambda_t P_t} \left[(1-\delta_h) + A_H \nu l_{ht+1}^{\nu} \left(\frac{G_{t+1}}{h_{t+1}}\right)^{1-\nu} \right] + \frac{\lambda_{t+1} P_{t+1}}{\lambda_t P_t} l_{gt+1} w_{t+1} \tag{3.C.11}$$

The time length that is devoted to leisure z_t can be obtained by using equations (3.C.11) and (3.C.2):

$$z_t = \left(1 + \frac{\psi_t}{\lambda_t}\right) \frac{(1-\omega)}{\omega} \frac{c_t}{h_t} \frac{1}{w_t} \tag{3.25}$$

Using (3.C.1) and (3.C.4):

$$1 + \gamma = \beta \left[(1-\delta_g) + A_G \alpha l_{gt}^{1-a} \left(\frac{k_t}{h_t}\right)^{a-1} \right] \tag{3.32}$$

Along a steady state $\frac{\eta_t}{\lambda_t P_t}$ is constant and using (3.C.1), and (3.C.11) is now:

$$1 + \gamma = \beta \left[(1-\delta_h) + A_H \nu l_{ht+1}^{\nu} \left(\frac{G_{t+1}}{h_{t+1}}\right)^{1-\nu} \right] + \beta l_{gt+1} w_{t+1} \frac{\lambda_{t+1}}{\eta_{t+1}}$$

Using (3.24) the growth rate can be shown as:

$$1 + \gamma = \beta \left[(1-\delta_h) + A_H \nu l_{ht+1}^{\nu} \left(\frac{G_{t+1}}{h_{t+1}}\right)^{1-\nu} \right] + \beta l_{gt+1} A_H \nu l_{ht}^{\nu-1} \left(\frac{G_t}{h_t}\right)^{1-\nu} \tag{3.C.12}$$

Using (3.16) along the balanced growth path:

$$\frac{G}{h} = \mu\left(\frac{m}{h}\right) + \tau\left(\frac{y}{h}\right) \tag{3.C.13}$$

(3.C.2) can be written as:

$$\frac{\omega_t}{1 - l_{gt} - l_{ht}} = \frac{\beta}{(1+\mu_t)} w_t \left(\frac{c_t}{h_t}\right) \tag{3.C.14}$$

Using (3.C.12) and (3.30) the long run growth is:

$$1 + \gamma = A_H \nu (1 - z)\left(\frac{G}{l_h h}\right)^{1-\nu} \tag{3.33}$$

3.C.2 Short-run Equations

We have ***18*** equations for ***18*** unknown variables. The unknown variables are:

$d_{t+1}, k_t, G_t,\ w_t,\ r_t,\ P_t, M_t, c_t,\ l_{gt}, l_{ht}, y_t,\ h_t, \pi_t,\ i_t\ s_t\ A_{Gt}, A_{Ht}, \mu_t$

The short-run system can be summarised as follow.

The standard discount factor d_{t+1} is given by:

$$d_{t+1} = \beta\left(\frac{\frac{c_t}{h_t}}{\frac{c_{t+1}}{h_{t+1}}}\right)\frac{1}{1 - \delta_h + A_{Ht} l_{ht}^{\nu}\left(\frac{G_t}{h_t}\right)^{1-\nu}}\left(\frac{\frac{1}{1+\mu_{t+2}}}{\frac{1}{1+\mu_{t+1}}}\right) \tag{3.C.15}$$

The balanced growth equation in terms of the physical capital net return, the Euler equation for k is:

$$1 = \beta d_{t+1}\left[\left(1-\delta_g\right) + A_{Gt+1}\alpha\left(\frac{k_{t+1}}{l_{gt+1}h_{t+1}}\right)^{a-1}\right] \quad (3.C.16)$$

The balanced growth equation in terms of the human capital net return, the Euler equation for h is:

$$1 = \beta d_{t+1}\left[\left(1-\delta_h\right) + A_{Ht}\nu l_t^{\nu}\left(\frac{G_t}{h_t}\right)^{1-\nu}\right] + \beta d_{t+1}A_{Ht}\nu l_t^{\nu-1}\left(\frac{G_t}{h_t}\right)^{1-\nu} \quad (3.C.17)$$

The labour's marginal product, the real wage w is:

$$w_t = A_{Gt}\left(1-a\right)l_{gt}^{-a}\left(\frac{k_t}{h_t}\right)^{a} \quad (3.C.18)$$

The real rate of return on capital r is:

$$r_t = aA_{Gt}k_t^{a-1}(l_{gt}h_t)^{1-a} \quad (3.C.19)$$

$\frac{k}{h}$ equation is:

$$\frac{k_{t+1}}{h_{t+1}} = \frac{l_{gt}\frac{W_t}{P_t} + \left(\frac{R_t}{P_t}\left(1-\delta_k\right)\right)\left(\frac{k_t}{h_t}\right) - \left(\frac{G_t}{h_t}\right) - \left(\frac{c_t}{h_t}\right)}{\left(1-\delta_h\right) + A_{Ht}l_{ht}^{\nu}\left(\frac{G_t}{h_t}\right)^{1-\nu}} \quad (3.C.20)$$

$\frac{G}{h}$ equation is:

$$\frac{G_t}{h_t} = \tau_t\frac{y_t}{h_t} + \mu_t\frac{c_t}{h_t} \quad (3.C.21)$$

The Euler equation for leisure is:

$$\frac{\omega_t}{1-l_{gt}-l_{ht}}=\frac{\beta}{(1+\mu_t)}\frac{W_t}{P_t}\left(\frac{h_t}{c_t}\right) \tag{3.C.22}$$

The output growth equation is:

$$\frac{y_{t+1}}{y_t}=\frac{A_{Gt+1}}{A_{Gt}}\left(\frac{k_{t+1}/h_{t+1}}{k_t/h_t}\right)^{\alpha}\left(\frac{l_{gt+1}}{l_{gt}}\right)^{1-\alpha}\left(\frac{h_{t+1}}{h_t}\right) \tag{3.C.23}$$

The human capital growth equation is:

$$\frac{h_{t+1}}{h_t}=1-\delta_h+A_H l_{ht}^{\nu}\left(\frac{G_t}{h_t}\right)^{1-\nu} \tag{3.C.24}$$

The inflation equation is:

$$1+\pi_t=\frac{(1+\mu_t)}{\left(\frac{h_t c_{t+1}}{h_{t+1}c_t}\frac{h_{t+1}}{h_t}\right)} \tag{3.C.25}$$

$\frac{i}{h}$ equation is:

$$\frac{i_t}{h_t}=\frac{k_{t+1}}{h_{t+1}}\frac{h_{t+1}}{h_t}-(1-\delta_k)\left(\frac{k_t}{h_t}\right) \tag{3.C.26}$$

$\frac{y}{h}$ equation is:

$$\frac{y_t}{h_t}=A_{Gt}l_{gt}^{1-a}\left(\frac{k_t}{h_t}\right)^{a} \tag{3.C.27}$$

The seigniorage is:

$$s_t = \mu_t \frac{c_t}{h_t A_{Gt} l_{gt}^{1-a} \left(\frac{k_t}{h_t} \right)^a} \tag{3.C.28}$$

$\frac{G}{y}$ equation is:

$$\frac{G_t}{y_t} = \frac{G_t}{h_t A_{Gt} l_{gt}^{1-a} \left(\frac{k_t}{h_t} \right)^a} \tag{3.C.29}$$

The process of the exogenous variables is as follow.

A_H process is:

$$A_{Ht} - \bar{A}_H = \rho_H \left(A_{Ht-1} - \bar{A}_H \right) + \varepsilon_t^H \tag{3.C.30}$$

A_G process is:

$$A_{Gt} - \bar{A}_G = \rho_G \left(A_{Gt-1} - \bar{A}_G \right) + \varepsilon_t^G \tag{3.C.31}$$

μ process is:

$$\mu_t - \bar{\mu} = \rho_\mu \left(\mu_{t-1} - \bar{\mu} \right) + \varepsilon_t^\mu \tag{3.C.32}$$

Appendix 3.D Steady-state values and assigned values of variables and parameters

Variables	Steady-state values	Parameters	Assigned values
z	0.5	β	0.9900
r	0.2	a	0.3600
l_g	0.14	ω	1.8400
l_h	0.10	$\bar{A}_G$	1.2000
r	0.2	$\bar{A}_H$	0.2100
w	0.2	ν	0.8000
G	0.16	ρ_G	0.5000
s	0.01	ρ_H	0.5000
π	0.03	ρ_μ	0.5400
γ	0.02	σ_G	0.2500
d_{t+1}	0.94	σ_H	0.2500
G	0.16	σ_μ	0.0100
τ	0.3000	V	0.0300
		δ_G	0.03
		δ_H	0.024
		μ	0.037

Appendix 3.E Dynare Codes

```
// Mod programme for the endogenous growth model when govt spends on education//

var  d w r kh lg lh gh ch ygrow hgrow ag ah mu infl ih yh gy sy;

varexo e_g e_h e_mu;

parameters beta alpha delta_k delta_h omega rho_g rho_h rho_mu meu aag aah neu tau;

//Most of the baseline parameters are taken from Gillman et al. CEPR paper@

meu=0.037;
neu=0.8;
tau=0.3;
aah=0.21;
aag=1.2;
beta=0.99;
alpha=0.36;
delta_k=0.03;
delta_h=0.024;
omega=1.84;
rho_g=0.50;
rho_h=0.50;
rho_mu=0.54;


model;

//The discount factor//
d=beta*(ch/ch(+1))*(1/hgrow)*((1+mu(+1))/(1+mu(+2)));

//real wage//
w=ag*(1-alpha)*(kh^alpha)*(lg^(-alpha));

//real rental price//
r=ag*alpha*lg^(1-alpha)*kh^(alpha-1);

//kh equation//
 kh=(lg(-1)*w(-1)+(r(-1)+1-delta_k)*kh(-1)-gh(-1)-ch(-1))
/(1-delta_h+ah(-1)*lh(-1)^neu*gh(-1)^(1-neu));

//gh equation//
gh=tau*yh+mu*ch;

//Euler equation for k//
 1=beta*d*(1-delta_k+ag(+1)*alpha*(lg(+1)^(1-alpha))*kh(+1)^(alpha-1));

//Euler equation for h//
```

```
(w/(neu*ah*lh^(neu-1)*gh^(1-neu)))-(w(+1)/(neu*ah(+1)*lh(+1)^(neu-1)*gh(+1)^(1-
neu)))*d*(1-delta_h+ah(+1)*neu*(lh(+1)^neu)*gh(+1)^(1-neu))
-(d*lg(+1)*w(+1))=0;

//Euler equation for leisure//
 omega/(1-lg-lh)=(beta/(1+mu(+1)))*(w/ch);

//y growth equation//
 ygrow=(ag(+1)/ag)*(kh(+1)/kh)^alpha*(lg(+1)/lg)^(1-alpha)*hgrow;

//hgrow equation//
 hgrow=(1-delta_h)+ah*lh^neu*gh^(1-neu);

//infl equation//
infl=(1+mu(+1))*((ch(+1)/ch)*hgrow)^-1;

//ih equation//
 ih=kh(+1)*hgrow-(1-delta_k)*kh;

//yh equation//
yh= ag*kh^alpha*lg^(1-alpha);

//ag process//
ag-aag = rho_g * (ag(-1)-aag) + e_g;

//ah process//
 ah-aah = rho_h * (ah(-1)-aah) + e_h;

//meu process//
mu-meu = rho_mu *( mu(-1)-meu) + e_mu;

//sy seigniorage//
 sy=mu*ch*(ag*kh^alpha*lg^(1-alpha))^-1;

//gy//
gy=gh/(ag*kh^alpha*lg^(1-alpha));
end;


initval;

gh=0.12;
kh =0.97;
lg =0.14;
lh =0.10;
ag =1.2;
ah =0.35;
mu =0.07;
ygrow=1.01;
hgrow=1.01;
```

```
ch=0.18;
d=0.94;
w=0.2;
r=0.2;
sy=0.1;
end;

steady;

shocks;
var e_g;
stderr .25;
var e_h;
stderr .25;
var e_mu;
stderr .01;
end;

varobs ygrow infl gy;

estimated_params;
neu,beta_pdf,.8,.1;
tau,beta_pdf,.3,.01;
aah,normal_pdf,.21,.1;
aag,normal_pdf,1.2,.1;
beta,beta_pdf,.96,.1;
alpha,beta_pdf,.36,.035;
delta_k,beta_pdf,.03,.02;
delta_h,beta_pdf,.024,.02;
omega,normal_pdf,1.84,.025;
rho_g,beta_pdf,.5,.10;
rho_h,beta_pdf,.5,.10;

stderr e_g,inv_gamma_pdf,.25,inf;
stderr e_h,inv_gamma_pdf,.25,inf;
end;

estimation(datafile=data,mode_compute=6,mode_check,mh_replic=2000,mh_nblocks=2,mh_
drop=.1,mh_jscale=0.23,bayesian_irf,irf=40) ygrow, lg, lh, kh, infl, gy, sy, hgrow;
```

Chapter 4

Non-linear Effects of Seigniorage on Growth in Developing Countries

Abstract

This chapter examines the relationship between seigniorage and economic growth. I explore two non-linear regression models which I intend to utilise in this study of the relationship between seigniorage and economic growth using a balanced panel-data set of 70 developing countries covering the period from 1994 to 2006. In order to examine the threshold value, Hansen's (1999) threshold model and the quadratic model are employed. The panel threshold model enables us to estimate even when the asymptotic distribution of the t-statistic on the threshold variable is non-standard. This helps us to find the number of seigniorage thresholds, the seigniorage threshold value, and the marginal impact of seigniorage on economic growth in different regimes. The implications of the models are confirmed in that seigniorage and economic growth have an inverse U shape. The results confirm that the seigniorage rates exceeding 2.2715 % are associated with lower economic growth. Below this threshold, there is a positive relationship between seigniorage and economic growth.

4.1 Introduction

Seigniorage has traditionally been a supplementary means of financing the fiscal deficit, utilised by central banks printing fiat money. It has been used directly to cover revenue shortfalls. Money creation is a relatively inexpensive means of raising funds for a government. Whilst it is ostensibly low in cost, the social costs of issuing money are almost certainly higher than the actual cost of printing bank notes. A number of empirical studies show that there is a positive relationship between the rate of money creation and inflation rate. This money creation leads to an increase in the general price level, which causes a decrease in the real value of the monetary unit (Tanzi, 1978). The inflation generated by money creation is considered as inflation tax and the terms 'seigniorage' and 'inflation tax revenue' are often used interchangeably. When the government pays for goods and services with seigniorage revenue, the public absorbs this increase in money holding to retain the real value for money balance, making it constant. These results, in inflation working like a tax. It is similar to the raising of taxes for government to finance extra spending.

In the early stages of economic growth in developing countries, there are less developed capital markets and fewer chances for external borrowing, thus fiscal deficits are often financed through money creation. Once the government decides to intervene in the economy through investment in infrastructure or education, it is necessary to find a way to finance these expenditures. In developing countries, more often the fiscal system is not developed yet as the tax base is perhaps too small or tax evasion may exist. It is easy for the government to raise the revenue and avoid the problems associated with broad tax reforms caused by inflationary finance [45]. Thus, monetisation of fiscal deficits in some less developed economies becomes the primary reason for money creation and inflation, resulting in an observably high

[45] In the case of Russia, most previous state-owned companies which have been privatized do not pay their taxes and the annual inflation rate reached 300% and 190% in 1994 and 1995 respectively (Ferreria, 1999).

seigniorage rate as well as a high inflation rate. Given the central importance of the argument for seigniorage or inflationary finance as a channel of economic growth in developing countries, numerous studies have explored this issue.

Aghevli (1977) suggested that the comparison between the total cost of inflationary finance and the benefit from the additional public expenditure should be considered since additional normal tax revenue is hard to obtain in developing countries. He developed a model where the government is forced to conduct deficit financing. He showed that, while money expansion causes inflation which imposes welfare costs, it contributes to future consumption and investment. Ferreira (1999) argued that public expenditures affect positively the growth in the model so that the distortionary effect of inflation tax, seigniorage, is covered by the productive effect of government expenditures. They demonstrated the equilibrium where steady state physical capital grows together with inflation. They proposed that government expenditures financed by inflation tax support private capital accumulation.

Cagan (1956) and Friedman (1971) examined the extent to which the government or the central bank can maximise seigniorage revenue. In the 1980s, with a view of seigniorage as an inflation tax, numerous economists estimated the optimal size of seigniorage in terms of optimal taxation theory. For instance, Mankiew (1987) and Trehan and Walsh (1990) showed the point where government revenue is maximised and the social cost induced by taxes and seigniorage revenue is minimised using an optimal level of inflation.

It is well known that seigniorage leads to high inflation through money expansion. High inflation has many adverse effects by imposing welfare costs on the economy, inhibiting financial development by causing higher intermediation costs, and relative price changes. Stockman (1981) developed the cash-in-advance model where the money is complementary to capital and found that inflation has a negative impact on long run growth. Jones and

Manuellie (1995) and Chari *et al*. (1996) also developed models which showed that monetary policy and economic growth have a negative relationship to each other.

Numerous theoretical and empirical studies found that inflation-growth interaction is non-linear. In Weiss (1980) and Summer's (1981) studies, public expenditure was shown to cause inflation and sustained growth through an externality by increasing the quality of labour services. However, this is not a linear effect since inflation which is too high can cause harm to the economy owing to the flight from money which can be detrimental to the inflation tax base. Huybens and Bruce (1998) demonstrated that inflation has a negative effect on long-term growth when the level of inflation is above a threshold level. For instance, higher inflation harms financial market frictions and the efficiency of the financial system, thereby inhibiting growth. Government spending can have an impact on growth when inflation is not too high. Basu (2001) found that there is a growth-Laffer curve type relationship between reserve-augmented seigniorage and output growth. He argued that the reserve-augmented seigniorage has two opposing effects on growth. The high reserve ratio, one financial repression policy has a distortionary effect on growth while there is also the positive effect of a high reserve ratio if the reserve-augmented seigniorage revenue is productively spent by the government.

Fischer (1993) showed that there is a nonlinear relationship with breaks at 15 and 40 % by using cross-sectional data covering 93 countries. He confirmed that medium and high inflation rates impede economic growth because of the adverse impact that changes in price level have on the efficient distribution of resources, while low inflation helps economic growth by making prices and wages more flexible (Lucas, 1973). Sarrel (1995) also discovered structural breaks in the relationship between inflation and growth, using the fixed effect technique and panel data covering 87 countries over a period ranging from the 1970s to the 1990s. He found that the estimated threshold level is 8 %, and if inflation rates exceed this threshold point, inflation will have a negative impact on growth. Following Sarrel's (1995) work, Christoffersen and Doyle (1998) found a non-linear relationship between inflation and growth and their threshold level is 13 %. Most of these studies confirm the idea that low inflation is a good thing for the economy because it has a favourable influence on growth performance. Bruno and Easterly (1995) found a negative relationship between high inflation rates and economic growth but doubt the growth-enhancing effect of low inflation.

Khan and Senhadji (2001) discovered a non-linear relationship where low inflation rates have a positive impact on growth, while high inflation rates have a negative impact on growth. Moreover, they found an inflation rate threshold point at 11 % for developing countries. In other words, when the inflation rate is above 11 %, there is a significant negative effect on growth. Fabayo and Ajilore (2006) followed by Khan and Senhadji (2001), examined the inflation-growth relationship, employing Nigerian data over the period 1970 to 2003. Their results show that, below 6%, there is a positive relationship between inflation and economic growth.

Given that seigniorage shows a high correlation with inflation, it is worth investigating whether seigniorage and growth have a non-linear relationship as other existing studies regarding the inflation-growth nexus suggest. Most previous studies examined the effect of inflation on economic growth based on cross-country evidence but only limited studies estimate as to whether there is a non-linear relationship between seigniorage and economic growth.

In the previous chapter, I developed the theoretical model where the seigniorage is spent on public education by governments. The balanced growth equation [46] implies that an increase in money growth and seigniorage impacts on growth. The effect of seigniorage on output

[46] Please refer to the section, 3.3.5.3.

growth can be both positive and negative since money growth has two opposing effects on the growth rate. In other words, money growth has a growth-enhancing effect as well as an adverse effect on the growth rate. There has been a considerable debate within academic literature on the positive and negative roles of inflation in economic growth during the financial repression in the 1970s and 1980s (Roubini and Sachs, 1991). The inflation tax has a negative impact as well as a positive effect on output. The negative effect is from inflation since inflation acts as a tax on the cash goods which distort the consumption of cash goods relative to credit goods. Substitution from the cash goods towards leisure reduces [47] the employed time and time invested in human capital so that this significantly decreases the output growth rate. In the New Keynesian model, inflation is costly through relative-price distortions (Bill, 2012). The prices of goods and services are sticky meaning that the prices adjust infrequently even though the general price level is increasing over the period. Therefore, in the context of general price inflation, many prices do not fully reflect the relative costs of production. The higher inflation rate will lead to a greater distortion owing to price stickiness. When nominal wages and prices are sticky or when the menu cost hypothesis applies, increase in demand by inflationary finance, given aggregate supply, generates some growth in the short run. However, excessive inflation will soon be noticed. It distorts expectations leading to negative impacts on economic growth. Since government spending rises via an increase in seigniorage, there is a growth-enhancing effect. Basu *et al*. (2012) showed the positive effect of inflation tax by the Tobin (1965) effect of inflation to a high capital to human capital ratio. Even when there is a distortionary tax like inflation, public spending can improve the welfare of the economy due to the spill-over effect of public education spending and productivity.

[47] The non-cash good is not subject to CIA constraint in this model.

Chapter 3 confirmed the positive effect of money on growth in the short-term. It may have nonlinearity in the short-term which I have not really explored because it is the log-linearized model. In order to observe the seigniorage-growth relationship, a full blown theoretical analysis of non-linearity in a DSGE growth framework is beyond the scope of this thesis. However, empirical analysis of non-linearity using cross-country-data will be conducted in this chapter. If a non-linearity in seigniorage-growth relationship exists, there will be a threshold level of seigniorage. If the distortionary effect dominates before or after the threshold of seigniorage, we may see a Laffer curve type relationship between seigniorage and output growth.

Within this context, this chapter addresses the following questions:

(1) In the process of the stable economic growth of the world economy during the last 20 years, how much do developing countries rely on seigniorage revenue?

(2) How does seigniorage revenue, a monetary policy, impact on economic growth?

(3) Is there any non-linear relationship between seigniorage and economic growth as theories suggest? If so, what are the threshold values?

(4) If policy makers should aim for a low rate of seigniorage, how low should it be? In particular, at what level does seigniorage negatively impact on growth?

The answer to the first question is shown in the preliminary analysis. It also gives some general idea of how the seigniorage rate has changed in developing countries over the chosen period of time. The next questions are explored by employing new econometric methods for non-linearity and threshold estimation. The standard quadratic function form determines the shape of the non-linearity prior to the estimation and as the value of the threshold level is unknown, we cannot estimate using the conventional gradient search techniques. The quadratic functional form presupposes a well-behaved inverted U shaped relationship which may not be supported by the data. The relationship may be highly non-linear, which cannot be tracked in a quadratic model. In this case, the new econometric method is needed which can explore a greater number of multiple thresholds by going beyond the quadratic model. Without making any pre-assumption about the shape of the non-linearity, Hansen's (1999) methodology enables us to estimate that the asymptotic distribution of the t-statistic on the threshold variable is non-standard. This helps us to find the number of seigniorage thresholds, the seigniorage threshold value, and the marginal impact of seigniorage on economic growth in different regimes. Both monetary and fiscal policies in many developing countries are targeted at decreasing seigniorage to a certain degree [48]. However, there is no clear empirical answer to this question with regard to the threshold level above or below which seigniorage is considered harmful. Knowing the seigniorage threshold level at which there are potential losses in economic output in the short and long run will be helpful for formulating macroeconomic policies. An appropriate choice of seigniorage targets will improve macroeconomic management of the economy. If the central bank knows the threshold at which an expansionary monetary policy can hurt growth, they will be more cautious in implementing such a policy.

The rest of this paper is organized as follows. Section 2 discusses the econometric methodology. Description of data and preliminary analysis is given in section 3. Non-linear features of the growth function, in an attempt to find the precise seigniorage threshold level using econometric techniques, are discussed in section 5. Finally Section 6 offers some concluding remarks.

[48] For instance, in some developed countries, like the UK, price stability is defined by the inflation target of 2%.

4.2 Methodology

4.2.1 Non-Linear Model: Hansen's Threshold Approach

In this section, I explore two non-linear regression models which I intend to utilise in this study of the relationship between seigniorage and economic growth in developing countries. In order to examine the threshold value, the Hansen's (1999) panel threshold model and the quadratic model are employed.

4.2.1.1 Model with Fixed Effect

Let's start with the standard linear regression:

$$y_{it} = \mu_i + \alpha x_{it} + e_{it} \tag{4.1}$$

where y_{it} is the dependent variable, x_{it} is a set of the regressors, subscripts $i = 1,..., N$ demonstrates the country, $t = 1,...,T$ indexes time, ε_{it} is the error term which is assumed to be iid with mean zero and variance σ^2, and μ_i is the country specific fixed effect. Following Hansen's (1999) approach I transform a linear economic model, equation (4.1), into the two regimes of threshold autoregressive (TAR) model as follows:

$$y_{it} = \mu_i + \alpha_1 x_{it} + \varepsilon_{it} \ , \quad \text{if} \quad s_{it} \le \gamma \tag{4.2}$$

$$y_{it} = \mu_i + \alpha_2 x_{it} + \varepsilon_{it} \ , \quad \text{if} \quad s_{it} > \gamma \tag{4.3}$$

where x_{it} is a set of the regressors, s_{it} , seigniorage, is one of explanatory variables, as well as the threshold variable, and divided the sample into two groups. γ is the threshold value, one of the elements in a strict subset of s_{it}. The above two equations are referred to as a samplesplit model or a threshold model which is similar to a structural break.[49] The regression parameters (α_1 and α_2) differ depending on whether the value of the threshold variable s_{it} is smaller than or larger than the threshold value γ. Equation (4.2) and (4.3) can be reduced to a single equation using the dummy variable:

$$y_{it} = \mu_i + \alpha_1 x_{it} d\left[S_{it} \le \gamma\right] + \alpha_2 x_{it} d\left[S_{it} > \gamma\right] + \varepsilon_{it} \tag{4.4}$$

where $d_t(\gamma) = 1$ is the dummy variable and $[\cdot]$ is the indicator function indicating the regime decided by the threshold variable s_{it}, and the threshold value γ. If the statement in parenthesis is true, $d_t(\gamma)$ will be equal to 1, otherwise it will be 0. For the elimination of the fixed effect, I use a method, which de-means the data and equation (4.4), simplifying and transforming it into equation (4.5) [50] :

$$Y^* = \alpha X^*(\gamma) + \varepsilon^* \tag{4.5}$$

4.2.1.2 Single Threshold Estimation

The threshold value γ is identified by estimating equation (5), finding the minimum of the concentrated sum of squared errors. The optimal threshold of the seigniorage is the least squares estimators of γ, which is given as:

$$S_1(\gamma) = \hat{\varepsilon}^*(\gamma)'\hat{\varepsilon}^*(\gamma) \tag{4.6}$$

$$\hat{\gamma} = \arg\min S_1(\gamma) \tag{4.7}$$

The residual variance is expressed as:

[49] *Time* is the threshold variable in a model with structural breaks.

[50] Appendix 4.A demonstrates how to eliminate the individual effects μ_i.

$$\hat{\sigma}^2 = \frac{1}{nT}\hat{\varepsilon}_t{}'\hat{\varepsilon}_t = \frac{1}{nT}S_1(\hat{\gamma}) \tag{4.8}$$

Hansen (1999) suggested restricting the search to a minimum percentage of values using specific quantiles, for instance, 1 or 5 % of the observation lies in each regime. In addition, Hansen (2000) advised that the initial search for the threshold should be performed within the region where we consider the optimal value should be. Andrews (1993) and Lee and Chen (2005) set the threshold variable observation between 15 and 85 percentiles. In this chapter, I solve the minimisation problem by a grid search over 100 percentiles. First, I construct a new variable containing 15-85 percentile of the original value of seigniorage. Second, I create the new variable where the number of percentiles is set as 100 which is used as the grid steps. I also demonstrate another grid search over the 393 capacity quantiles {1.00%, 1.25%, 1.50%, …, 98.75%, 99%} and estimate the equation (4.5) using these percentile and quartile grid methods. The threshold value where there is a minimum sum of squared errors can be defined when the estimations with all the grid steps are completed.

It is crucial to test the significance of the threshold. When the threshold value is identified through estimations with a grid search, the maximum likelihood ratio test will be conducted under the null hypothesis of the no threshold effect. In other words, unbiased estimators of α_1 and α_2 are important for the test if a threshold is significant, which can be shown by the following linear restriction by testing equation (4.5):

$$H_0 : \alpha_1 = \alpha_2 \tag{4.9}$$

The restricted model, equation (4.1) is examined by OLS. However, once the estimators are identified, the standard statistical test will be performed but here traditional test statistics have non-standard distributions so they cannot be employed to test the null hypothesis of no threshold effect [51]. In other words, the traditional test statistic in a large sample distribution cannot be determined by the χ^2 distribution. Depending on nuisance parameters which are threshold parameters in this chapter and which can only be shown under the alternative hypothesis, the asymptotic distribution of the likelihood ratio will be different (Davies, 1977). In order to overcome this problem, the bootstrap method is employed to simulate the asymptotic distribution of the likelihood ratio test and obtain the asymptotically correct p-value (Hansen, 1996). The maximum likelihood estimators test if the cut-off value, the threshold value, is valid under the asymptotic distribution of the statistic.

The likelihood ratio test of the null hypothesis of the no threshold effect is:

$$F_1 = \frac{S_0 - S_1(\hat{\gamma})}{\hat{\sigma}^2} \tag{4.10}$$

where S_0 is the sum of squared errors of the null hypothesis of the no threshold model and $S_1(\hat{\gamma})$ is for the alternative hypothesis of the threshold model. Since F_1 depending on the moments of the samples does not have non-standard distribution which cannot belong to the χ^2 distribution as there are nuisance parameters and it depends the moments of the samples. The bootstrapping is conducted as follows:

-Estimate the equation (4.1), the linear model, and obtain the sum of squared errors (S_0);

-Estimate the equation (4.5), the threshold model, and find the threshold value with the minimum sum of squared errors ($S_1(\hat{\gamma})$);

-Compute the likelihood ratio test of the null hypothesis of no threshold, F_1 statistics;

---

[51] The threshold value is $\gamma = \gamma^*$ under the null hypothesis of the no threshold effect. γ^*, the true value of γ, which is not defined in this case. Since the cut-off value is unknown, the standard econometric inference cannot be applied.

-Hold the regressors x_{it} and threshold variable S_{it} fixed during the bootstrapping procedure;

-Take the regression residuals $\hat{\varepsilon}_{it}^{\ *}$ from the estimated null model, and group them by country, $\hat{\varepsilon}_i^* = \left\{\hat{\varepsilon}_{i,1}^{\ *}, \hat{\varepsilon}_{i,2}^{\ *}, ..., \hat{\varepsilon}_{i,t}^{\ *}\right\}$, and make the sample $\left\{\hat{\varepsilon}_1^*, \hat{\varepsilon}_2^*, ..., \hat{\varepsilon}_n^*\right\}$ which is treated as an empirical distribution for the bootstrapping procedure;

-Draw a new sample size n, with a replacement from the sample which is created from 5 and generate the bootstrap dependent variable calculating the fitted value and residuals [52].

-Estimate the model under the null hypothesis and the alternative hypothesis to obtain the sum of squared errors S_0 and $S_1(\hat{\gamma})$ respectively. Then compute the simulated value of the likelihood ratio test;

-Repeat given procedure 300 times;

-Compute the percentage of draws for which the simulated likelihood ratio statistics are greater than the initial F_1 [53]. This is the bootstrap asymptotic p-value for the likelihood ratio under the null hypothesis of the no threshold and if the p-value is less than 5%, the null hypothesis of the no threshold will be rejected;

4.2.1.3 Confidence Intervals

Chan (1993) and Hansen (1996, 1999, and 2000) explained, in the case of the threshold effect, the estimated threshold value $\hat{\gamma}$ is consistent with γ^*, the true value of γ. In order to compute the confidence intervals the concept of "no-rejection region" is used, which has a non-standard distribution. I examine the threshold value, γ in order to obtain the asymptotic

[52] The likelihood test statistics F_1 is not affected by the parameter α_1 under the null hypothesis of the no threshold effect.
[53] It counts as 1 otherwise 0.

distribution of the statistics, applying the maximum likelihood ratio test statistics. The null hypothesis is:

$$H_0 : \gamma = \gamma^* \tag{4.11}$$

where γ^*, the true value of γ and the likelihood ratio test static is:

$$LR(\gamma^*) = \frac{S_1(\gamma^*) - S_1(\hat{\gamma})}{\hat{\sigma}^2} \tag{4.12}$$

where $S_1(\gamma^*)$ is the sum of squared errors for threshold γ^*, and $S_1(\hat{\gamma})$ is the sum of residuals' squares for threshold $\hat{\gamma}$ from equation (4.6) . In order to form the no-rejection region, $LR(\gamma^*)$, setting γ^* a range from $\gamma_{\min}$ to $\gamma_{\max}$, is conducted and compare it with the critical value. At $\gamma = \gamma^*$, $LR(\gamma^*)$ takes the value of zero and tends to have a random variable ψ with distribution function $\Pr(\psi \le x) = (1 - e^{-x/2})^2$ which can be inversed to find the critical value for the likelihood ratio test statistics. $LR(\gamma^*)$ statistics do not have a normal distribution so that their no-rejection area $c(a)$ is computed:

$$c(a) = -2\ln\left(1 - \sqrt{1-a}\right) \tag{4.13}$$

If $LR(\gamma^*)$ is less than $c(a)$, where the no-rejection area is, the null hypothesis cannot be rejected.

4.2.1.4 Multiple Thresholds

If there is one single threshold, the testing of multiple thresholds should be undertaken. The presence of double thresholds can be estimated throughout the same procedure as the single threshold test. The second threshold value γ_2 can be determined by setting the null hypothesis of only one threshold. By holding the first threshold estimate $\hat{\gamma}_1$ fixed, the second threshold $S_2(\gamma_2)$ criterion is expressed:

$$S_2(\gamma_2) = S(\hat{\gamma}_1, \gamma_2) \text{ if } \hat{\gamma}_1 < \gamma_2 \tag{4.14}$$

$$S(\gamma_2, \hat{\gamma}_1) \text{ if } \gamma_2 < \hat{\gamma}_1$$

where $S_2(\gamma_2)$ is the minimum of the concentrated sum of squared errors from the second-threshold estimation and it can be rewritten as:

$$\hat{\gamma}_2 = \arg\min S_2(\gamma_2) \tag{4.15}$$

Under the null hypothesis of one threshold value and the alternative hypothesis of two threshold values, the likelihood ratio test statistic is:

$$F_2 = \frac{S_1(\hat{\gamma}_1) - S_2(\hat{\gamma}_2)}{\hat{\sigma}_2^2} \tag{4.16}$$

where $S_1(\hat{\gamma}_1)$ is the sum of squared residuals in the single threshold model, and $S_2(\hat{\gamma}_2)$ is the sum of squared residuals in the double threshold model. As the likelihood ratio test under the null hypothesis has a non-standard distribution, the bootstrap procedure is needed to calculate the asymptotically corrected p-value. This procedure is repeated to decide the number of thresholds where the null hypothesis cannot be rejected.

4.2.2 Non-Linear Model with Instrumental Variables

In order to overcome the endogeneity problem and consider the threshold nonlinearity at the same time, Caner and Hansen (2004) proposed a threshold regression with an instrumental variable approach:

$$y_{it} = \mu_i + \alpha_1 S_{it-1} d\left[S_{it-1} \leq \gamma\right] + \hat{c} d\left[S_{it-1} \leq \gamma\right] + \alpha_2 S_{it-1} d\left[S_{it-1} > \gamma\right] + \phi x_{it} + \varepsilon_{it} \tag{4.17}$$

μ_i is an individual effect which will be removed using a fixed effect estimation. x_{it} is a vector of endogenous variables x_{2it} and exogenous variables x_{1it} . Instead of using mean differencing for the fixed effect, I employ forward orthogonal deviations developed by Arellando and Bond (1995). The method subtracts the mean of all future observations of a variable so that it is no longer correlated with the error terms. Three steps are performed. First, I test the endogenous variables on a set of valid instruments using LS method and obtain the predicted estimates of the endogenous variables. In other words, a reduced form regression for the endogenous variables, x_{2it} , as a function of the set of instruments, z_{2it} . Based on the reduced form, I establish predicted estimates for the endogenous variables and substitute into the structural equation of interest. Second, I use the fitted values of endogenous variables to estimate the threshold parameter, γ , which is the smallest sum of squared residuals [54]. Third, based on the threshold parameter, γ , the slope parameters of α_1 and α_2 are obtained using the generalized method of moments (GMM) or conventional two-stage least squares (2LSL).

4.2.3 Quadratic Model

[54] See Equation 7.

One other approach would be to examine the presence of the nonlinear relationship in a quadratic model. For example, Minea *et al.* (2008) employed a quadratic functional form applied to OECD countries and found a non-linear relationship between seigniorage and economic growth. I postulate that the seigniorage parameter can be written as:

$$y_{it} = \mu_i + \omega_0 + \omega_1\phi_{it} + \omega_2 \frac{S_t}{Y_t} + \omega_3 \frac{S_t}{Y_t}^2 + \varepsilon_{it} \tag{4.18}$$

where μ_i is the individual effect and ϕ_{it} is a vector of control variable. Setting $\omega_3 = 0$ provides the linear model, meaning that the degree of seigniorage either increases or decreases monotonically. Having a quadratic interaction term we can count for non-linear growth effects of the threshold variable. The quadratic model is more flexible as the rate at which economic output grows varies with absorptive capacity. For instance, if $\omega_2 > 0$ and $\omega_3 < 0$, the initial positive impact of seigniorage on economic growth fade away after the turning point, $\xi = -\frac{\omega_2}{2\omega_3}$. In other words, this indicates whether the threshold variable has more or less impact on the marginal effect of the threshold on the dependent variable beyond a certain level**.** The asymptotic variance of this critical value can be calculated using the delta method, providing consistent of ω_2 and ω_3. Following Kuha and Temple (2003), the variance can be written as:

$$Var(\hat{\xi}) = \frac{1}{4\hat{\omega}_3^2}\left[\text{var}(\hat{\omega}_2) + 4\hat{\varsigma}\,\text{cov}(\hat{\omega}_2, \hat{\omega}_3) + 4\hat{\varsigma}^2\,\text{cov}(\hat{\omega}_3)\right] \tag{4.19}$$

To estimate equation (4.18) Generalized Method of Moments- Instrumental Variables (GMM-IV) is used for static panels as suggested by Arellano and Bond (1991). However, a threshold in a quadratic model is unique while the panel threshold model can have multiple threshold values.

4.3 Data and Preliminary Analysis

4.3.1 Description of Data

The following empirical analysis in this chapter employs a balanced panel-data set of 70 developing countries [55] covering the period from 1994 to 2006. The decision to start in 1994 is due to the availability of data. The decision to choose 2006 as the end year is to avoid some possible structural changes in the private sector or policy maker's behaviour due to the financial or euro crises. I have obtained the data mainly from World Bank World Development Indicators (WDI), and International Financial Statistics (IFS). The sample consists of the following variables.

-Real Per Capita GDP Growth (Y) [56] is measured as annual percentage growth rate of GDP per capita based on constant local currency [57];

-Seigniorage (S) is computed as the change in the monetary base as a share of GDP. The main advantage to using ratios is that no assumptions are needed regarding the exchange rate and purchasing power parity (Haslag, 1998). In order to test if the Laffer-Curve exists in developing countries or not, I apply the change in the monetary base divided by GDP as the threshold variable;

-Government Spending (G) is measured as general government final consumption as a share of GDP;

-Investment (I) is measured as gross capital formation in GDP. It consists of the fixed assets of the economy and net changes in the level of inventories;

[55] The list of countries is shown in table 4.1

[56] The variable mnemonics used in the chapter are given in parentheses.

[57] Real per capital GDP at 1990 = Nominal per capital GDP at $1990 \times \frac{GD2005}{GD1990}$, where GD is GDP Deflator.

-Trade Openness (O) is measured as the sum of exports and imports of goods and services measured as a share of GDP**;**

-Initial Income (J) is measured as the logged GDP per capita from the previous period;

-Population Growth (P) is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship;

-Terms of Trade Growth (T) is computed as exports divided by imports;

-Standard Deviation of Terms of Trade (ST);

All empirical analysis of the impact of seigniorage on economic growth has to include controls for the influence of other economic variables that are related to the rate of seigniorage. The control variables are selected in accordance with the empirical growth literature, see Islam (1995) or Khan and Senhadji (2001). Therefore, control variables in this chapter are; Government Spending, Investment, Trade Openness, Initial Income, Terms of Trade Growth, Population Growth, Standard Deviation of Terms of Trade, which passed the robustness tests of Levine and Renelt (1992) or Sala-i-Martin (1997).

4.3.2 Statistics Summary

Table 4.1 provides a summary of the characteristics of the data. I specifically selected the period from 1994 to 2006 because of missing data in some explanatory variables (in both seigniorage and control variables) and this gives me a potential sample size of 910(17×30) observations of yearly variables, which is sufficient for applying panel threshold model.

Table 4.1 Descriptive Statistics: 1994-2006

Variable	Observations	Mean	Standard Deviation	Maximum	Minimum
Real Per Capita GDP Growth (Y)	910	0.030230	0.067947	1.475486	-0.472872
Seigniorage (S)	910	0.013185	0.020374	0.151068	-0.16494
Government Spending (G)	910	0.141010	0.056404	0.429503	0.034604
Investment (I)	910	0.226271	0.082159	0.766945	-0.237626
Trade Openness (O)	910	0.812613	0.389034	2.204068	0.146102
Initial Income (J)	910	0.103503	0.022949	0.158828	0.058352
Terms of Trade Growth (T)	910	0.008753	0.152174	1.323273	-0.972805
Population Growth (P)	910	0.015690	0.012757	0.097705	-0.057809
S.D. of Terms of Trade (ST)	910	0.051677	0.066426	0.731236	0.000032

The average value of growth rate of real per capita output is 3.0 %. Seigniorage has an average value of 1.3 %. The difference between the minimum and maximum values is substantial. Real per capita GDP growth range from a low of -47.2 % to 147.5 % and seigniorage range from -16.4 % to 15.1 %. This evidence shows that economies in some countries grow much faster than others, whilst some also create money at a rapid pace. Investment has an average value 22.6 %. Population growth has an average value of 1.5 %, which is higher than developed countries. Trade openness of the economy has an average value of 81.2 %, which indicates that countries are very export and import oriented.

4.3.3 The Average and Distribution of Seigniorage in Developing Countries

Table 4.2 provides each country's central tendency by showing the sample mean over the period 1994-2006.

Table 4.2 Average of Annual Seigniorage in Developing Countries (%): 1994-2006

Country	Mean	Country	Mean
Argentina	0.014383364	Lesotho	0.007854992
Azerbaijan	0.022478963	Macedonia	0.010339794
Barbados	0.015096315	Madagascar	0.014147064
Belize	0.009949942	Malaysia	0.005431500
Bolivia	0.014547892	Mali	0.013126484
Bulgaria	0.040589633	Mauritania	0.009491676
Cambodia	0.017626029	Mauritius	0.009550036
Cameroon	0.008710140	Mexico	0.005987456
Cape Verde	0.016938529	Mongolia	0.018206788
Chad	0.012045892	Morocco	0.021529913
Chile	0.013906700	Mozambique	0.012868584
China	0.046505336	Namibia	0.003535486
Colombia	0.007990560	Nepal	0.017044076
Comoros	0.012039869	Nicaragua	0.018142108
Congo	0.010625023	Oman	0.005993176
Costa Rica	0.016874721	Pakistan	0.017369231
Cote D'Ivoire	0.00766791	Panama	0.001506906
Czech Republic	0.007952061	Paraguay	0.016975164
Dominica	0.009800418	Peru	0.014191667
Dominican Republic	0.018566133	Philippines	0.010724742
Ecuador	-0.001777230	Poland	0.009855566
El Salvador	0.005230090	Rwanda	0.003754646
Estonia	0.016382422	Senegal	0.010261535
Ethiopia	0.017916800	Sierra Leone	0.014696225
Georgia	0.017437348	South Africa	0.006094030
Grenada	0.013436998	Sri Lanka	0.008557565
Guatemala	0.013317652	Sudan	0.016791611
Honduras	0.024563874	Swaziland	0.002040342
Hungary	0.011512531	Tanzania	0.011745706
India	0.017005218	Thailand	0.008003782
Indonesia	0.019356008	Trinidad and Tobago	0.009718927
Jordan	0.013192170	Turkey	0.021554527
Kazakhstan	0.019314205	Uganda	0.007912082
Kenya	0.007465975	Uruguay	0.006406243
Latvia	0.021777415	Vanuatu	0.011135570

One interesting finding in this table is how the reliance on seigniorage revenue differs in developing countries. However, most of the countries collect, on average, less than 2 % of GDP by means of money creation. In this sample, China relies most heavily on seigniorage, having revenues around 4.7 % of GDP, on average, through money creation. On the other hand, Ecuador does not depend on seigniorage as the average value of seigniorage rate is around -0.2 %.

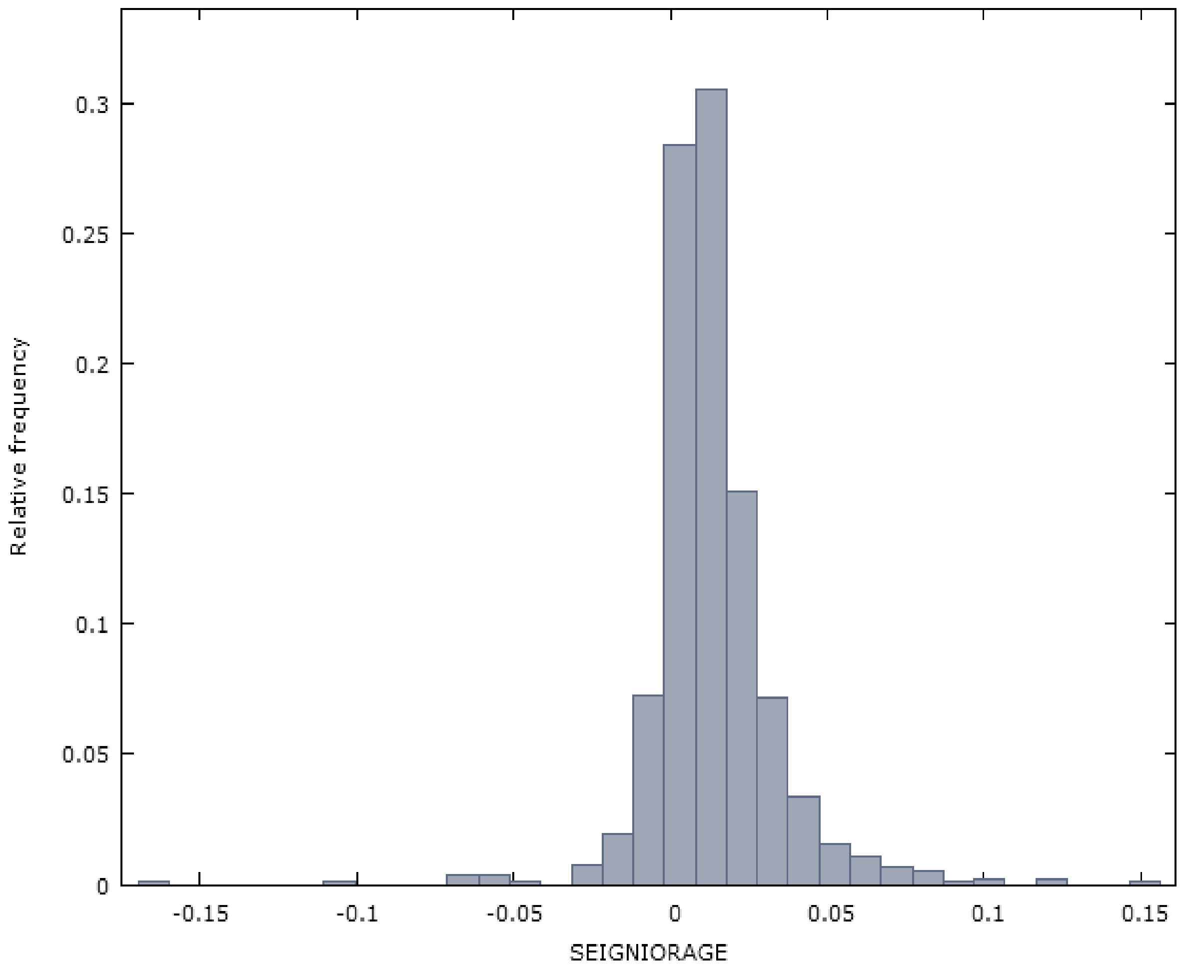
According to Table 4.3, from 1994 to 2006, seigniorage gradually decreased until the late-1990s and it rebounded from its lowest level after the Asian currency crisis. Compared to the record-high in 1994, by 1997 the ratio of seigniorage to GDP had dropped from 1.84 % to 0.22 %. In this case, one of reasons why seigniorage rate dropped in the late 1990s is that demand for money decreased and the rates of the legal reserve system was lowered. However, the seigniorage was gradually increased to 1.74 % and reached 1.90 % in 2006.

Table 4.3 Average of Seigniorage in Developing Countries by Year (%): 1994-2006

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Seigniorage (%)	1.84	1.04	1.52	0.22	1.30	0.76	1.25	1.13	1.11	1.74	1.42	1.92	1.90

Figure 4.1. reveals more information about the distribution of seigniorage across the full sample of countries from a timeless perspective.

Figure 4.1 Distribution of Seigniorage : 1994-2006



Overall distribution of seigniorage is slightly right skewed (positive skewed) toward the higher-seigniorage-reliance tail of the distribution. However, over 80 % of the observed seigniorage rates were between 0 % and 1 %.

Seigniorage rate may vary from country to country and also from time to time. Such differences can be caused by the presence of the reserve requirement system, average reserve ratio, interest rate differences among countries, the share of non-interest bearing liabilities which is held by the central bank, and so on.

4.3.4 Correlations of Variables

In order to understand the relationship between seigniorage and economic growth in more depth, I observe the cross-country correlation between the annual average seigniorage rate and economic growth in 70 developing countries. All values are shown in Table 4.4. The correlation coefficient between a country's average reliance on seigniorage revenue and its economic growth is 0.0658 with p-value 4.7 %. Therefore, the high correlation coefficient shows that countries with high seigniorage rates may have a higher economic growth rate. In other words, countries that depend, on average, more heavily on seigniorage revenue tend to experience burgeoning economic growth. By contrast, countries that depend relatively little on money creation as a source of revenue do not tend to exhibit the high economic growth.

In addition, formal statistics support the notion that the seigniorage rate and investment are positively related: the correlation coefficient between seigniorage and investment is 0.1007. This may imply that countries with large values of seigniorage revenue tend to experience greater investment. However, the seigniorage rate and population growth are negatively related as the correlation coefficient is -0.0877. GDP per capita growth is also positively correlated with investment, trade openness, and terms of trade growth and their correlation coefficients being 0.1806, 0.0584 and 0.0651. However, economic growth is negatively correlated with population growth and standard deviation of trade openness, with correlation coefficients of -0.0692, and -0.1360 respectively.

Table 4.4 Average of Annual Seigniorage in Developing Countries (%): 1994-2006

Correlation (Probability)	Y	G	I	O	P	J	T	ST	SO	S
Y	1.0000									

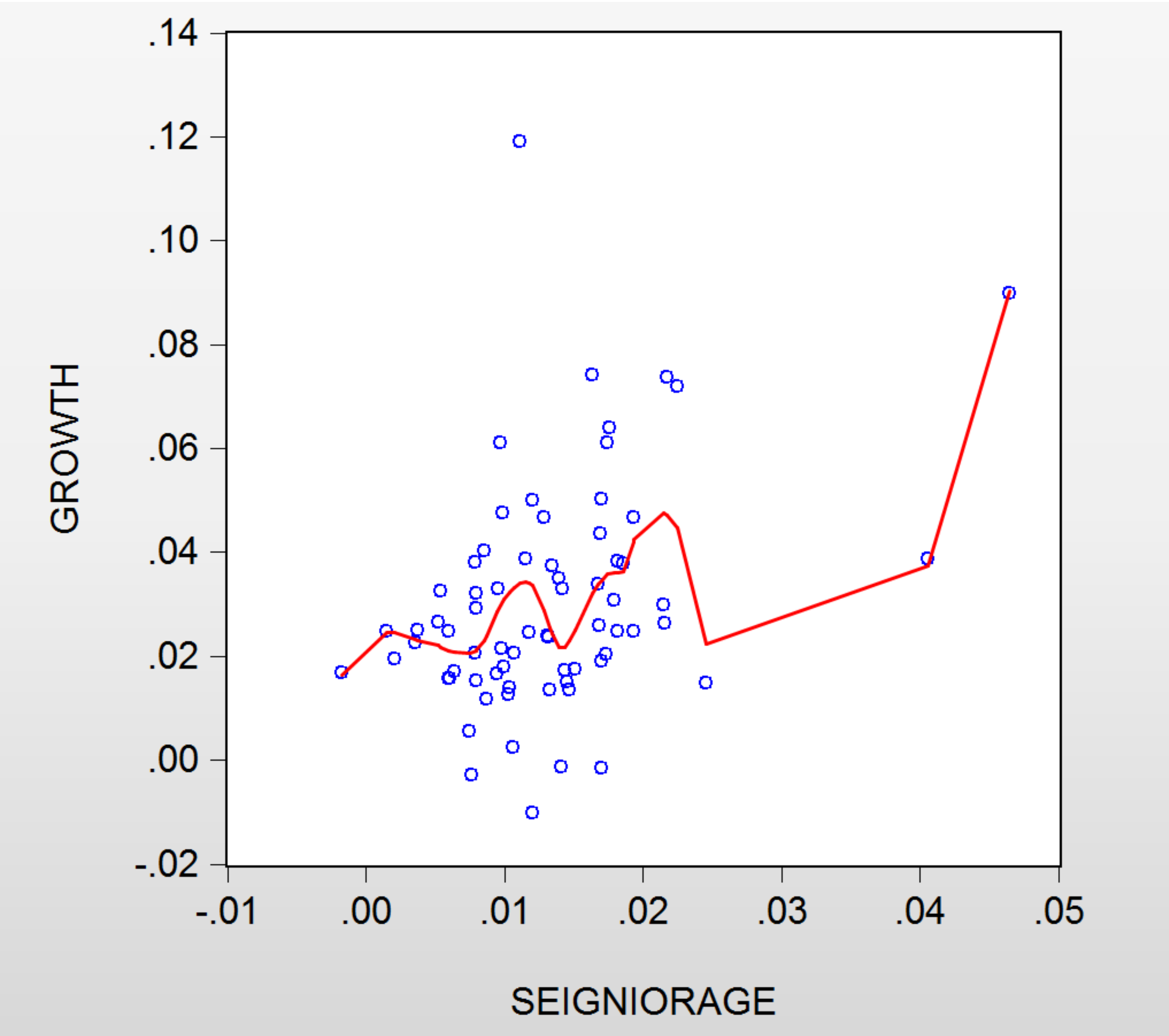
G	-0.0116	1.0000								
	(0.7278)	-----								
I	0.1806***	0.2512***	1.0000							
	(0.0000)	(0.0000)	-----							
O	0.0584*	0.3575***	0.3469***	1.0000						
	(0.0780)	(0.0000)	(0.0000)	-----						
P	-0.0692**	-0.1889***	-0.1519***	-0.2399***	1.0000					
	(0.0368)	(0.0000)	(0.0000)	(0.0000)	-----					
J	-0.0396	-0.1899***	-0.1055***	-0.0118	0.0987***	1.0000				
	(0.2324)	(0.0000)	(0.0014)	(0.7227)	(0.0029)	-----				
T	0.0651**	-0.0363	-0.0668**	-0.0059	0.0963***	0.0158	1.0000			
	(0.0497)	(0.2742)	(0.0440)	(0.8586)	(0.0037)	(0.6335)	-----			
ST	0.0226	-0.0649*	-0.0725**	-0.0556*	-0.0072	-0.0610*	0.2570***	1.0000		
	(0.4966)	(0.0504)	(0.0288)	(0.0938)	(0.8293)	(0.0661)	(0.0000)	-----		
SO	-0.1360***	-0.1172***	-0.0688**	-0.0703**	-0.0697**	-0.0286	0.0189	0.2650***	1.0000	
	(0.0000)	(0.0004)	(0.0381)	(0.0339)	(0.0355)	(0.3881)	(0.5689)	(0.0000)	-----	
S	0.0658**	-0.0319	0.1007***	-0.0175	-0.0877***	-0.0414	-0.0134	0.0179	0.0553*	1.0000
	(0.0471)	(0.3368)	(0.0024)	(0.5984)	(0.0081)	(0.2125)	(0.6859)	(0.5889)	(0.0955)	-----

Note: P-values are given in parentheses, */**/*** indicate the 10%/5%/1% significance level.

4.3.5 Seigniorage and Economic growth

The relation between per capita GDP growth and seigniorage in our sample is depicted on Figure 4.2. The average rates over the period from 1994 to 2006 of per capita GDP growth and seigniorage rate in 70 developing countries are conducted.

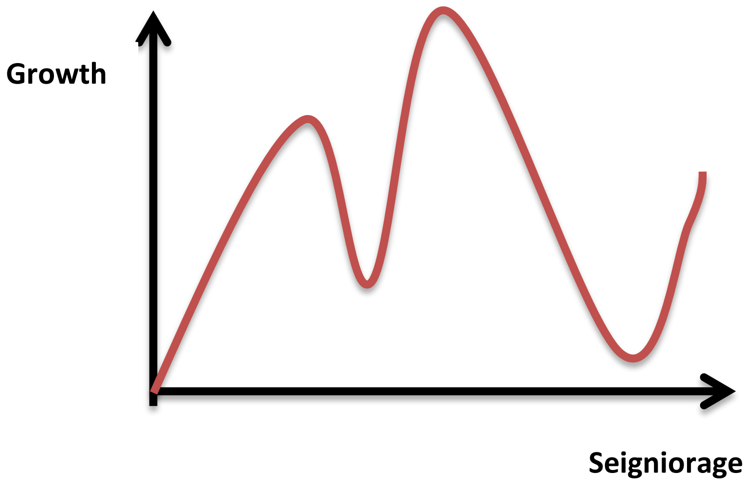
Figure 4.2 Seigniorage and Per Capita GDP Growth Per Annum (%)



Note: Redline is the nearest neighbour fit. The polynomial degree is 3 and bandwidth (sample fraction) is 0.5. Number of evaluation points (approximation) is 100.

Due to the high degree of dispersion in the data, this evidence is only tentative. In the next section, a more rigorous analysis of the relationship between seigniorage and economic growth is shown, but nonetheless, one feature is worth noting. It does not look clear that the relationship is linear. When we look at the red line, the polynomial degree is 3. It infers that seigniorage and economic growth may have a non-linear relationship as Figure 4.3 shows. Because of the nonlinearity, one can find the optimum seigniorage that promotes the greatest economic growth rates. The relationship may be highly nonlinear, which cannot be tracked in a linear model.

Figure 4.3 Growth - Seigniorage



Thus, two facts emerge from this preliminary review of the data. These findings serve to answer the primary question of how much developing countries depend on seigniorage revenue. First, for most developing countries in the sample, seigniorage revenue accounts for less than 2 % of GDP. Second, the evidence suggests that there might be a non-linear relationship between seigniorage and economic growth. If the relationship between seigniorage and output growth is nonlinear, a small increase or decrease in seigniorage can give a substantial effect on economic growth.

4.4 Estimation Results

4.4.1 Linear and Quadratic Models

Let me begin the empirical analysis of the relationship between seigniorage and economic growth with a linear growth regression and a quadratic growth regression. First of all, I performed Variance Inflation Factor (VIF) and Spearman's Rank Correlation Test to capture any possible multicollinearity. The results are reported in Table 4.5 and 4.6 and they confirm [58] that there is no multicollinearity among variables.

Table 4.5 Spearman's Rank Correlation

	A	g	b	O	P	C	f	h	m	s
a	1									
g	-0.0404	1								
b	0.3221	0.1705	1							
o	0.0828	0.3432	0.393	1						
p	-0.2685	-0.2078	-0.2541	-0.2664	1					
c	-0.0805	-0.1373	-0.0742	0.021	0.1183	1				
f	-0.0348	-0.0525	-0.1281	0.0096	0.0479	0.0215	1			
h	-0.0293	-0.0695	-0.1017	-0.0707	0.0199	-0.0335	0.0518	1		
m	-0.0428	-0.1156	-0.0349	-0.053	0.0411	-0.0257	0.0064	0.2008	1	
s	0.1724	-0.0882	0.16	-0.0159	-0.0739	-0.0202	0.0654	0.0346	0.069	1

[58] There is no multicollinearity, when the value is between -.08 and 0.8 in Spearman's Rank Correlation test and the value is less than 3 in VIF test.

Table 4.6 Variance Inflation Factor Test

Variable	VIF	1/VIF
o	1.3	0.767495
g	1.25	0.802317
b	1.21	0.826879
h	1.16	0.859612
p	1.11	0.897855
m	1.11	0.903495
f	1.09	0.915206
c	1.06	0.942514
s	1.05	0.955642
Mean VIF	1.15	

All variables in Table 4.7 show that the impact of seigniorage on growth is positively signed, implying that higher seigniorage will significantly boost economic growth. Panel unit root tests are conducted for the stationarity test. The null hypothesis for testing a panel unit root test is $H_0 : y_t \sim I(1)$ and alternative hypotheses under each testing approach is $H_1 : y_t \sim I(0)$. $I(1)$ which indicates that y_t is integrated of order one which has a panel unit root and $I(0)$ shows that y_t is stationary. The results are reported in Appendix 4.B. While trade openness and initial income data series are non-stationary, other data series are stationary at the 5 % significance level. Johansen's maximum likelihood method test for co-integration relationship is conducted among non-stationary data. Using Johansen's test, both the trace statistics and maximal eigenvalue statistics unanimously confirm that there is no co-integrating relationship at the 5% significance level. Since time dummies are employed as additional instruments, inference based on asymptotic standard errors for the one-step estimators is more suitable than that of the two-step GMM (Arellano and Bond, 1991). Therefore, only the one-step estimators with robust test statistics are reported. In order to deal with the potential endogeneity of some of independent regressors (seigniorage, government spending, investment, trade openness and initial income) I alternatively use a set of instruments. The values of regressors lagged one period and terms of trade and standard trade of terms of trade are selected on the basis of appropriate specification tests for instrument validity (Hansen J statistics) and relevancy (Kleibergen-Paap test). As the Hansen J statistics for the over identification test does not reject the null of instrument validity, it confirms that the sets of instruments in this test are valid. In the linear specification for real GDP growth the GMM-IV coefficient of seigniorage is positive and significant at the 5 % level. One point increase in seigniorage increases output growth by 3.9.

Table 4.7 GMM-IV Linear Panel Regression of Real GDP Growth

$$y_{it} = \alpha s_{it} + \beta x_{it} + e_{it}$$

	Coefficient	Standard Error	t-Statistic	Prob
S	3.930686**	2.018916	1.95	0.05
G	-0.7752651**	0.353077	-2.20	0.03
I	0.2336462*	0.123619	1.89	0.06
J	-28.664531***	10.46700	2.74	0.01
O	0.120944***	0.486936	2.48	0.01
P	-0.590825	0.622657	-0.95	0.34
Instruments	S_{t-1}, G_{t-1}, I_{t-1}, O_{t-1}, J_{t-1}, F, H			
Hansen J Statistics	0.903 (0.80)			
Kleibergen-Paap Statistic	6.804 (0.15)			
Time Dummies	Yes			
Observations	910			

Notes: */**/*** indicate the 10%/5%/1% significance level. Sample period is 1994 through 2006. The estimated time dummies and country-specific effects are not reported. Instruments F and H are terms of trade and standard deviation of terms of trade. The one-step GMM estimators are reported. All statistics are robust to heteroskedasticity. The Hansen J- statistics tests for the over-identification under the null of instrument validity. The Kleibergen-Paap tests for the under-identification test. P-values are reported in brackets. For eliminating individual effects, the fixed effect estimation is applied.

In Table 4.8. as SS, the squared value of S, is included, it is possible to identify whether there are any non-linearities in this relationship.

Table 4.8 The IV/GMM Non Linear Panel Regression of Real GDP Growth

$$y_{it} = \alpha s_{it} + \beta x_{it} + e_{it}$$

	Coefficient	Standard Error	t-Statistic	Prob
S	2.780106*	1.654598	1.68	0.09
SS	-10.43571	0.6214588	-1.31	0.19
G	-0.5242669*	0.3028932	-1.73	0.08
I	0.2807306**	0.1163755	2.41	0.02
J	-19.33524*	11.0275	-1.75	0.08
O	0.0802974*	0.428683	1.87	0.06
P	-0.6482503	0.6214588	-1.04	0.30
Instruments	S_{t-1}, G_{t-1}, I_{t-1}, O_{t-1}, J_{t-1}, SS_{t-1}, F, H			
Hansen J Statistics	4.581 (0.20)			
Kleibergen-Paap Statistic	5.458 (0.24)			
Time Dummies	Yes			
Observations	910			

Notes: */**/*** indicate the 10%/5%/1% significance level. Sample period is 1994 through 2006. The estimated time dummies and country-specific effects are not reported. SS is the quadratic seigniorage term. Instruments F and H are terms of trade and standard deviation of terms of trade. The one-step GMM estimators are reported. All statistics are robust to heteroskedasticity. The Hansen J- statistics tests for the over-identification under the null of instrument validity. The Kleibergen-Paap tests for the under-identification test. P-values are reported in brackets. For eliminating individual effects, the fixed effect estimation is applied.

One lagged squared value of S is added in the instruments set in this regression. The validity of our set of instruments is not rejected by the data (Hansen's J statistics and Kleibergen-Paap test). Since the coefficient on S is positive and the coefficient on SS is less than zero, the evidence suggests that the relationship is concave. However, the coefficient on *SS* is *not* significantly different from zero, while coefficient on S is significantly different from zero. It confirms that the countries with high seigniorage tend to boost economic growth but it is not known if any non-linearity exists in the relationship between seigniorage and economic growth in developing countries. Quadratic functional form needs to know the shape of the non-linearity prior to the estimation and presupposes a well-behaved inverted U shaped relationship which may not hold in the data so that I cannot estimate with the conventional gradient search techniques. Bearing this shortcoming in mind, the next section will be a discussion of the estimates from the threshold model, which is a more flexible estimation strategy.

4.4.2 Panel Threshold Model

Following the modified version of the panel threshold model introduced by Hansen (1999), an empirical analysis on seigniorage threshold and economic growth is conducted. Having the results from the linear regression earlier, the following relationship between seigniorage and growth is considered:

$$y_{it} = \mu_i + \alpha_1 d\left[S_{it} \le \gamma_1\right] + \alpha_2 d\left[\gamma_1 < S_{it} \le \gamma_2\right] + \alpha_3 d\left[\gamma_2 < S_{it}\right] + \beta x_{it} + \varepsilon_{it} \qquad (4.20)$$

where equation (4.20) indicates a double threshold model. x_{it} denotes the additional regressors that include G, I, O, P, and J. In each seigniorage regime, the marginal impact of seigniorage on economic growth might be different. In order to overcome the endogeneity problems, I used one lag for each endogenous variable except population growth in this model.

4.4.2.1 The Threshold Point Estimate

In order to identify the number of thresholds, equation (4.20) was examined by conventional least squares, allowing for zero and one threshold sequentially. Following the work of Andrew (1993), and Lee and Chen (2005), I set the threshold variable observation between 15 and 85 percentiles.

Table 4.9 shows the Likelihood ratio (F_1 and F_2) and the corresponding bootstrap p-values for developing countries. 300 bootstrapping procedures were performed.[59] The likelihood ratio test is conducted as follows. Obtain the sum of squared errors of the alternative hypothesis of the threshold model and subtract the sum of squared errors of the null hypothesis of no threshold model, which is 2.875885 and divide by variance of the alternative hypothesis of the threshold model. While setting the threshold variable, changes in monetary base divided by GDP, I discover that the likelihood ratio (F_1) is 11.992358, which is significant at the 5 % level in one threshold testing and the bootstrap p-value is 0.03. The null hypothesis of the no threshold ($\alpha_1 = a_2$) can be rejected significantly, which indicates that there is at least one threshold in this model.

The result demonstrates a clear rejection of a linear relationship between seigniorage and growth. This indicates that there is a threshold effect existing. However, when the second step is performed, the likelihood ratio (F_2) statistics 0.296909 and the bootstrap p-value is 0.93. This indicates that the null hypothesis of one threshold cannot be significantly rejected.

[59] Since the asymptotic distribution of F_1 is non-standard, the bootstrapping procedures for conducting p-value is performed. Hansen (1996) demonstrated that bootstrapping procedures have a first-order asymptotic distribution so that bootstrap p-values are asymptotically valid.

Table 4.9 The Number of Seigniorage Threshold

$$y_{it} = \alpha_1 d\left[S_{it} \le \gamma_1\right] + \alpha_2 d\left[\gamma_1 < S_{it} \le \gamma_2\right] + \alpha_3 d\left[\gamma_2 < S_{it}\right] + \beta x_{it} + \varepsilon_{it}$$

70 Developing Countries	
Search Range for Threshold	{15%-85%]
No threshold	
Likelihood Ratio (F_1)	10.494006
p-Value	0.030000
(10%, 5%, 1% Critical Values)	5.782851, 7.693340, 15.270475
One threshold	
Likelihood Ratio (F_2)	0.431349
p-Value	0.933333
(10%, 5%, 1% Critical Values)	6.558189, 9.486989, 15.930390

Note: The sequential test procedure indicates that the number of seigniorage thresholds is 1. 300 bootstrap replications were used to obtain p-values. Fixed effects estimation with all repressors lagged are applied.

Therefore, there is strong evidence that there are two seigniorage regimes to analyse, one is when the seigniorage is large and the other is when it is small. For the remainder of the analysis I work with this one threshold model [60] and now rewrite the equation (4.20) with fixed effects [61] as follows:

$$y_{it} = \alpha_1 x_{it} d\left[S_{it} \le \gamma\right] + \alpha_2 x_{it} d\left[S_{it} > \gamma\right] + \beta x_{it} + \varepsilon_{it} \tag{4.21}$$

[60] One may argue that the quartic model and the panel threshold model should be not different if there is only one threshold. However, it is still valid that the panel threshold model has more advantage over the quadratic model. Without pre-assumption of the shape of the nonlinearity, this methodology of Hansen's (1999) enables us to estimate even the asymptotic distribution of the t-statistic on the threshold variable is non-standard.

[61] In order to confirm if fixed effect is more appropriate in this test, the Hausman test is conducted. The null hypothesis of the Hausman tests is that the coefficients estimated by the efficient random effects estimator are the same as the ones estimated by the consistent fixed effects estimator. The P-value in Hausman test is 0.012. Since it is a statistically significant P-Value, the fixed effect is used in this model.

With the view of the existence of one seigniorage threshold, the next step is to find the exact location of the threshold. Table 4.10. shows the estimated threshold point together with 95 % confidence interval and sum of squared error.

Table 4.10 Seigniorage Threshold in the Seigniorage-Growth Nexus

$$y_{it} = \alpha_1 x_{it} d\left[S_{it} \leq \gamma\right] + \alpha_2 x_{it} d\left[S_{it} > \gamma\right] + \beta x_{it} + \varepsilon_{it}$$

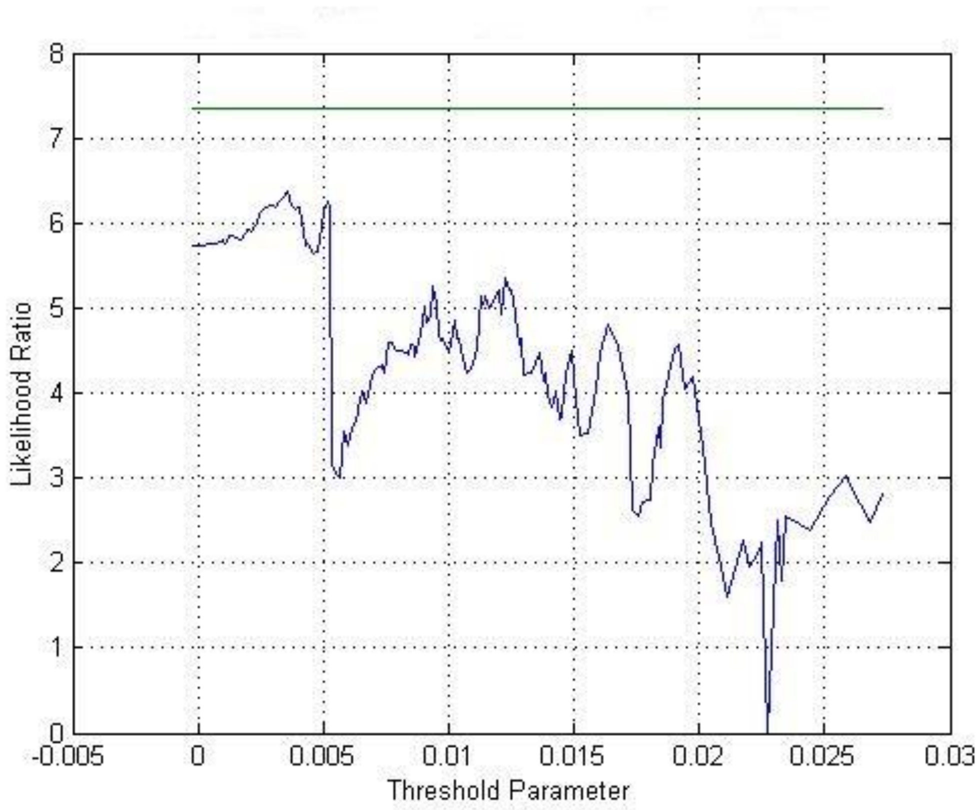
70 Developing Countries	
Search Range for Threshold	{15%-85%]
Threshold Estimate (γ)	0.022715
95% Confidence Interval	-0.000192 , 0.027308
Sum of Squared Error	2.831781

Note: The sum of squared errors of the null hypothesis of no threshold model is 2.875885.

The point estimate locates at a conventional seigniorage of 2.2715 % at the 5 % significant level in this growth threshold model. The next question should be how precise this point estimate is. In order to answer this question, the confidence region around the threshold estimate is conducted. While the presence of the threshold effects in the non-linear relationship between seigniorage and growth can be widely accepted, the precise threshold point is still an insurmountable issue. In terms of the likelihood ratio test, the 95 % confidence interval around the point estimate is between -0.0192 % and 2.7308 % in this model. The difference is around 2.6 %, which is not very narrow but it can still imply that the threshold is reasonably examined.

More information can be found about the threshold estimate from the plots of the confidence interval in the single threshold model by looking at concentrated likelihood ratio function $F_1(\gamma)$ in Figure 4.4.

Figure 4.4 Confidence Interval in Single Threshold Model



The point estimate, 2.2715 % in this growth threshold model is the value where the likelihood ratio is the zero, which is in the right part of the graph. Following equation (4.12) in section 4.2.1.3, it can be written at 2.2715 % as $LR(\gamma^*) = \frac{S_1(\gamma^*) - S_1(\hat{\gamma})}{\hat{\sigma}^2} = 0$. The point estimate, 2.2715 % $\hat{\gamma}$ is closed to γ^*, the true value of γ. The 95 % confidence interval for the threshold point estimate can be found under the dotted line.

4.4.2.2 Seigniorage- Growth Nexus

Table 4.11. displays the estimation results of equation (4.21) obtained for developing countries. Fixed effects have been adopted to control for cross-country heterogeneity.

Table 4.11 Seigniorage and Growth: Non-Linear Flow Effects

$$y_{it} = \alpha_1 x_{it} d\left[S_{it} \le \gamma\right] + \alpha_2 x_{it} d\left[S_{it} > \gamma\right] + \beta x_{it} + \varepsilon_{it}$$

γ	0.022715		
Regime-dependent regressors			
	Coefficient	standard error	t-statistics
$S_{it} \le \gamma$	0.489217**	0.197723	2.474
$S_{it} > \gamma$	-0.216809*	0.126551	-1.731
Regime-independent regressors			
	Coefficient	standard error	t-statistics
G	-0.215850**	0.117393	-1.839
I	0.098166**	0.044646	2.199
O	0.0888251***	0.016419	5.410
P	-0.804833*	0.423942	-1.898
J	-11.836802	7.973013	-1.485

Note: The panel has 910 observations, which is over 1994-2006, for 70 countries (N). */**/*** indicate the 10%/5%/1% significance level. Sample period is 1994 through 2006. Fixed effects estimation with all repressors lagged are applied. The estimated time dummies and country-specific effects are not reported. 300 bootstrap replications were used to obtain the p-values to test for the number of thresholds.

The regime-dependent regressors a_1 and a_2 indicate the marginal impact of seigniorage in two regimes. The regressions coefficient, white standard errors, and t-statistics are shown in this table. The coefficients of seigniorage in this sample for which the threshold estimate is

2.2715 %, have the right signs and are statistically significant at the 5 and 10 % level. Since there is a non-standard distribution under the null hypothesis, a threshold effect cannot be examined by a classical test so that the bootstrap distribution of the likelihood ratio is employed. However, control variables still use their usual distribution of the t-values under the null hypothesis of a threshold effect [62].

While the seigniorage rate under its threshold level has a positive impact on economic growth, seigniorage rate above the threshold level has a negative impact on economic growth in developing countries. This result demonstrates that a 1 percentage point increases in seigniorage will lead to a 0.49 percentage point increase in economic growth when seigniorage below its threshold level. On the other hand, when seigniorage is above its threshold level, a 1 percentage point increase in seigniorage will cause a 0.22 percentage point decrease in economic growth. Not only seigniorage but also some of the regime-independent variables are also in line with theoretical prediction. Most literatures predict that investment: GDP ratio and trade openness have a positively significant effect on economic growth [63]. It shows that a 1 percentage point in the investment-GDP ratio will lead to a 0.10 percentage point increase in GDP and an increase in trade openness boost GDP growth by 0.08 percentage points in developing countries. In general, trade openness is inferred as a large domestic traded good sector which helps to increase steady-state capital stock. When there is one percentage increase in population growth, there will be 0.80 percentage point decrease in output growth. With regard to this interpretation, the results, the size and sign of the variables, are consistent with theory.

[62] The asymptotic distribution of all coefficients in this model is multivariate normal with a variance- covariance matrix given by $\hat{\Phi} \sim N(\Phi, U^{-1}VU^{-1})$ (Chan and Tsay, 1998)

[63] Anderson (1990), Khan and Reinhart (1990), Blomstorm *et al.* (1996), and Harrison (1996)

Table 4.12. demonstrates the number (percentage) of countries which lie in the two regimes each year.

Table 4.12 Number of Countries in Each Regimes By Year

	Year						
Regimes	1994	1995	1996	1997	1998	1999	2000
$\gamma \leq 0.022715$	53 (75)	57 (80)	57 (80)	67 (94)	57 (80)	61 (86)	55 (77)
$\gamma > 0.022715$	18 (25)	14 (20)	14 (20)	4 (6)	14 (20)	10 (14)	16 (23)
	Year						
Regimes	2001	2002	2003	2004	2005	2006	
$\gamma \leq 0.022715$	57 (80)	62 (87)	57 (80)	55 (77)	49 (69)	50 (70)	
$\gamma > 0.022715$	14 (20)	9 (13)	14 (20)	16 (23)	22 (31)	21 (30)	

Note: The panel has 910 observations, which is over 1994-2006, for 70 countries (N). The percentages are given in parentheses.

The percentage of countries in the low seigniorage ($\gamma \leq 0.022715$) category starts from 69 % to 94 % of the sample over the period of 1994 to 2006. The high seigniorage countries ($\gamma > 0.022715$) range from 6 % to 31 %. There appeared to be a reduction in the number of countries with lower seigniorage by 1997, whilst the number of countries with higher seigniorage increased afterwards.

In terms of the above empirical results, there is a threshold effect and a non-linear relationship, which is concave between seigniorage and economic growth in developing countries.

4.4.3 Robustness

In order to confirm that our results are robust, I conducted an additional test with instrumental variables. In the section 4.4.2, all regressors are required to be exogenous. However, in growth regressions with panel data, some variables such as initial income can be endogenous. In order to solve the potential endogeneity bias, this section includes *panel threshold model with instrumental variables.* Most of the robustness tests remain consistent and support the previous results. However, having instrumental variables in the model weakens the negative effect of seigniorage on output growth in developing countries, above the threshold point of seigniorage.

4.4.3.1 Panel Threshold Model with Instrumental Variables

The model with instrumental variables closely follows Bick (2010) and Kremer *et al.* (2013).

The second threshold growth regression takes the form:

$$y_{it} = \alpha_1 d\left[S_{it-1} \le \gamma\right] + \hat{c}d\left[S_{it-1} \le \gamma\right] + \alpha_2 d\left[S_{it-1} > \gamma\right] + \phi x_{it} + \varepsilon_{it} \tag{4.22}$$

In this equation, seigniorage S_{it} is the threshold variable and the regime dependent regressor. x_{it} denotes the vector of exogenous and endogenous control variables and its slope coefficients are the regime independent regressors. I set the endogenous regressors, government spending (G), investment (I), Trade Openness (O), and Initial income (J) with one lag and terms of trade growth (T) and standard deviation of terms of trade (ST) as instrumental variables.

The case of an endogenous threshold variable needs an alternative estimation approach, however, to my best knowledge the methodology has not been developed yet in order to eliminate the endogeneity of the threshold variable, I alternatively proceed to examine its own lagged values, S_{it-1}. The individual specific effects μ_i are removed by employing standard fixed effects indicating all the coefficients of variables are not time-invariant.

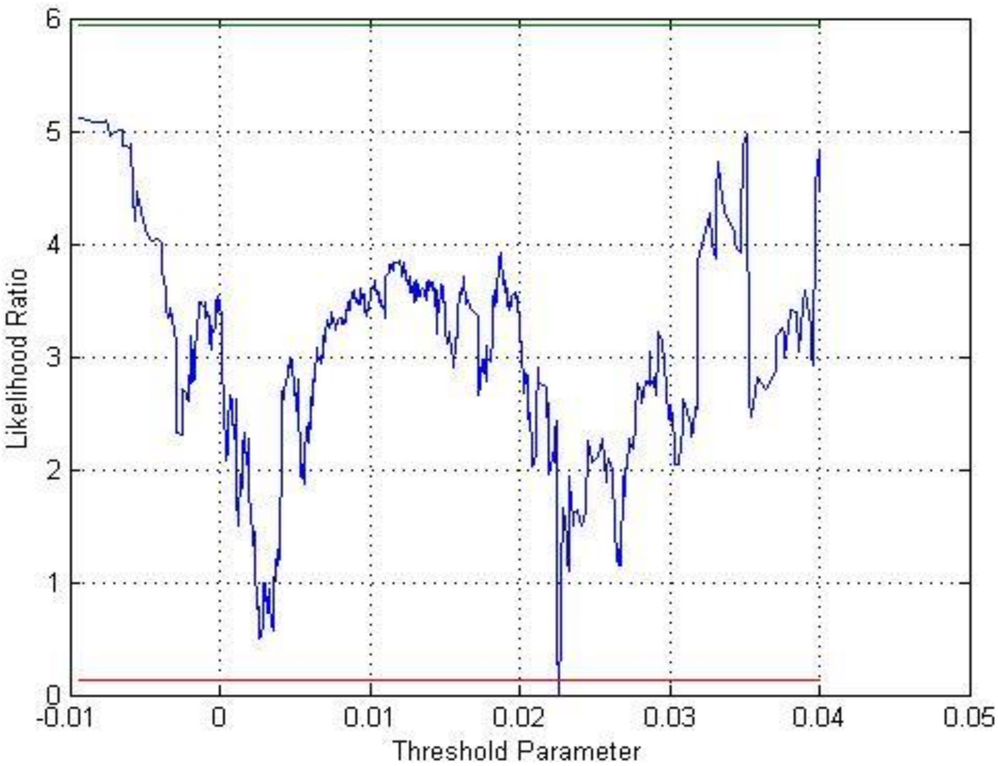
Table 4.13 Seigniorage and Growth: Non-Linear Flow Effects with Instrumental Variables

$$y_{it} = \alpha_1 d\left[S_{it} \le \gamma\right] + \hat{c}d\left[S_{it} \le \gamma\right] + \alpha_2 d\left[S_{it} > \gamma\right] + \phi x_{it} + \varepsilon_{it}$$

γ	0.022619		
95% Confidence Interval	[-0.009355, 0.040017]		
Regime-dependent regressors			
	Coefficient	standard error	t-statistics
$S_{it} \le \gamma$	0.459129***	0.142927	3.2123322
$S_{it} > \gamma$	-0.028084**	0.013782	-2.0377304
Regime-independent regressors			
	Coefficient	standard error	t-statistics
G	-0.308039***	0.102313	-3.0107513
I	0.174422**	0.088663	1.9672468
O	0.059375**	0.027479	2.1607409
P	0.214789	3.264511	0.06579515
J	-7.637207	5.958291	-1.2817781
$\hat{c}$	0.005152	0.005585	0.9224709

Note: The panel has 910 observations, which is over 1994-2006, for 70 countries (N). */**/*** indicate the 10%/5%/1% significance level. Sample period is 1994 through 2006 and each regime has at least 5 % of all observations. Instrumental variables are one lag of G, I, O and J and terms of trade growth as suggested in Hansen's J-test for joint null that the instruments are valid in the previous GMM test. Fixed effects estimation is applied. The estimated time dummies and country-specific effects are not reported. 300 bootstrap replications were used to obtain the p-values to test for the number of thresholds.

Figure 4.5 Confidence interval in Single Threshold Model with Instrumental Variables



Having time dummies in equation (4.22) will not affect the main results. $\hat{c}$ indicates the difference in the regime intercepts and is applied the same for all variables. Table 4.13 presents the estimate of the location of the threshold and the coefficient estimates from the equation (4.22).

The point estimate locates at a conventional seigniorage of 2.2619 % at the 5 % significant level in this growth threshold model. Figure 4.5 plots the simulated 90% asymptotic confidence interval around the threshold estimate using concentrated likelihood ration function. The point estimate, 2.2619 % is the value where the likelihood ratio equals to zero. The 95 % confidence interval around the point estimate is shown the under the dotted line where is between -0.9355 % and 4.0017 %. The threshold location with instrumental variables is almost identical to the result obtained with all the lagged variables.

The result shows that a 1 percentage point increase in seigniorage will lead to a 0.46 percentage point increase in growth when seigniorage below its threshold point, 2.2619 %. However, when seigniorage is above its threshold estimate, 2.2619 %, a 1 percentage point increase in seigniorage will lead to a -0.028 percentage point decrease in growth. The results on the coefficient of the low-seigniorage turns out to be very close to the outcome with lagged variables but the high-seigniorage effect is less powerful with instrumental variables.

Some of the regime independent regressors are consistent with the previous main results. The estimates show that a 1 percentage point increase in the investment will lead to a 0.17 percentage point increase in growth and an increase in trade openness cause a 0.06 percentage point increase in GDP. However, government spending has a negatively significant effect on output growth. A 1 percentage point increase in the government spending will decrease GDP growth by 0.31 percentage point. In fact, most results in this section are almost identical to the results obtained with lagged variables.

4.5 Conclusion

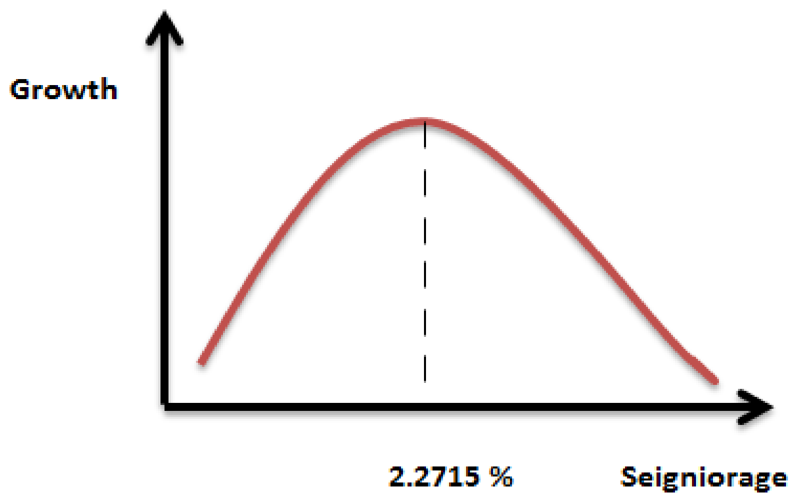
There have been different views on the impact of seigniorage on growth. Seigniorage has a growth-enhancing effect through productive government spending. For instance, the government expenditure financed by seigniorage can improve the welfare of the economy because of the higher productivity which results from the capital accumulation from the public infrastructure (Basu, 2001). This echoes work of chapter 3 that showed the positive effect of seigniorage on economic growth through public investment on education. On the other hand, seigniorage has a negative impact on growth through inflation. Mundell (1963) and Friedman (1971) argued that a higher inflation owing to deficit financing causes a substantial welfare cost on the real balance of money holders. In the previous chapter, I also developed a model where money growth has two opposing effects on the growth rate. The inflation tax, seigniorage, distorts the consumption of cash goods relative to credit goods, which leads to a decrease in the output growth. However, there is a positive effect of seigniorage on output growth through government spending on education.

If these different effects of seigniorage overlap or offset each other, or significantly impact on growth only for certain ranges of seigniorage, the relationship between seigniorage and economic growth can be determined by seigniorage thresholds. A natural starting point for the empirical analysis of seigniorage thresholds is the quadratic model. Yet, the application of the quadratic model to the analysis of the seigniorage growth nexus has some limitations. The standard quadratic function form needs to know the shape of the non-linearity prior to the estimation and as the value of the threshold level is unknown, we cannot estimate with the conventional gradient search techniques. The quadratic functional form presupposes a well-behaved inverted U shaped relation which may not hold in the data.

In order to overcome the drawback of the standard quadratic model approach, in this chapter, I investigated the seigniorage-growth association for developing countries using Hansen's (1999) threshold techniques to identify the non-linear effect. Without any presumption of the shape of non-linearity, Hansen's (1999) panel threshold model enables us to find the number of seigniorage thresholds and the seigniorage threshold value even when asymptotic distribution of the t-statistic on the threshold variable is non-standard. Empirical evidence based on a recent low-seigniorage period, using a panel of 70 developing countries from 1994 through to 2006 at annual frequency, supports the existence of an inverted-U relation between seigniorage and economic growth. The relationship between per capita GDP growth and seigniorage in the panel threshold model is depicted in Figure 4.6.

In a study of 70 developing countries, I found that the common linear seigniorage-growth model equation has to be rejected in favour of a threshold model. Seigniorage has a positive impact on economic growth if it is less than the threshold and impedes economic growth otherwise. I discovered that there is a single threshold level that equals 2.2715 %, which is strongly significant at the 5 % significance level. In other words, seigniorage increases growth only if it is below 2.2715 %. By contrast, seigniorage decreases economic growth when it is above 2.2715 %. I also confirm the robustness of the threshold estimates by estimating the panel threshold model with instrumental variables. The results indicate that the null hypothesis of one threshold cannot be significantly rejected and only one single threshold exists. The point estimate locates a conventional seigniorage of 2.2619 % at the 5 % significant level in this growth threshold model with instrumental variables. Most of the robustness tests remain consistent and support the previous results.

Figure 4.6 Growth – Seigniorage in Panel Threshold Model



During the last two decades, a number of central banks in developing countries have become aware of the importance of keeping a low-level of seigniorage since there is a positive relationship between low-level seigniorage and economic growth (Hawkins, 2003). Between 1960s and 1980s, double digit levels of seigniorage were frequently observed, after which those levels decreased to single digits, a trend which has since been maintained. Mankiew (1987) and Trehan and Walsh (1990) presented deriving an optimal level of inflation to maximise government revenue to minimise the social cost by seigniorage revenue theoretically. Empirically, this chapter confirms the optimal level of seigniorage at 2.2715% to maximise output growth in developing countries. Knowing the seigniorage threshold level at which there are potential losses in economic output in the short and long term will be helpful for formulating macroeconomic policies. This empirical finding supports such policies and identifies the level of seigniorage that should not be exceeded in the selected developing countries.

However, it is important to note that there is a limitation to this empirical test since the panel threshold model, in this chapter, has a potential endogeniety bias even introducing the instrumental variable. Therefore, in future research, it would be worth investigating whether the endogenous potential of seigniorage can have a non-linear relationship with economic growth using a more advanced econometric methodology. In addition, the inflation threshold in developing countries can be affected by the further characteristics of a particular country so that the appropriate threshold level of the inflation may also be country-specific. An analysis for the threshold value in a single country can be analysed by using a regime switching regression model. This extension of the analysis will be left for future research.

Appendix 4

Appendix 4.A   Derivation of (5): Fixed Effect Elimination

Following Hansen (1999), this section shows how to derive equation (4.5). Let s start by rewriting equation (4.4) in a simple way:

$$y_{it} = \mu_i + \alpha x_{it}\left(\gamma\right) + \varepsilon_{it} \tag{4.A.1}$$

Where $\alpha = (a_1, a_2)$ and $x_{it}(\gamma) = \begin{pmatrix} x_{it} d\left[\dfrac{S_{it}}{Y_{it}} \leq \gamma\right] \\ x_{it} d\left[\dfrac{S_{it}}{Y_{it}} > \gamma\right] \end{pmatrix}$.

By taking averages of equation (4.A.1) over the time index t generates:

$$\overline{y}_{it} = \mu_i + \alpha \overline{x}_{it}\left(\gamma\right) + \overline{\varepsilon}_{it} \tag{4.A.2}$$

In order to eliminate the individual effect μ_i, take difference between equations (4.A.1) and (4.A.2) it produces:

$$y_{it}^{*} = \alpha x_{it}^{*}\left(\gamma\right) + \varepsilon_{it}^{*} \tag{4.A.3}$$

where $y_{it}^{*} = y_{it} - \overline{y}_i$, $x_{it}^{*}(\gamma) = x_{it}(\gamma) - \overline{x}_i(\gamma)$ and $\varepsilon_{it}^{*} = \varepsilon_{it} - \overline{\varepsilon}_i$.

Then reformulate equation (4.A.3) by denoting the data stacked over all individuals and it yields:

$$Y^{*} = \alpha X^{*}\left(\gamma\right) + \varepsilon^{*} \tag{4.5}$$

Where $Y^* = \begin{bmatrix} y_1^* \\ . \\ . \\ y_i^* \\ . \\ . \\ y_n^* \end{bmatrix}$, $X^*(\gamma) = \begin{bmatrix} x_1^*(\gamma) \\ . \\ . \\ x_i^*(\gamma) \\ . \\ . \\ y_n^*(\gamma) \end{bmatrix}$ and $\varepsilon^* = \begin{bmatrix} \varepsilon_1^* \\ . \\ . \\ \varepsilon_i^* \\ . \\ . \\ \varepsilon_n^* \end{bmatrix}$.

Appendix 4.B Panel Unit Root Test: Augmented Dickey Fully Test

Variable	Symbol	t-statistics	Prob
Real Per Capita GDP Growth	*Y*	-5.38184	0.0000***
Seigniorage	*S*	-4.26645	0.0000***
Government Spending	*G*	-3.67653	0.0001***
Investment	*I*	-9.36507	0.0000***
Trade Openness	*O*	1.06579	0.8567
Initial Income	*J*	4.18613	1.0000
Terms of Trade Growth	*T*	-17.6467	0.0000***
Population Growth	*P*	-15.1983	0.0000***
S.D. of Terms of Trade	*ST*	-17.4969	0.0000***

Note: */**/*** indicate the 10%/5%/1% significance level.

Chapter 5

Conclusion

5.1 Overview and Reflections on the Findings

"Monetary Policy refers to changes in the money supply, or the rate of growth of the money supply, to achieve particular macroeconomic goals." (Arnold, 2008, P. 166)

Monetary policy has fundamentally changed the way in which the economy operates. Monetary policy plays a crucial role in influencing economic growth through numerous channels. Yet, the scope of such a role may be changed by the current pursuit of other objectives of monetary policy or uncertainty facing policy makers. This section discusses the findings and some of the possible extensions and applications of the money supply and seigniorage that have occupied the centre stage in research on monetary policy related issues.

This research has sought to know whether the effect of money supply can result in output growth through various channels. The general theoretical literature on this subject and especially in the context of monetary policy is inconclusive on several vital questions within the role of money supply. This thesis has endeavoured to examine various aspects of money growth effect by examining money supply. The aim of this thesis was to explore the effect of money supply and seigniorage on output growth.

In what follows, I shall conclude the thesis by highlighting the key findings and reflections on the findings. I started with the argument on the role of money in monetary policy. The empirical findings in chapter 2 have addressed the study's two research questions. The first question was whether monetary aggregates should not be seen as playing an active role in monetary policy decisions. The second question addressed what exactly is the transmission mechanism of money that affects economic activity. In order to answer these two questions, recursive and non-recursive VAR models are adopted.

The New Keynesian monetary model sets up the interest rate and supply of the quantity of money demanded by a market at a given interest rate. In this case, money plays an unimportant role in the monetary policy. Contrary to the New Keynesian models of monetary policy, the results obtained in the second chapter suggested that shocks to money in South Korea do contain information on the future path of output. A positive shock to money supply led to an increase in output. Moreover, the Mundell-Tobin effect (1965) exists in South Korea as there is a positive relationship between interest rates and output. The results are robust to changes in variables.

Our findings suggested that current monetary policy may neglect a crucial determinant of output dynamics but pay less attention to monetary aggregates. A clear-cut prediction of New Keynesian models of monetary policy is decisively rejected by this research. Money can provide information for evaluating the proper stance of monetary policy, which is not considered in simple interest rate rules. Thus, while I found that monetary aggregates can stimulate output in the short term, ignoring money in the conduct of monetary policy can cause some substantial long-run risks. In addition, policy makers' knowledge of the output gap may not always be superior to their knowledge in the behaviour of money velocity so that it can be useful for them to consult money data as an early indicator of observing or predicting economic conditions.

There are channels through which monetary aggregates contain incremental information for output. This confirms that the money supply does play an important role in the transmission mechanism in South Korea.

First, a shock to money supply affects the financial markets. A change in the monetary aggregates is immediately transmitted to banking lending. This is because a rise in money supply generates more liquidity in banks, which can provide more loans to the public. Policy-induced changes in monetary aggregates can also affect stock prices. The stock prices are influenced by the portfolio-rebalancing effect. This is because investors usually show an intention to decrease an interest-bearing asset component in their portfolios as the money supply increases and they subsequently increase an equity component considerably. A sudden expansion in money supply also impacts on the exchange rates. An unexpected rise in the money supply will probably cause an immediate depreciation of the domestic currency in foreign exchange markets.

Second, a change in money supply affects in non-financial markets. Trade is affected by a monetary policy change. Both import and export increase when there is a shock to the money supply. This is because the money supply affects the trade through the exchange rate channel. Many manufacturing firms in South Korea are exposed to foreign competition. Producers of exports will have more competitive advantages if the exchange rates depreciate. Since South Korea is highly dependent on energy imports, if exports rise, imports will rise. The spending decision of individuals, firms and the government respond to the changes in money supply is altered. The results showed increases in both investment and government consumption when there is a shock to money supply. The response of investment of money supply can be through stock markets. The gain of capital from stock market is an important determinant of investment for all firms. In addition, the inflation tax can result in an increase in government spending.

The results provide institutional and empirical evidence that monetary aggregates and financial and non-financial channels are relevant for analysing South Korea's economy. Should such effects from money supply to these markets prove important, neglecting money in the conduct of monetary policy will come at a potentially large cost.

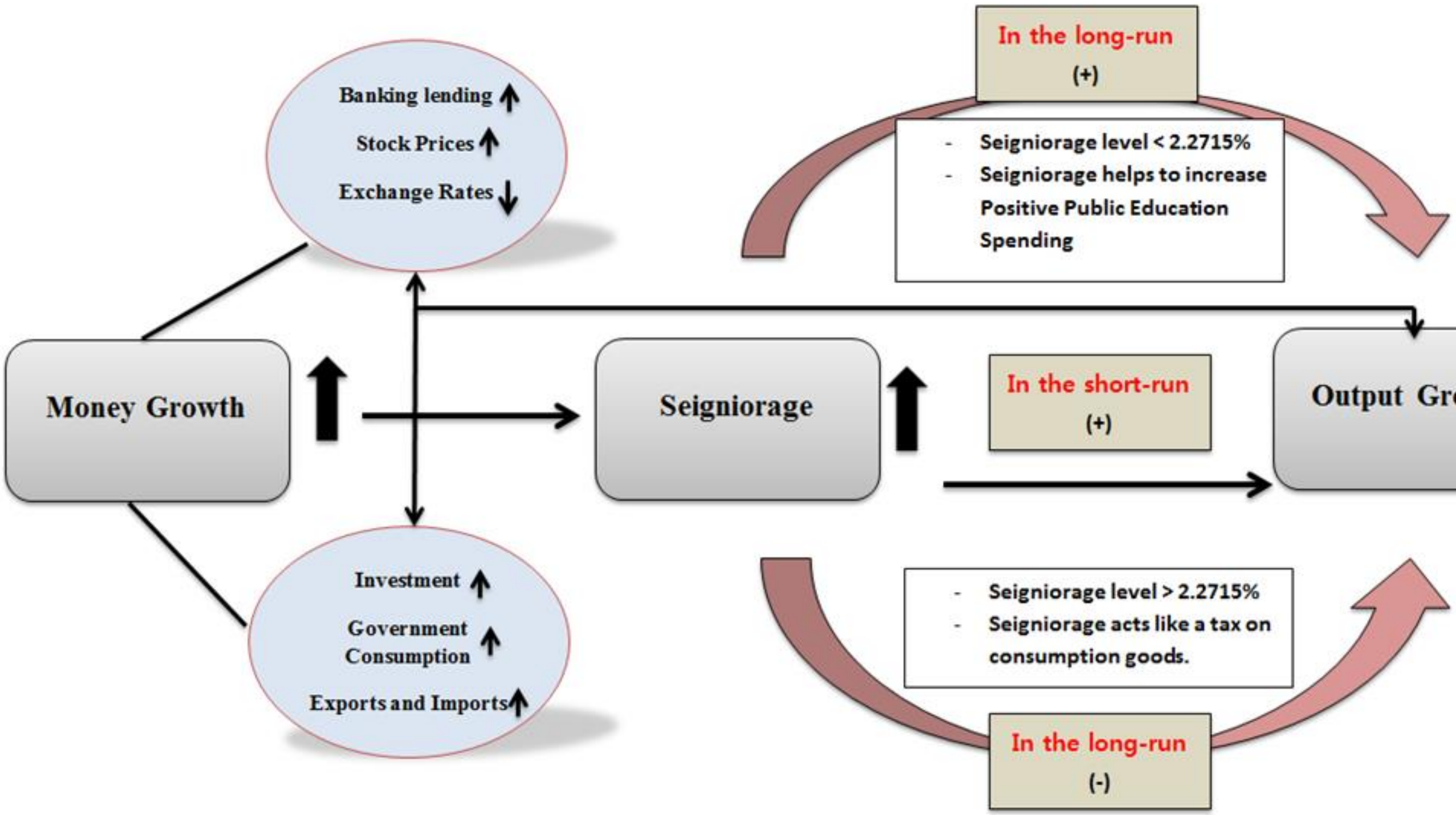
Chapter 3 contributed to answering the questions regarding money supply, seigniorage and economic growth. It, in particular, focuses on the effect which seigniorage has on economic growth. Changes in seigniorage are directly caused by changes in the money supply growth rate. I have presented an estimated dynamic stochastic general equilibrium model for the US economy. This model is framed in the cash-in-advance and human capital based endogenous growth model. Seigniorage is used as main government revenue which is spent on public education. Interacting between fiscal and monetary policy, this research gives intuition on how seigniorage causes the linkage between inflation and human capital utilization. The model showed a strong linkage between the magnitudes of the seigniorage-growth. Seigniorage has a growth enhancing effect from human capital production since government spends productively on education. However, it also has an adverse effect from inflation as it acts as a tax on the cash goods.

The importance of this research is that it shows short-run seigniorage effects that can support the current monetary expansion policy in the US. Using the estimated Bayesian model, I simulated how the economic variables would respond to a money supply shock. Using data on three key macroeconomic variables (output, inflation, and government consumption), the main stylised facts of the US business cycle in terms of money shock are presented. The impulse response analysis provides important information on the transmission mechanism of money shocks through a human capital channel. The results showed that an expansionary monetary policy is followed by an increase of output in the short run. A positive money shock leads to an increase in seigniorage and government spending, which impacts on human capital production positively. An implication of the finding is that the macro-level ambiguity of the seigniorage growth link need not be interpreted as it is unimportant for growth. Appropriate government education spending can help turn seigniorage into a more efficient engine of growth.

The balanced growth equation derived in chapter 3 infers that the effect of seigniorage on output growth may have two opposing effects in the long run. One is a growth-enhancing effect and the other is a diverse effect on output growth. Nonlinearity may exist in the short run, which I could not explore due to the use of the log-linearised model. Therefore, chapter 4 has investigated new evidence on the possibility of a non-linear relationship between seigniorage and economic growth using Hansen (1999)'s panel threshold model. In particular, our empirical findings suggested that seigniorage distorts economic growth when it exceeds a certain critical value. Adopting the correct econometric model is of crucial importance. This panel threshold model can provide information on the number of threshold, the value of threshold, and the marginal impact of seigniorage on growth while the standard quadratic model can lead to biased estimates.

Our results support the seigniorage targets for 70 developing countries which are about 2.2715 %, and which are more or less explicitly announced by many economists and policy makers. Contributing to the on-going debates on the effects of seigniorage rates, these findings demonstrated that seigniorage rates below a critical value of 2.2715 % are positively correlated to economic growth, whereas the opposite is true below that level. The identification of seigniorage thresholds in the seigniorage-growth nexus provides useful information about the appropriate location and width of a seigniorage targeting band. This finding convincingly suggests that the level of seigniorage that should not be exceeded in the selected developing countries. Figure 5.1 demonstrates the summary of the findings in this thesis. Overall, money supply does impact on economic growth through the financial and non-financial channels. In particular, money growth generates the seigniorage which has opposing effects on economic growth in the long run. The positive effect can be from human capital production and the negative effect can be caused by the inflation tax.

Figure 5.1 Summary of the Findings



Up to a certain level, the positive shock to money can lead to an increase in output growth in the long-term. In the short run, a shock to money supply leads to an increase in output because of the public education spending.

5.2 Limitations of This Study and Future Research

Based on the limitations and dissection presented in this research, the following suggestions are developed for future research, which may be taken from this study for the purpose of future studies in order to enhance the role of money supply.

Regarding chapter 2, there are some limitations. The finding is limited to one single country and it does not provide an alternative theoretical framework that supports for these results. In addition, it is not clear as to the causality direction between the money supply and the transmission channels. The following recommendations are made:

- Draw a large and less stylised model: regarding the role of money, the model in the second chapter used to interpret the data is highly stylised and money proxies for other crucial omitted factors. Furthermore only one single country is analysed in the second chapter so that data can be extend to a large group of countries for a further research. Ideally, one would like to estimate the model over subsamples depending on the stage of economic development;

- Adopt various measures of money: innovations in the financial sector raise measurement issues with regard to the appropriate definition of money;

- Develop a theoretical model that allows a detailed look into the dynamics of money shock in a framework that accounts for both monetarist and New Keynesian transmission mechanisms;

- Access the direction of causation between money and transmission channels. It can be uni-directional from money to the transmission channels or vice versa;

Based on chapter 3, some limitations need to be highlighted. First, this chapter presents a general but comprehensive theoretical model by integrating fiscal policy, which does not cover the government revenue from bond market and public spending on goods sector. For instance, the treatment of fiscal policy and monetary policy in chapter 3 is very simplistic. As this was a closed-economy mode, I have omitted an important source of fluctuations such as external shocks. The following recommendations are made:

- Develop a modelling which considers the open market operation as government revenue in an open economy;

- Consider the financial markets in the model. There was no well-developed financial sector in my model. An interesting extension would therefore be to develop the model with the financial accelerator channel of monetary policy;

- Employ different data on seigniorage. Since there are a number of different definitions of seigniorage, it is worth analysing the effect of monetary seigniorage, or opportunity cost seigniorage or inflation tax;

- Estimate the model with data focusing on emerging economies. Since most studies are related to advanced economies, sensible explanations for the markedly observed fluctuations in developing countries are needed;

In terms of Chapter 4, the following points can be discussed for future studies:

- Examine the relationship between seigniorage and growth in industrialised countries. Chapter 4 only focused on developing economies so that the comparison between emerging economies and advanced economies will provide a useful guideline for policy makers;

- Conduct an empirical test based on a single country. The performance of seigniorage targeting in emerging economies can be affected by further characteristics of countries;

- Investigate the channels through which seigniorage affects growth in the empirical framework;

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