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INFLATION AND THE FEDERAL RESERVE SYSTEM LARGE-SCALE ASSET PURCHASE: AN EMPIRICAL ANALYSIS OF THE U.S. CASE

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Resumo

Nos finais de 2008 o Sistema de Reserva Federal dos Estados Unidos começou um programa de compra de activos em grande escala, que consiste em adquirir grandes valores de activos de longo-prazo com o objectivo de estimular a economia. Esta intervenção tem causado diversos debates relativamente ao papel dos bancos centrais na economia, eficácia da política monetária quando a taxa de juro está (quase) a zero, entre outros. Um dos tópicos mais debatidos tem sido o medo de hyperinflação. Desde o seu início o programa foi associado a inflação severa (com base na teoria quantitativa da moeda) apesar de, até hoje, não existir sinais de hyperinflação. Sendo assim, o objectivo desta dissertação é procurar por uma relação não linear entre a política monetária e a inflação e, no caso de uma resposta afirmativa, estudar essa mesma relação, através do modelo TVAR, nos diferentes estados da economia encontrados. A primeira conclusão tirada é que a inflação reage à política monetária de forma differente, dependendo da estado da economia em que nos encontramos. A segunda é que a inflacão é menos sensível quando a taxa de juro é baixa, o que corresponde a uma grande posse de activos por parte do Fed. E finalmente, que um único choque aos activos do Fed aumenta a inflação com algum desfasamento e, como a compra de activos do Fed corresponde a choques contínuos a essa variavél, não é provável que o país tenha hyperinflação.

Palavras-chave: Sistema de Reserva Federal, Compra de Activos em Grande Escala, Inflação, Modelo TVAR.

JEL Classification: E58**,** E31

Abstract

The Federal Reserve System (Fed) Large Scale Asset Purchases (LSPAs), which consists in Fed buying huge amounts of long-term securities in order to stimulate economic activity, is one of the most controversial program a central bank has employed. This is a result of its magnitude, which has caused major debates regarding the role of central banks in the economy, the efficacy of monetary policy at the zero-lower bound on nominal interest rates, among others. One of the most debated topics is the fear of hyperinflation. Since the beginning the program has been associated with severe inflation (based on the quantitative theory of money) although, as of today there is no signs of the latter. Hence, the objective of this dissertation is first to search for a nonlinear relationship between monetary policy and inflation and, in case of an affirmative result, study this same relationship in the different regimes found, by employing a threshold vector autoregressive model. The first finding is that inflation reacts to monetary policy differently, depending on the state of the economy we are in. Second, that it is less responsive when interest rates are low and Fed is increasing its holdings of securities. And finally, that a unique shock to Fed holdings of securities will increase inflation with some lag so, as Fed LSAPs correspond to continous shock to that variable, it is not likely that the country will experience hyperinflation.

Palavras-chave: Federal Reserve System, Large Scale-Asset Purchase (LSAP), Inflation, Threshold Vector Autoregression (TVAR) Model.

JEL Classification: E58**,** E31

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1. Introduction

The US financial crisis and economic recession that started in 2007 has brought new challenges for monetary theory and policy and has revived some old ones. The present dissertation concentrates its analysis in one of the Federal Reserve System (the central bank of the US) response to the crisis, which is Large-Scale Asset Purchases (henceforth LSAPs). By applying LSAPs the Federal Reserve engages in purchases of huge amounts of long-term securities – Treasuries, federal agency debt and mortgage-backed securities – with the main goal of decreasing long-term interest rates to stimulate economic activity. Although asset purchases in the context of (near) zero nominal interest rates are not an innovation it is a policy with little empirical experience, which was used only once before Fed's implementation and, in a different economic context.

It seems no exaggeration at all to say that LSAPs has been the most controversial issue in contemporaneous macroeconomic policy. Over the last decade there was two major novelties in macroeconomic policy, considering the status quo established over the last forty years or so: one on the fiscal side, the other on the monetary side.

On the side of fiscal policy there was what has become known as the President Obama fiscal stimulus package.[1] This fiscal package, despite the large controversy it launched in the US in the late 2009s, represented basically a political fight between Republicans and Democrats much more than a real discussion on the side of modern macroeconomic policy. In fact, it mounted to just a $787 billion bill to cover the period between 2009 to 2019, and on average, it represented no more than $80 billion a year for a decade.[2] As Krugman pointed out, the impact of the package would be too small and disappointing because "it does not cover even one-third of the gap" (Krugman, 2009). A fiscal package that is directed for a ten-year period, and represents around 0.55% of real GDP can hardly be considered as a serious matter for macroeconomic controversy.

The second major novelty was in fact LSAPs, first announced by the Fed in November 2008. And here, yes, we have all the ingredients for a real political and economic controversy for four major reasons:

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[1] The formal name of this package is "The American Recovery and Reinvestment Act of 2009 (ARRA)".
[2] Considering that the level of real GDP was in 2009 close to 14,400 billion US dollars, 80 billion per year amounts to no more than 0.55% of GDP.

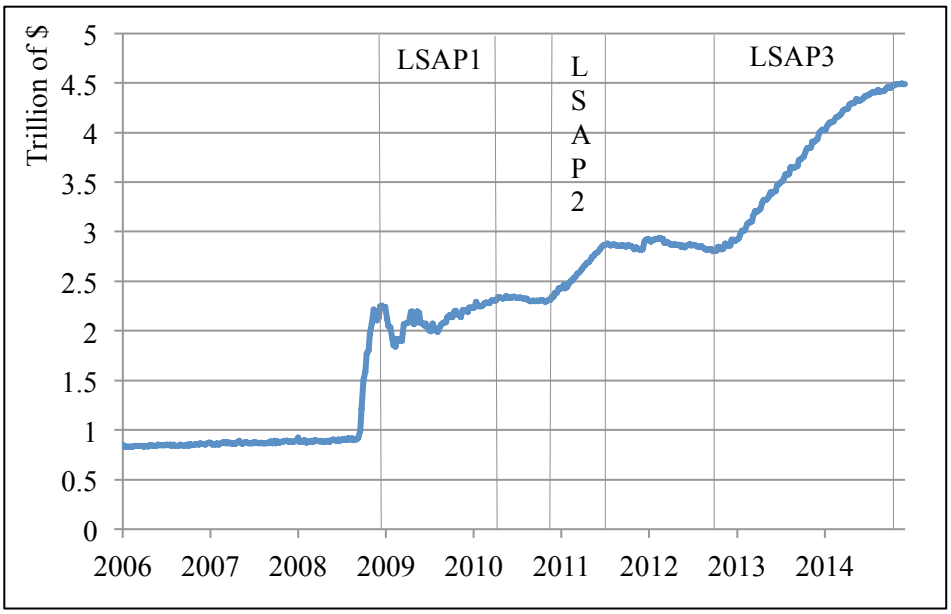

Figure 1.1: Evolution of the Federal Reserve Total Value of Assets
Source: The Federal Reserve System of Saint Louis. Note: The regions LASP1, LSAP2 and LSAP3 show the increase in Fed's total value of purchases under the first, second and third, respectively, round of purchases.

1. The magnitude of the monetary intervention;
2. The rather unchartered territory that monetary policy was entering to in the US and;
3. The immediate impacts that could be easily observed after the initial steps of the policy had been implemented in the US.

The magnitude of the intervention was absolutely outstanding, as it will be detailed further on chapter 2.1. The program involved values that are totally unprecedented in the history of monetary policy in the United States. From a mere accounting procedure, it caused the Monetary Base of the Fed to increase from a humble $800 billion in 2008, to $4.48 trillion in 2014 (**Figure 1.1**). Such an unprecedented movement and the magnitude of the values involved sparkled, from the start, an enormous controversy in US. Ron Paul, a Republican Party candidate for the Presidency of the US, declared, in December 2013, that it was time for turning the Fed down:

> "Today, however, we do know better. We know that the Federal Reserve continues to strengthen the collusion between banks and politicians. We know that the Fed's inflationary monetary policy continues to reap profits for Wall Street while impoverishing Main Street. And we know that the current monetary regime is teetering on a precipice. One hundred years is

long enough. End the Fed."[3]

Moreover, in November 2010, twenty-two top world economists (including John B. Taylor, an economist whose ideas on LASPs will be analyzed later), journalists and businessmen wrote an open letter to the Ben Bernanke calling for an immediate stop to the LSPAs programs. The letter opened with:

> "We believe the Federal Reserve's large-scale asset purchase plan (so-called "quantitative easing") should be reconsidered and discontinued. We do not believe such a plan is necessary or advisable under current circumstances. The planned asset purchases risk currency debasement and inflation, and we do not think they will achieve the Fed's objective of promoting employment."[4]

Despite large opposition in the US among economists, journalists and policymakers, the Fed continued with its asset purchases launching different rounds of the program: the last round was announced September 2012 and finished October 2014.

The second major issue that leads to a natural controversy about LSAPs is the fact that – in clear contrast to discretionary fiscal policy, the nature of which is very well known in macroeconomics due to its widespread use in the 1950-1980s – the Fed was entering into a complete new territory. In fact, a territory that had been dismissed of any major relevance in the Japanese experience with Quantitative Easing (QE) in the 2000s. Japan had implemented a rather timid version of LSAPs since the early 2000s with little success. In a much-cited paper, three top economists of the Bank of Japan (BoJ) made it clear that there seemed to exist more reservations to QE than mere cheers in its favor:

> "During the course of prolonged economic stagnation, it is becoming clearer in Japan that monetary policy is neither a cure-all for an economic slump nor a substitute for policy measures directed at latent structural problems on the supply side." (Fujiki et al, 2001: 125)

So from the start it was not clear that unconventional monetary policy would deliver the goals that had been established by the Fed, and which motived the launch of such

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[3]See here for the full message: http://www.the-free-foundation.org/tst12-16-2013.html. Or see Paul (2009) for further details.
[4]See full letter: http://blogs.wsj.com/economics/2010/11/15/open-letter-to-ben-bernanke/.

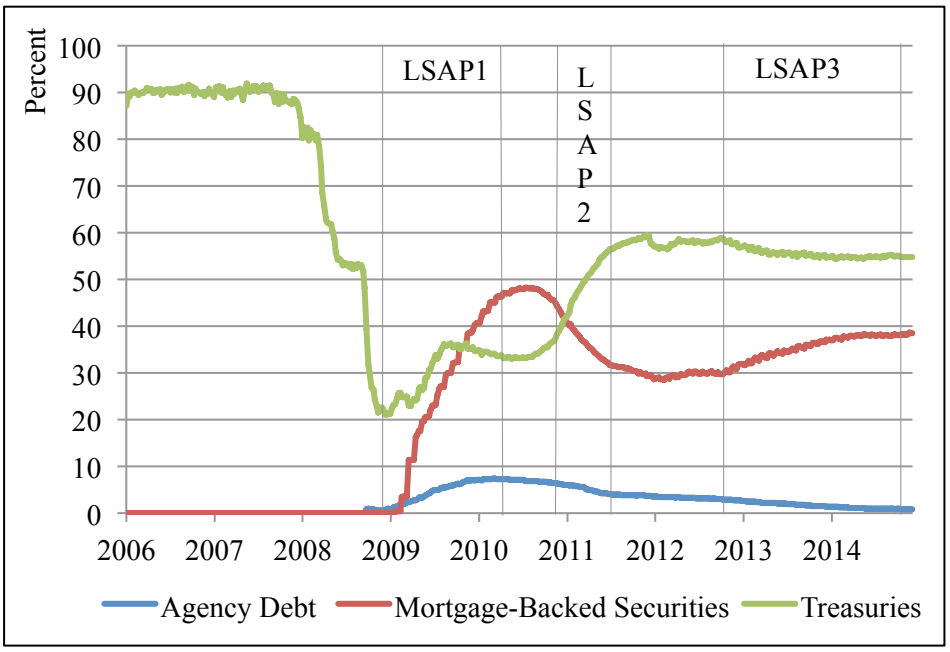

Figure 1.2: Composition of the Federal Reserve Assets
Source: Federal Reserve Bank of Saint Louis

controversial measures. Empirically, it did not worked in Japan as it was supposed to; theoretically, there was a limited number of works discussing the various issues that would certainly be raised in the implementation of such a program. Two major concerns emerged about its execution. The first reservation about its possible negative implications concerns the levels of risk that would overshoot in the economy due to the large scale of the acquisition of long term, and more risky, assets. There was a massive change in the composition of the Fed balance sheet, certainly injecting an unperceived level of risk into the fundamental monetary institution of the US (**Figure 1.2**).

Another major concern was about the risk of hyperinflation. With the Monetary Base increasing by more than 100% in some years, many economists raised the point that this policy would certainly lead to hyperinflation and to the debasement of the dollar. Statistical evidence on this will not be provided here (because this thesis will deal essentially with the problem of hyperinflation, or the lack of it), but the fact is that there has been no sign of any relevant inflationary pressures in the US economy, and hyperinflation is beyond any conceivable reasonable scenario, given that we had LSAPs

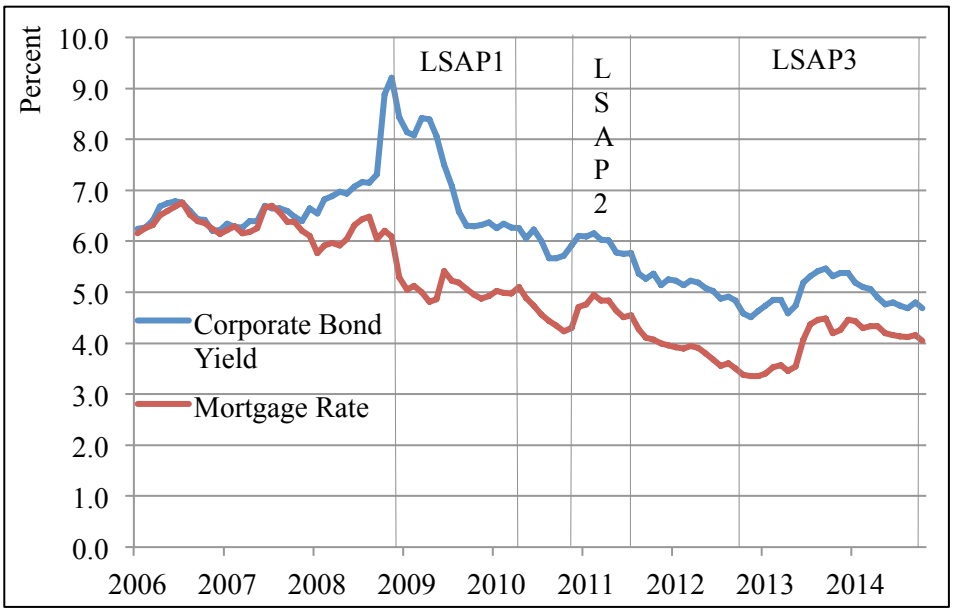

Figure 1.3: Evolution of Long-term Interest Rates
Source: Federal Reserve Bank of Saint Louis

for six years altogether.[5]

The more dramatic aspects of LSAPs can actually be found in the immediate impacts that could be easily observed after the initial steps were implemented in the US. If from a mere theoretical point of view, we had more doubts than certainties (and the problem of risk was something that nobody could overlook), the implementation of this monetary policy framework led to large positive and surprising effects upon crucial macroeconomic variables. It led to a significant decline in long-term interest rates (**Figure 1.3**), to a remarkable surge in stock prices and correcting declining inflation expectations (**Figure 1.4**, below).

The choice of LSAPs as the main topic for this dissertation is associated first, with my personal interest in monetary theory and policy, and second with all the above-mentioned controversies, which makes this one of the most current and reviewed topic in terms of macroeconomic policy. More specifically, the proposed objective of this dissertation is to see if the relationship between monetary policy and inflation changes when monetary policy is constrained by the zero lower bound on nominal interest rates. As mentioned previously, inflation has been relatively stable besides Fed's

[5]More recently, Stephen Williamson defended a totally opposite view to the hyperinflationary effects of LSAPs. Making use of a mere identity equation (the Fisher equation), Williamson defended the point that LSAP will be, in fact, deflationary, not inflationary (Williamson, 2013).

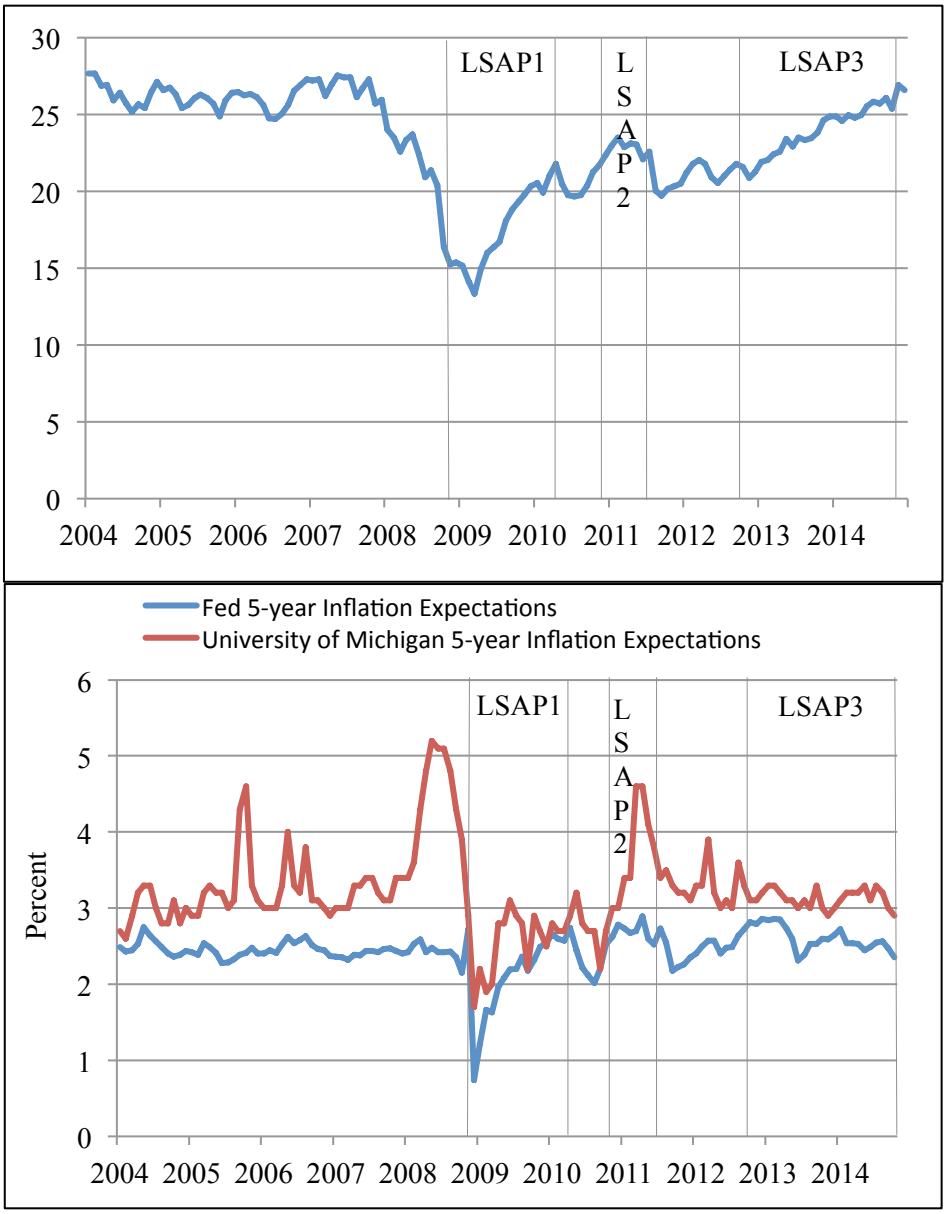

Figure 1.4: Evolution of the Robert Shiller's Stock Market Index (1st panel) and of Inflation Expectations (2nd panel)

Source: www.econ.yale.edu/~shiller/data/ie_data.xls (1st panel) and Federal Reserve Bank of Saint Louis (2nd panel). Note: the Robert Shiller's Stock Market Index is usually known by CAPE, or Cyclically Adjusted Price Earnings Ratio, and is defined as the price of stocks divided by the ten year moving average of earnings, and adjusted for inflation

expansionary monetary policy, with fears of deflation being more likely than fears of inflation.

And in fact, two different regimes (corresponding to different states of the economy) are found when Fed holdings of Treasuries, agency debt and MBS (a proxy for Fed LSAPs) is used as a threshold variable. Given this, a Threshold Vector Autoregression

(TVAR) Model is applied to study the effect of LSAPs on inflation, in those two regimes which corresponds to states of the economy where Fed massively buys assests and thus interest rates are low and, the opposite.

The structure of this thesis will be organized as follow: chapter 2 will describe the Federal Reserve System Large Scale Asset Purchase, the theoretical rationals used to employ this program, its benefits and costs, the major debates it encouraged (the different opinions of prestigious economists), among other aspects related to it; chapter 3 will present the empirical analysis employed to study the existence of a nonlinear relationship between monetary policy and inflation, describing first the theoretical models and concepts used, and after, the results and; chapter 4 presents the main conclusions of the present dissertation.

2. Large Scale Asset Purchase

The Federal Reserve System has at its disposal three monetary policy tools - reserve requirements, discount rate and open market operations; to help achieve its statutory mandate of maximum employment, price stability and moderate long-term interest rates. By using these tools Fed influences the liquidity of depository institutions, and thus, the rate they charge to lend money to each other (federal funds rate). Changes in this rate affect short-term, which in turn influence long-term rates and both affect the quantity of money and credit and, in the end, the level of employment, output and prices.

Through the discount window Fed lends money to depository institutions at the discount rate. Loans are extended for a short-term period (usually overnight) and against eligible collateral. The main reason depository institutions borrow money from each other and the Fed is to meet reserve requirements – there is a minimum amount of funds these institutions have to hold as a reserve (deposits at the Fed or cash in bank vaults). Reserves requirements are set by the Fed and calculated as a percentage of specific deposits liabilities. Since October 2008 Fed has been paying interest on required reserves and excess reserves (reserves held beyond the mandatory ones). Open market operations are the main monetary policy tool and it represents sales and purchases of securities by a central bank (normally short-term Treasury and agency debt). Even though transactions are conducted with primary dealers, the reserves of depository institutions are affected through the accounts the former have on the latter.

Fed sets a target for the overnight federal funds rate it wants in the interbank lending market. Theoretically the discount rate represents the upper limit of fed funds rate, as a depository institution will not borrow money from other at a higher rate than it can borrow from the Fed. The interest on reserves (IOR) represents the floor, since banks will not lend money at a lower rate than the one they can earn keeping it as a reserve. Open market operations are used to add or drain depository institutions' reserves, in order to maintain fed funds rate around the target. For example, if fed funds rate is below target, Fed can sale short-term securities to decrease depository institutions' reserves – primary dealers withdraw money from their bank account to pay the securities – increase their demand for balances, and thus, the price of these balances (fed funds rate).

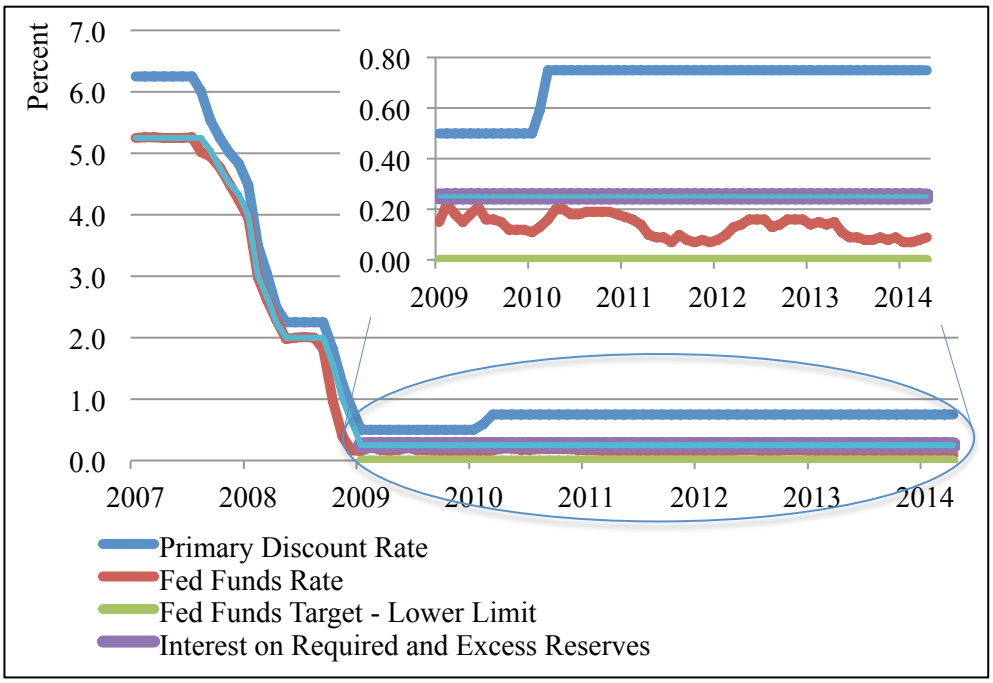

Figure 2.1: Evolution of Federal Reserve Interest Rates
Source: Federal Reserve Bank of Saint Louis

Fed decreases fed funds rate target when it intends to stimulate economic activity, for example in times of recession (expansionary monetary policy). The decrease becomes effective by reducing the discount rate, interest on reserves and/or reserve requirements, and/or buying short-term securities. This will put a downward pressure on short-term interest rates - which in turn will influence long-term rates - increase the quantity of money and credit, peoples' and firms' demand for goods and services, output, employment and prices. The financial crisis and subsequent recession of 2007 led Fed to gradually decrease fed funds rate target from 5.25% in September 2007 to a range of 0 to 0.25% in December 2008, decrease primary and secondary discount rates that are now 0.75% and 1.25% respectively[6] and, implement interest on reserves of 0.25%, as it can be seen in **Figure 2.1**.

The figure shows that interest on reserves has not been an effective floor for fed funds rate that has been below 0.25%. Among other reasons, there is the fact that some institutions are allowed to lend money in federal funds market but cannot earn interest on the accounts they have at the Fed. Despite this, it is important to state that short-term rates are close, but not at their lowest level of 0 due to the interest paid on reserves.

[6]Primary credit is granted to depository institutions with good financial conditions. The remaining institutions have to apply for secondary credit.

From April 1999 to August 2000 and from 2001-2006, Bank of Japan (BoJ) provided ample funds for commercial banks and achieved a 0% overnight rate. This was possible because, at that time, BoJ was not paying interest on reverses. After the global financial crisis, BoJ substantially increased banks' balances but the overnight rate decreased only to 0.1%, the value implemented for IOR (Woodford, 2012).

With fed funds rate close to its lower bound of 0, the effectiveness of Fed's monetary policy has been called into question by making use of the concept of liquidity trap. A liquidity trap is a situation where monetary policy becomes impotent to stimulate the economy, because central bank cannot decrease interest rates. John Maynard Keynes introduced the concept and he believed the only way monetary policy could have an effect on real economy was by changing the level of interest rates. A decrease in the cost of investment should stimulate it, increasing employment, output and thus, promoting economic growth (Keynes, 1936).

In fact, with interest rates close to their zero lower bound, purchases of short-term securities have almost no room to lower fed funds rate and short-term rates. Furthermore, monetary expansions will not lead to significant increases in the quantity of credit and money. First, short-term rates are so low that money and short-term securities can be considered perfect substitutes. An exchange of one for another will not make banks feel more liquidity and increase credit. Second, in the U.S. case, banks were reluctant to lend money and preferred to earn interest on reserves (a more secure investment for their funds). Even if money supply increases, private sector would be hesitant to spend it, given the state of the economy and conditions of their balance sheet.

But, unlike Keynes, Fed believed it had other ways to fight the recession so it turned to unconventional policies such as forward guidance and asset purchases. Forward guidance is a central bank clear statement about the future path of its monetary policy (Woodford, 2012), and is used to influence private sector expectations of future short-term rates and thus, long-term rates, as current fed funds rate and short-term rates are almost at zero. As an example, the statement issued after the Federal Open Market Committee[7] (FOMC) meeting of December 2008 declared "weak economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time". As people anticipate low levels of short-term interest rates, there will be a downward

[7]The committee responsible for open market operations.

pressure on long-term rates, easing financial markets condition and stimulating aggregate demand.

It was in this context that Fed launched the Large Scale Asset Purchase (LSAP) program.

2.1 A description of Fed Large Scale Asset Purchase

Fed announced the first program (LSAP1) in November 2008, when fed funds rate target was still 1%. LSAP1 included purchases of up to $100 billion in agency debt - debt of housing related Government-Sponsored Enterprises (GSEs)[8] Fannie Mae, Freddie Mac and Federal Home Loan Banks - and up to $500 billion in Mortgage Backed Securities (MBS)[9] backed by Fannie Mae, Freddie Mac and Ginnie Mae[10]. As spreads on these securities had increased substantially and credit strains were still present, the purpose of this program was to reduce interest rates, mainly mortgage rates, and increase credit availability. In the end, LSAP1 was supposed to stimulate housing market and improve conditions in broader financial markets.

To offer even grater support to the economy Fed decided, in March 2009, to increase purchases of agency debt by $100 billion, agency MBS by $750 billion and buy up to $300 billion of long-term Treasury securities. Reinforce mortgage credit and stabilize financial markets stopped being the main focus of the program, becoming a way to achieve the ultimately goals of economic recovery and price stability. Since the target for the overnight rate was already at 0-0.25% and the U.S. economy was still in recession, purchases of long-term securities were an unconventional way to provide monetary easing for the economy. Fed objective was to directly influence (decrease) long-term rates, as its capacity to indirectly influence them was exhausted. Lower long-term interest rates should stimulate economic activity through increases in long-lasting consumption and investment. Acquisitions were concluded March 2010.

Bernanke (2012) states that Tobin (1965) and Friedman (2000) advocated for purchases of long-term securities after short-term interest rates were down to zero in the case of the Great Depression and Japan's deflationary trap, respectively. It is important

[8]Privately owned companies created, by the U.S. Congress, with the public purpose of improving credit availability for some borrowing sectors of the economy (agriculture, home finance, education and others).
[9]Security that it is collateralized by a set of mortgages.
[10]U.S. Government Corporation created to encourage home ownership.

to note that Friedman's suggestion was made with an intermediate goal, other than the one Fed used to pursue LSAPs. Friedman viewed these acquisitions as a way to increase monetary base, while Fed viewed them as a way to decrease long-term rates. Clouse *et al* (2000) suggest there were two factors constraining recovery when Fed decreased short-term rates to zero in the 1930s: the fact that long-term rates were still high and, the existence of significant spreads on private debt. Spreads on commercial paper and corporate bonds actually rose throughout the Great Depression. The authors consider that by decreasing these rates Fed could have added more accommodation to the economy. They call attention that this also happened in Japan in the 1990s.

After LSAP1, the Federal Reserve System adopted two more rounds of the program that were primarily designed to stimulate strong economic recovery and assure inflation is in line with Fed's goal of price stability. Following the end of the recession (June 2009) the U.S. went through periods of slow recovery in output and employment. Spending and demand for houses increased sluggishly, as households concentrated in repairing their balance sheet and credit availability was tight. Unemployment registered minor decreases and these were mainly attributable to reduced labor force participation, than job creation. Long-term inflation expectations were stable, but inflation was running been below the Fed's objective of 2% (Bernanke, 2010).

LSAP2 was launched at the November 2010 FOMC meeting, and it consisted in purchases of $600 billion of long-term Treasury securities until June 2011 (average of $75 billion per month). Economic recovery continued to be below expectations and, according to Bernanke (2011), weak financial conditions and a depressed housing sector were the factors slowing down recovery, both separately and in combination. Bernanke explains that even though conditions in financial markets were improving, access to credit were still tight, limiting demand for houses and housing market recovery. The latter, in turn, has negative effects on financial institutions and credit conditions (declines in house prices may lead to mortgage defaults).

LSAP3 was launched September 2012 mainly to contribute to Fed objective of maximum unemployment. Fed believed the economy needed more monetary easing to grow and generate significant improvements in labor market conditions (unemployment was still high, decreasing at a slow pace). The objective was to fight the short-run gap of employment, since monetary policy cannot influence the long-run trend (Bernanke, 2013a). Under LSAP3 Fed pledged to buy, per month, $40 billion of agency MBS until there was a "substantial improvement" in labor market conditions that had to be

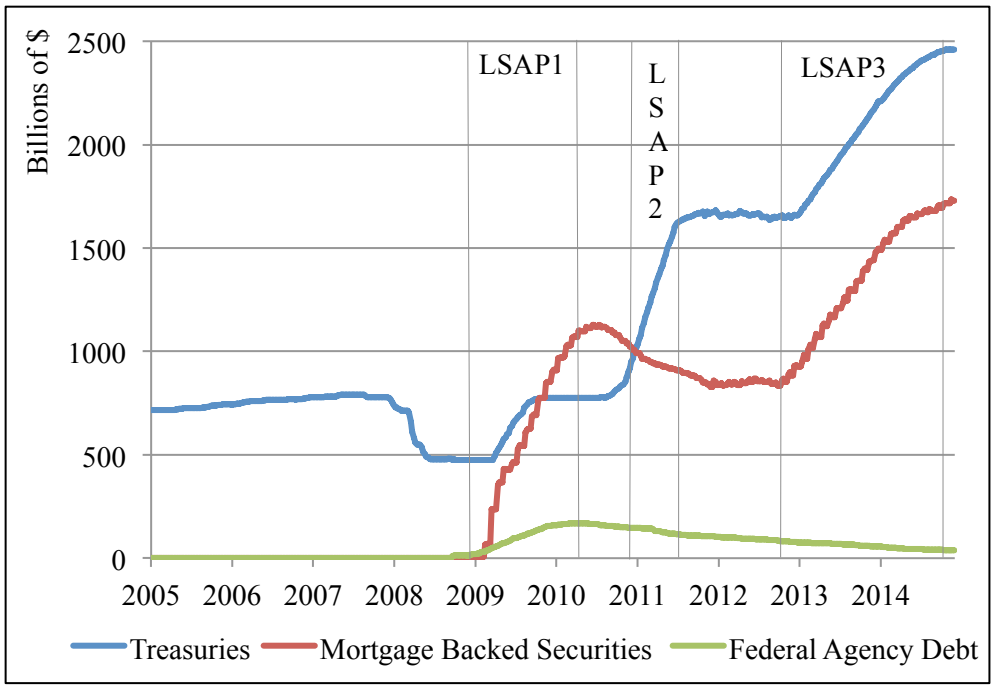

Figure 2.2: Evolution of Federal Reserve System Securities Holdings

Source: Federal Reserve Bank of Saint Louis. Note: The regions LASP1, LSAP2 and LSAP3 show the increase in Fed's securities under those rounds of purchases.

achieved in a situation of stable prices. In LSAP1 and LSAP2 acquisitions were made on a predetermined time course, which led Fed to close the program when the economy might have needed more stimulus. LSAP3 was expanded December 2012 to include monthly purchases of $45 billion of long-term Treasury securities. The decision to stop or decrease purchases depended, again, on the outlook for the labor market. Fed would also pay close attention to the evolution of the program's benefits and costs. **Figure 2.2** shows the massive increase in Fed assets under LSAP1, LSAP2 and LSAP3.

Bernanke gave the first clue with regard to a winding-down of LSAP3 in May 2013. In a testimony before the Joint Economic Committee of the U.S. Congress he declared Fed could decrease purchases of long-term securities in forthcoming FOMC meetings. The decision depended on incoming data about the state of the economy, namely about the labor market. Sustained improvements in the latter would induce a decrease in the pace of purchases, although increases were also an option, if recovery was to slow and/or inflation to decrease. Later that day Fed released the minutes of the April 30-May 1, 2013 FOMC meeting, which stated that "a number of participants" wanted to decrease purchases in the next meeting (June), if incoming data confirmed sustained economic growth. After these two announcements stock prices slumped and long-term rates and mortgage rates rose. Higher rates tightened financial conditions in subsequent

months. Fed's purchases are expected to raise stock prices and lower interest rates (chapter 2.4.1), so changes in its pace can lead to corrections in these variables.

In the press conference after the June FOMC meeting, Bernanke explained that a decrease in the pace of purchases was not a tightening, since Fed would still be adding accommodation to the economy. Purchases would continue, just at a slower pace:

> "To use the analogy of driving an automobile, any slowing in the pace of purchases will be akin to letting up a bit on the gas pedal as the car picks up speed, not to beginning to apply the brakes." (Bernanke, 2013b: 6)

Fed postponed the decision to lower the pace of purchases for 4 FMOC meetings (June, July, September and October). According to statements, although there was some progress in labor market conditions, the unemployment rate (considered by Bernanke the single measure that best describes conditions in that market) continued to be at a high level. Restrictive federal fiscal policy was slowing economic recovery and improvements in the state of the labor market. Fed showed concerns about the tightening of financial conditions, because if it continued it could also be a constraint for the recovery.

The first downward change in LSAP3 was announced December 2013. Federal Reserve decreased purchases of MBS and long-term Treasury securities by $5 billion each. Financial conditions had stabilized and the negative effects of restrictive fiscal policy appeared to be declining. Although the unemployment rate was still high, it considerably declined in the last months before the meeting. When Fed started LSAP3 (September 2012) the unemployment rate was 8.1%, decreasing to 7.5% in June 2013. From June to the time Fed decided to decline purchases, the unemployment rate had decreased 0.5%, to 7%. Fed believed the economy was in a good pace towards sustained growth and thus, improvements in employment level. Remember LSAP3 was supposed to continue until there was, "in a context of price stability", a "substantial improve" in labor market conditions.

Further reductions of $5 billion were announced January, March, April, June, July and September 2014. The decrease in the pace of purchases can be seen in **Figure 2.2**, beginning 2014. The FOMC meeting of October 2014 determined the end of the program. Fed believes the economy is in a good path to achieve its dual objective of price stability and maximum employment. Fed's strategy to normalize the size of its balance sheet is to let securities roll off the portfolio as they mature, instead of selling

them like it was previously announced (Bernanke, 2013a). Sales might be used in the longer run to remove any remaining MBS. This normalization policy was announced after the FOMC meeting of September 2014.

2.2 LSAP, (Pure) Quantitative Easing and Credit Easing

Fed large scale-asset purchase program is commonly called Quantitative Easing (QE) and the name derived from Bank of Japan (BoJ) asset purchases, adopted from 2001 to 2006, to stimulate Japan economy since it was going through a persistent deflation caused by the burst of the asset price bubble in 1989. BoJ decreased its overnight rate (call rate) to zero and, in face of this limitation, adopted QE, changing its policy instrument to commercial bank's reserves. Under QE it bought long-term securities, mainly Japanese government bonds, in order to achieve the target it set up for bank's reserves and increase money supply (Girardin and Moussa, 2011).

Bernanke (2009) calls attention to the fact that Fed program is conceptually different from the one BoJ put into practice, which is sometimes called pure quantitative easing (Woodford, 2012). He suggests their program should be know as "credit easing", because it was created to stabilize credit strains in U.S. financial markets. Nonetheless, this name fits LSAP1 (apart from its expansion) better than the following LSAPs. Bernanke explains that, while BoJ was focused on its liabilities (money in circulation plus reserves) and how its increase would stimulate aggregate demand and prices, Fed was focused on the composition of its assets (on the securities it was purchasing) and how these would stabilize financial conditions and promote aggregate demand. Given Japan persistent deflation and the global financial crisis, BoJ returned to QE in October 2010 and in April 2013 it announced an aggressive 2-year program.

Bank of England (BoE) is another central bank that has engaged in QE, as in March 2009 it decreased the bank rate (BOE overnight lending rate to banks) to 0.5% and was unwilling to lower it further. Throughout time BoE raised the total amount of its purchases, and in July 2012 it announced the last increment. Beyond government bonds it also purchased a small amount of private debt to directly ease firms' borrowing. Bank of England expects QE to affect economic activity through a variety of channels that include both, Fed and BoJ ideas. In BoE point of view, QE affects the economy through decreases in assets interest rates, increases in their prices and increases in bank credit,

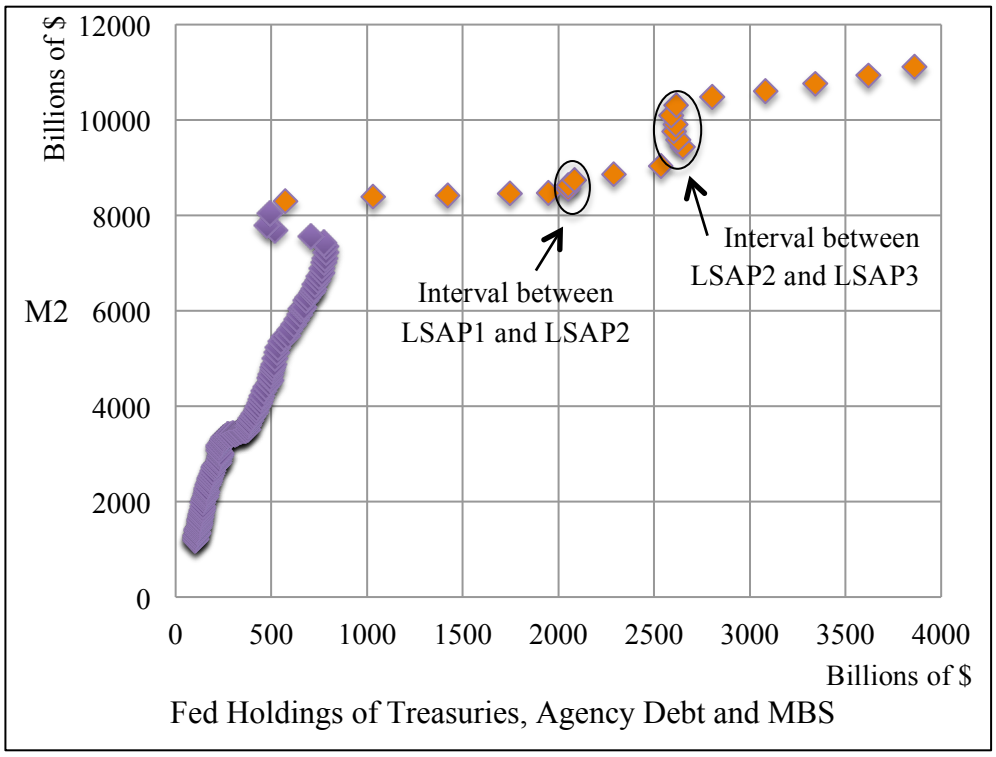

Figure 2.3: LSAPs effect on Money Supply

Source: Federal Reserve Bank of Saint Louis (M2) and Federal Reserve System (Fed Holdings of Securities). Note: The figure represents the relationship between M2 and Fed holdings of Treasuries, Agency Debt and MBS from the first quarter of 1977 until the first quarter of 2014. The orange dots represent the later relationship after the beginning of LSAPs (January 2009).

although it reckons the latter channel may have weak effects because banks are reluctant to lend money. This is why BoE is buying assets mainly from private sector businesses.

Also, the European Central Bank (ECB) have extended, in January 2015, its private sector asset purchase programmes to include now sovereigns bonds issued by euro area central governments, agencies and European institutions. This will lead to monthly asset purchases of €60 billion. They intend to keep this program until September 2016 with the objective to reach price stability (inflation has been two low) by easing financial conditions. Once again, this policy was implemented because the ECB had its main interest rates at their lower bound of 0%.

2.3 Transmission Mechanism of LSAP

The Federal Reserve System implemented LSAPs in order to lower long-term interest rates, which in turn would ease financial conditions and boost economic activity. Lower long rates can fuel asset prices, allow households to refinance their loans and, reduce

the cost of capital for businesses, increasing consumption and investment and stimulating economic activity. Fed does not consider LSAPs will improve economic situation through increases in money supply. The reason is that banks are keeping most of the funds they receive from Fed's purchases as excess reserves, rather than lending them (Bernanke, 2010). **Figure 2.3** shows the relationship between M2 and Fed holdings of Treasuries, agency debt and MBS, from the first quarter of 1977 until the first quarter of 2014. As it can be seen, this relationship was strong and positive before Fed start LSAPs (purple dots), but since their beginning (orange dots) it has substantially weakened. In fact, M2 has been rising at its normal pace indicating that Fed's large-scale purchases and thus, massive increase in holdings of securities, has had little effect on it.

In Fed's point of view, LSAPs affect long-term rates through portfolio-balance channel and signaling channel (Bernanke, 2012). According to standard theories of the term structure of interest rates, long-term rates are determined by current and expected path of short-term rates and, a risk premium, as follow (Clouse *et al*, 2000):

$$i_t^L = \frac{1}{N}\sum_{j=0}^{N-1} E_t\left(i_{t+j}\right) + \theta_t^L \tag{2.1}$$

LSAPs influence current short-term rate (i_t) and expectations of future short rates through signaling channel, because the program signals the nature of Fed's monetary policy, in this case, its willingness to follow a looser policy. The portfolio-balance channel works by influencing the risk premium (θ_t^L), through changes in the supply of assets. **Figure 2.4** (page 26) presents a summary of the transmission mechanism of LSAPs.

2.3.1 Portfolio-Balance Channel

When Fed buys long-term securities it decreases the available supply of these assets, increasing the price investors are willing to pay for them and decreasing the yield they are ready to accept. Reduced supply induces investors to search for similar assets to buy (similar credit risks, maturity, *et cetera*) raising prices on these assets and lowering their yields. Together, Fed's action and investors' portfolio re-allocation should decrease long-term interest rates. As an example, purchases of MBS decrease the supply

available of these assets, lowering their risk premium. Investors can substitute MBS for high quality corporate bonds, decreasing company's borrowing rates.

Krishnamurthy and Vissing-Jorgensen (2011) analyzed the effects of LSAP1 and LSAP2 on interest rates and concluded that LSAP1 contributed to larger decreases in corporate yields, than LSAP2. They suggest the difference has to do with the fact that LSAP1 involved purchases of MBS, while LSAP2 was only long-term Treasury securities. Among other channels, reduced availability of MBS led investors to buy corporate bonds lowering their default risk premium.

The effect asset purchases have on interest rates occurs through the stock of assets Fed holds (or the total supply it leaves available for investors), rather than by the quantity of new purchases (Bernanke, 2010). Changes in the supply of assets influence their premium and the ones of broadly similar assets, because of the assumption of imperfect substitutability between different financial securities (Bernanke, 2012). If the two securities being exchanged are perfect substitutes, the total supply available of that type of asset will not vary, keeping risk premium unchanged. There are many reasons assets are taken to be imperfect substitutes, as the existence of transactions costs, different risk characteristics and investors with different "preferred habitats". Portfolio-balance effect was developed in the works of Allan Meltzer, Karl Brunner, James Tobin, Milton Friedman and, Marco Modigliani and Richard Sutch.

Modigliani and Sutch (1966 and 1967) propose the Preferred Habitat Theory, a new theory of the term structure of interest rates, in which each investor has a preference regarding the period of time they want to keep funds invested and, requires a premium to compensate the risk and cost of investing outside it. This risk has to do with the fact that the return gained from shorter or longer investments will be uncertain. In this model long-term interest rates are defined by current and expected short-term rates and, a risk premium, which can be positive if investors have short-term habitats, or negative, otherwise. Interest rates (risk premium) are affected by the relative supply and demand of assets with different maturities. If the supply of a short-term asset increases, exceeding their demand by investors with short-term habitat, its interest rate rises because investors with long-term habitats require a higher risk premium to acquire the new supply. The existence of preferred habitats makes assets from different maturities imperfect substitutes for each other.

The authors estimate how changes in U.S. government supply of short-term and long-term debt affect the term structure, and find that the former have weak effects on the

latter. They call attention that results may be due to limitations in their empirical method. In face of these poor quantitative outcomes, Modigliani (1971) specifies the channel through which monetary policy affects aggregate demand in the Federal Reserve-MIT-Penn model[11] and, ignores the portfolio-balance effect. He suggests monetary policy tools affect short-terms interest rates, which in turn affect long-term rates through expectations. The latter, by discounting the expected value of future dividends, influence the price of equities and thus consumers' wealth and spending.

Doh (2010) presents a preferred habitat model that includes the zero lower bound on nominal interest rates. In this model, higher risk aversion by arbitrageurs leads to higher changes in interest rates as a response to variations in the supply of assets (but risk aversion cannot be very extreme). At the zero lower bound, arbitrageurs' aversion increase, leading LSAPs to induce significant decreases in the term premium. The model implies LSAPs are more effective lowering interest rates than forward guidance.

Tobin was one of the first authors to develop the idea of portfolio-balance effect. In Tobin (1961), he presents an economy with three ways of holding wealth: money, capital and bonds, but with only two assets, money and capital, since he considers money and bonds as one (perfect substitutes). Changes in the relative supply of capital and money (government debt) influence the yield difference between these two assets, because of their imperfect substitution. Tobin (1961: 34) writes, "Among assets that are not perfect substitutes, the structure of rates will depend upon relative supplies. In general, an increase in the supply of an asset – e.g. long-term government bonds – will cause its rate to rise relative to other rates, but less in relation to assets for which it is directly or indirectly a close substitute – in the example, short-term securities and money – than in relation to others – in the example, capital."

He contrasts his economy with the one Keynes developed in his "General Theory". The latter presents a model with several assets (4 or 5) but investors regard government bonds, private debts and capital as perfect substitutes. Once again, there is only one yield differential to be explained –that of interest rates on bonds over the zero rate of money – and it depends on the relative quantity of these two assets. In Keynes model, the removal of government long-term debt, because of a budget surplus, is

[11]A macro-econometric model developed by a group of economists from the Federal Reserve System, Massachusetts Institute of Technology (MIT) and University of Pennsylvania and that was used by the Fed for forecasting and policy analysis.

expansionary. Interest rates decrease, since the relative supply of bonds decreases, and investment increases. In Tobin's economy, the removal will be deflationary, since long-term rates are fixed (given perfect substitutability with money) and so investors require a higher rate of return on capital to shift from bonds to capital. From Tobin's point of view, the variable that should be taken into account when evaluating the effects of policy action is the supply price of capital (investors' required rate of return to hold the stock of capital left in the economy). If investors require a higher rate of return than the one the existing capital can yield, investment decreases.

In a money-capital economy there is no room for monetary policy because money supply and government debt are the same. Tobin analyzes the effect of this policy in a new paper (Tobin, 1963), wherein he presents an economy with a higher number of assets that are taken to be imperfect substitutes for each other. An open market purchase has a deflationary effect by decreasing the supply of short-term debt (as explained above) that will be more than compensated by the expansionary effect of increasing the quantity of money. Investors use their new supply of money to buy capital and, to avoid an excess demand for the existing stock of capital, the supply price of capital falls.

The oldest best-known Tobin's work in portfolio-balance effect might be Tobin (1969). This work can be seen as a summary of his ideas expressed above. He presents a money-capital and a money-securities-capital economy, in which assets are taken to be imperfect substitutes. In the latter economy, open market purchases are expansionary. Changes in the quantity of money and securities influence interest rates and prices to induce investors to actualize their portfolio. A decline in the relative supply of securities decreases its interest rates, which induce people to hold the higher supply of money and use it to buy capital. This raises the price of existing capital relative to its replacement cost ("q") increasing investment and aggregate demand. Thus, in relation to monetary policy Tobin (1969: 29) states, "There is no reason to think that the impact will be captured in any single exogenous or intermediate variables, whether it is monetary stock or a market interest rate". Monetary policy affects a variety of interest rates and prices.

Brunner and Meltzer share the same ideas as Tobin in regard to the portfolio-balance channel and thus, the fact that monetary policy transmission mechanism cannot be assessed only by a single interest rate (Brunner and Meltzer, 1973; Meltzer, 1995). Friedman also acknowledged the existence of portfolio-balance effects and recommended purchases of long-term bonds when nominal interest rates hit the zero lower bound (Nelson, 2011). In the meanwhile, there is an important difference between

the views of Tobin and Friedman. As it can be seen above, Tobin gave more importance to the portfolio-balance effect on the price of assets (capital in his model, or equity if we think of a company) and he believed this price was more important for aggregate demand and monetary transmission mechanism, than interest rates. Friedman believed the opposite as he gave more emphasis to the effect of interest rates.

2.3.2 Signaling Channel (Portfolio-Balance Channel in NKM)

The New Keynesian Model (NKM) – nowadays the main framework used to analyze the design and conduct of monetary policy – refutes the existence of portfolio-balance effect when central bank acquires long-term securities and, introduces another rationale for LSAPs which is to signal the nature of central banks current policy commitments and, therefore, influence private sector expectations. In this model, because of the existence of nominal rigidities, monetary policy affects aggregate demand by influencing the real interest rate ($i_t - E_t\pi_{t+1}$), through changes in the short-term nominal interest rate (i_t) that is assumed to be the central bank policy instrument. The NKM implies the expected future path of real rates also matters for aggregate demand, so that is not only current police rate that is important for monetary policy, but also private sector expectations regarding future policy rate. This can be seen in equation **(2.2)** that is derived from the expectational investment saving (IS) equation, which in turn results from the Euler condition for optimal consumption (Walsh, 2009):

$$y_t = -\left(\frac{1}{\sigma}\right)\sum_{j=0}^{\infty} E_t\left(i_{t+j} - \pi_{t+j+1} - r^n_{t+j}\right). \tag{2.2}$$

In a situation where a real disturbance affects the economy and the natural real rate of interest (r_t^n: the rate consistent with output equalizing its potential and stable prices) becomes negative, central bank decreases policy interest rate to stabilize the economy. If r_t^n is so negative that current policy rate is decreased to zero, the only way monetary policy can still affect real economy is by influencing expectations of the future path of that rate. To achieve this, Eggertsson and Woodford (2003) suggest, based on their NKM that central banks promise to keep i_t at zero, even when the economy starts to recover and r_t^n becomes positive. This will keep expectations of short-term nominal rates low and increase inflation (π_t) expectations. From equation **(2.2)**, expectations of low nominal interest rates decrease long-term real interest rates even if expectations of

inflation remain unchanged and, higher inflation expectations decrease long-term real rates as long as expectations of short-term nominal rates remain low. A decrease in the real rate leads private sector to forego future consumption (decrease savings) in favor of current consumption, increasing output (y_t).

Equation **(2.2)** shows that in the NKM long-term interest rates are considered as an expectation of current short-term rates (Andréz, López-Salido and Nelson, 2004). The risk premium term (θ_t^L) in equation **(2.1)** is considered as exogenous. Central bank shifts in the supply of assets do not have a portfolio-balance effect on interest rates and, at the zero lower bound, LSAPs are important only if they influence expectations of short-term nominal rates (Eggertsson and Woodford, 2003). Beyond promising to keep the policy rate at zero, central bank can engage in LSAPs to signal this commitment because "(…) private sector may be uncertain about the nature of the central bank's policy commitment, and so it may scrutinize the bank's current actions for further clues" (Woodford and Eggertsson, 2003: 164). A promise to maintain short-term interest rates at a low level will be more credible if accompanied by central bank assets purchases.

Eggertsson and Woodford (2003) and Woodford (2012) explain why central bank assets purchases do not have a portfolio-balance effect on interest rates on modern, general-equilibrium asset pricing models with a representative-household (for example the NKM). In these models it is assumed that investors value assets only for the monetary returns they give. Assets can be imperfect substitutes for each other, but just because of their different risk characteristics (different state-contingent payoffs). The market price of an asset is determined by the present value of its expected returns, and changes in the supply of that asset do not affect its expected returns that depend on the risk associated with the asset, nor the discount rate. The discount rate results from the representative household's marginal utility of income, which depends on consumption that in turn is affected by output. Although output is an endogenous variable, is not influenced by the supply of assets.

In fact, Woodford (2012) explains that a model requires two conditions to make ineffective the portfolio-balance effect of central bank assets purchases. The first condition is that investors have to value these assets only for the monetary returns they give. The only factor that affects these returns and makes assets imperfect substitutes for each other is their risk characteristics. The second condition is the nonexistence of financial market segmentation: any investor can buy any quantity of any asset at the same market price that any other investor. The NKM satisfies these two conditions and,

for example, considering a representative-household in the model fulfills the second one. Bernanke (2012) does not believe these assumptions are met in practice.

Andréz, López-Salido and Nelson (2004) make some modifications to the standard NKM that leads to a violation of those two conditions and, allow central banks' open market operations to produce an effect on long-term interest rates and aggregate demand that goes beyond the expected future path of short-term interest rates. First, the authors introduce two financial frictions that make long-term assets imperfect substitutes for the short-term ones: transactions costs in long-term bond market that are treated as exogenous in the model and, self-imposed "reserve requirements" on long-term investments, which are considered to be endogenous and represent the need investors have to increase their holdings of money when investing in long-term bonds, as they perceive these assets to be less liquid than the short-term ones.

This modification creates a risk premium in long-term rates that is affected by the supply of money to long-term assets, as a result of their different liquidity characteristics. If the supply of long-term assets increases, their interest rates have to increase to stimulate investors to buy these less liquid securities. To make the risk premium affect the aggregate demand, the authors introduce agent heterogeneity in the standard NKM model by considering two types of households form the economy: households that can invest in short- and long-term assets and regard them as imperfect substitutes and, the others that can only invest in long-term bonds. The authors argue this kind of financial market segmentation exists in reality since the first type of household can be seen as the ones that deposit their savings in commercial banks and, the second type as the households that operate directly in long-term markets or invest through institutions such as pension funds, which are not averse to long-term investments like commercial banks.

With this second change, LSAPs affect aggregate demand through portfolio-balance effect on interest rates. The rationale is that by buying long-term assets and decreasing their risk premium and expected returns, central bank induces the households that are only allowed to trade in long-term assets to change the discount factor, as they cannot move their investments between short- and long-term assets to equate the expected returns. To change the discount factor these investors change their consumption, which in turn affects aggregate demand (Chen, Cúrdia and Ferrero, 2011).

Summarizing, the assumption of imperfect substitution allows LSAPs to affect long-term interest rates through changes in the risk premium and, the assumption of agent

heterogeneity allows aggregate demand to be affected by these risk premium changes. Central bank securities acquisitions do not affect long-term interest rates or aggregate demand if the elasticity of the risk premium to the supply of assets is zero. Andrés, López-Salido and Nelson (2004) present an empirical analysis for the U.S. economy and find support for the two assumptions. This result contrasts with the ones presented in Chen, Cúrdia and Ferrero (2011). The latter finds low responsiveness of the risk premium to the supply of assets and low levels of financial market segmentation, leading to moderate effects of LSAPII on real economy.

Turning back to the study of the signaling channel, the analysis in Eggertsson and Woodford (2003) can be seen as a development of Krugman (1998). Krugman presents a two-period model with price stickiness, in which, once again, expectations of inflations are a key variable to pull the economy out of the liquidity trap. However, Krugman does not discuss the role of interest-rate policy in producing these expectations or, the consequences of LSAPs. For him, central banks should increase inflation target in a considerable amount, in order to actually increase inflation expectations. Increased inflation expectations associated a zero nominal interest rate turn real interest rates negative, stimulating economy activity. Krugman (2013a) recognizes that this is a weaker channel, as it's not easy to convince central banks to pursue inflation, or convince private sector that central banks are actually pursuing it.

Krugman (1998) idea on inflation was that a central bank would be confronted with the zero lower bound on nominal interest rates if it cannot persuade the public that its monetary expansion is permanent because of its objective of price stability. The only way an economy can get out of a liquidity trap is by changing expectations, namely expectations of inflation, making people believe the increase in money supply will not be reversed and thus, that central bank will seek an higher inflation rate. Krugman (1999) considers LSAPs can be important to reinforce this willingness to increase inflation and, although he recognizes securities purchases might have a portfolio-balance effect, questions how large are these effects, how much LSAPs would be needed to stimulate the economy. But, despite the fact that LSAPs' effect on economy is uncertain, Krugman (2013a) believes the program should be used along with fiscal policy, since this latter cannot be used alone as governments are usually pressured to move into consolidation.

The Federal Reserve System has been keeping fed funds rate target at a range of 0 to 0.25% for 6 and half years now and, it is committed to maintain short-term rates at a

low level until it sees sustained improvements towards its goal of maximum unemployment and price stability. Bernanke (2012) acknowledges that LSAPs signal an accommodative monetary policy that reinforces that commitment and thus, strengthens expectations of low short-term interest rates, putting an additional (beyond portfolio-balance effect) downward pressure on long-term rates. Nonetheless, Kohn (2009) makes clear Fed is not open to let inflation expectations rise, because they can stay increased for a longer period than desired. He states that in the models, long-run inflation expectations are perfectly anchored but, in practice, anchoring inflation expectations is not easy and achieving it has been a continuous work of decades. Bernanke (2010) also emphasizes this idea. The only thing Fed recognizes is that through signaling channel LSAPs can contribute to alleviate fears of deflation (Bernanke, 2012).

Figure 2.4 below presents a summary of the LSAPs' transmission mechanism.

2.4 Cost and Benefit of LSAP

Fed's decision to start the LSAP program was mainly guided by theoretical works since, as mentioned before, at that time there was little empirical experience on this subject (only the Japanese one, which is different from what the Fed would implement). As time passed and different rounds of the program were completed, several empirical studies have assessed their effects on interest rates and the real economy (the majority of these studies focus on interest rates' outcomes). Although the underlying results are mixed, Bernanke (2012) considers that in general the program have lowered long-term interest rates in a meaningful amount (Treasury, MBS and Corporates yields), increased stock prices, and significantly helped economic recovery and avoid deflation.

In fact long-term interest rates have decreased considerably since the crisis, but the portion attributable to LSAPs is uncertain since there are several factors that can contribute to this downward trend (for example, forward guidance). An illustration of this uncertainty is the fact that the 10-year Treasury actually rate rose through LSAP1 and LSAP2, always decreasing after the end of these rounds (Woodford, 2012). In terms of economic activity, Chen, Cúrdia and Ferrero (2011) for example, study the effect of LSAP2 on output and prices through the portfolio-balance channel and find weak to moderate influence of the latter on the former. This is a consequence of their finding of low responsiveness of interest rates' risk premiums to asset purchases, and thus, low effect of these rates on aggregate demand.

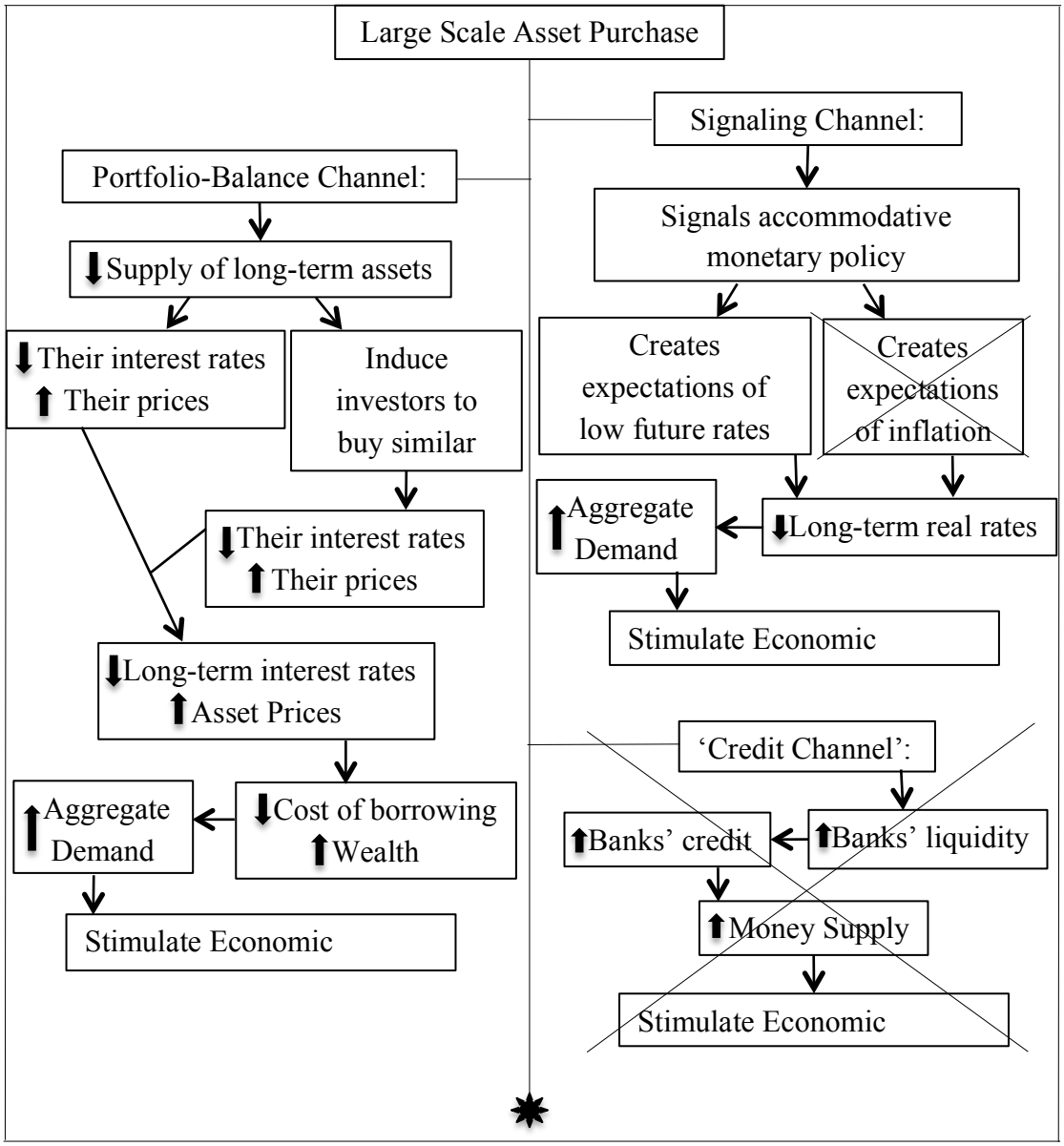

Figure 2.4: Transmission Mechanism of LSAPs

Note: The canals with crosses represent the ones LSAPs will not affect the economy through, according to the Federal Reserve System.

Assessing the empirical effects of this program is important as it allows to see if its potential benefit outweighs its potential cost. One of the latter is the fact that Fed can become the main actor in Treasury, MBS and agency debt markets, leaving little assets for investors to trade, which can damage their liquidity and price determination. Also, by inducing a decrease/increase in interest rates/asset prices, LSAPs might jeopardize financial stability through excessive leverage and/or risk-taking by investors and price bubbles. Another cost may be loss of public confidence in Fed, in the sense that they

might doubt Fed's capacity to unwind all of these purchases when the right time comes, increasing inflation expectations. Fed's balance sheet can also be damaged in case of an unexpected interest rate rise, since this will decrease the value of Fed's huge amount of securities. Bernanke (2012) shows that Fed is concerned with all these risks and others not yet cited, but sees no signs of worry in relation to them. As mentioned above, one of the aspects Fed is taking into consideration when deciding the continuity of LSAP3 is the analysis of its benefit and cost.

2.5 Opponents of LSAP

The effectiveness and potential results of LSAPs have been subject to a lot of debate since the Federal Reserve announced the implementation of the program. After presenting the arguments in favor, the subchapters below introduce the arguments of several economists against Fed's purchases. The opinions varies between the fact it is are not an effective tool to stimulate the economy to the fact that it is harmful to latter, as it can create financial market disruptions or/and severe inflation.

2.5.1 Richard Koo and Stephen H. Roach: The Balance Sheet Recession View

Richard Koo and Stephen H. Roach are two economists that do not agree with Fed's usage of LSAPs to stimulate economic activity, as they argue the program will not reach the expected results when we are in presence of balance sheet recessions (this is how they label the U.S. recession of late 2007 through mid 2009). Koo (2011b) explains that balance sheet recessions result from the burst of asset price bubbles that are funded by debt, like the U.S. recession that is a product of the house price bubble, which was also funded by increased household debt-to-income ratio, among other factors. The downfall in prices leads investors to increase savings and, pay down their liabilities that were paid before by rising asset prices. Given that households are saving, spending only the necessary, and no one is interested in borrowing, the economy falls into a deep recession (Keynes' paradox of thrift, which Koo calls the fallacy of composition).

In these recessions monetary policy is ineffective as households with balance sheet problems are not interested in borrowing, regardless the interest rate. Promoting inflation will also be ineffective because central banks cannot increase money supply through banks' credit. This is a result of the shortage of borrowers, but also of lenders,

since creditors are not willing to lend money to households with impaired balance sheets, or themselves can also have the same problems. The solution lies on fiscal policy. Government bonds have nearly zero risk of default so households are not afraid to lend their savings to this institution, financing its expenditures. For Koo, monetary policy is important in financial crisis because the latter results from problems on the lender side, and central banks, as the lender of last resort can provide liquidity to the markets and restore confidence on the financial system. On the other hand, balance sheet recessions result from borrower's problems, so government should play the role of "borrower of last resort" until private sector stops deleveraging.

Based on these ideas it should be ease to understand Koo's approval of LSAP1, but condemnation of further rounds of the program. In chapter 2.1 it was mentioned that the first round of purchases was directed to relieve financial stresses through provision of liquidity, while its expansion and further rounds were meant to stimulate economic recovery. Since households are paying down debt and not interest in borrowing, Fed's potential attempt to encourage economic activity will not be accomplished. Roach (2013a) adds that LSAP1 was important because U.S. was suffering from a short-term decrease in aggregate demand (U.S. was still in recession when Fed started this round). Private sector's damaged balance sheets are lengthy problems that cannot be solved by LSAPs, as the program does nothing to decrease/increase private sector debt overhang/savings.

Krugman (2010) contests the ineffectiveness of monetary policy in fighting balance sheet recessions because, although there might be several agents facing balance sheet problems and thus, not reacting to interest rate changes; he does not think this behaviour is characteristic of all. There is the lenders which are receiving the debt payments and still react to fluctuations in interest rates, expectations of inflation, *et cetera*. Eggertsson and Krugman (2010) develop a model in which deleveraging of several agents drives the economy into recession (a model based on Koo's approach) and find a role for monetary policy at the zero lower bound through inflation expectations. The latter decreases private sector's real value of debt, which in turn induces them to spend. Koo does not agree with this idea as he defends inflation expectations might raise interest rates, regardless of Fed's massive purchases, raising agents' debt costs (Koo, 2013b).

In relation to the portfolio-balance channel Koo (2011a) declares that LSAPs will induce investors to buy mainly assets, as government debt are almost all in Fed's balance sheet and private sector is not borrowing or, investors are not willing to buy

their debt. This run on assets can cause asset price bubbles because, in Koo's point of view it is not asset price rises that stimulate economic activity (through the wealth effect) but the inverse, and with a weak U.S. economy the increase in prices may not be justified by, for example, the discounted cash flows in case of stocks, or real demand in case of commodities. Nonetheless, Koo thinks any sign of bubbles will lead investors to sell their assets nullifying the portfolio-balance channel, as investors are now carefully analysing market movements. In this case, even if increases in asset price induce investors to raise consumption/investment it will not be enough to stimulate economic activity (Koo, 2013a).

This idea is in agreement with Roach (2013b) observation that only significant asset price increases (which might mean asset price bubbles) can boost economic activity, as the wealth effect, the effect asset price increases have on real economy, is found to be small. He argues large-scale asset purchases can only benefit wealthy people, an opinion also shared by Koo (2013a). Policies that minimize debt overhang and increase savings are the solution to balance sheet problems and thus, to the slow economic recovery (Roach, 2013a). Even LSAPs would benefit from these policies, since private sector would take a better advantage of wealth effects if it were not going to use the wealth appreciation to pay down its debt.

Turning now to the effect on long-term interest rates, Koo (2013b) recognizes that the implementation of LSAPs gave an initial boost to the economy, by decreasing mortgage rates that were at a high level before the start of the program. Nevertheless, this influence has vanished since private sector is not interested in borrowing even with roughly zero interest rates. For Koo, the main cost of the program is the possibility of an unwinding of purchases leading to a weaker economy through interest rate rises, which might force Fed into another round of purchases. An attempt to unwind this new round can increase rates, which may damage the economy and thus, induce additional purchases. This pattern will continue to repeat leading Fed to fall in what Koo calls "QE Trap" (because Koo refers to LSAPs as QE)[12]. At this point it should be remembered that Fed's hint, in May 2013, of a possible tapering of purchases raised interest rates and it is one of the reasons Fed postponed the unwinding (chapter 2.1). In Koo's point of view LSAPs' benefits do not compensate its costs (**Figure 2.5** below).

[12] http://www.businessinsider.com/koo-says-no-one-can-refute-the-qe-trap-2013-10

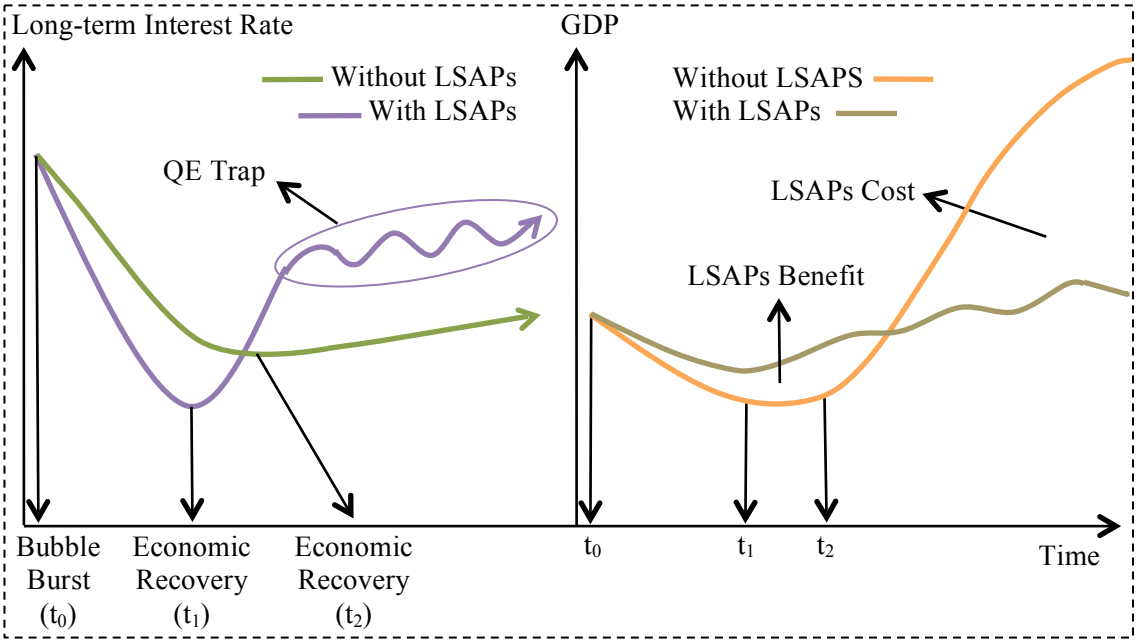

Figure 2.5: Koo's perspective on LSAPs' Cost and Benefit

Adapted from http://www.businessinsider.com/koo-says-no-one-can-refute-the-qe-trap-2013-10. Note: This is how Koo sees the evolution of long-term interest rates and GDP in the case that Fed implements LSAPs and in the case that it doesn't.

2.5.2 Eugene Fama and John Cochrane

Before examining Cochrane's and Fama's ideas on LSAPs, it will be interesting to know the latter's peculiar point of view regarding the U.S. difficult times of 2007 through 2009. Unlike what is widely accepted (which is described in chapter 1) Fama thinks the U.S financial crisis resulted from an economic recession and not the other way around (Cassidy and Fama, 2010). He considers that in early-mid 2007 there was a recession that limited agents, mainly subprime borrowers' capacity to meet their mortgage payments and this, in turn, increased credit default and damaged financial institutions' balance sheets leading to a severe financial crisis. The cause of the recession he argues is unknown since economists never know the source of slumps (the Great Depression one is still undetermined). The fact that the decline in home prices predated the recession is not extraordinary; as for Fama prices can decrease before or at the time of recessions.

About LSAPs Cochrane (2011a) and Fama (Fama and Santelli, 2013) agree with the fact that it's just a swap of short-tem for long-term securities, with no effect on economic activity, inflation or interest rates, since Fed is buying long-term debt and paying funds that are being held as interest-bearing excess reverses. The latter can be

equated to short-term debt because of extremely low short-tem rates that make banks indifferent between holding one or the other. The outcome of the swap should be a decrease in long-term interest rates and an increase in short-term ones, but the second presents a downward trend that Fama states is apart from Fed's intervention not, as markets argue, because of it. He does not think Fed can control interest rates (it can influence it a bit, through inflation expectations) a subject he develops in Fama (2013). Concerning long-term rates he stresses that although Fed's intervention is being done in a large-scale, it is not large enough in relation to the size of long-term bonds market (Fama and Roberts, 2012).

Besides thinking LSAPs are ineffective, Fama believes it can hinder Fed's capacity to control inflation because, with the implementation of interest on reserves (to avoid a massive increase in money supply and thus, an increase in the price level) inflation will now be determined by currency instead of currency plus reserves - the monetary base (Fama and Litterman, 2012). On the other hand, Cochrane calls attention to the fact that by buying long-term Treasuries, Fed can decrease the maturity structure of government debt in private hands and leave government vulnerable to bad news on his budget condition, since these would obstruct its rollover of maturing short-term debt. Moreover, a decrease in the maturity structure changes the timing of inflation (but not its total magnitude) bringing future inflation to the present. This idea is based on the fiscal theory of the price level, developed in Cochrane (2011b).

Cochrane (2011b) explains that most of the times (but not all of them) fiscal policy is made in accordance with what is followed by monetary policy. For example, if central bank wants to decrease inflation it increases interest rates and this, in turn, raises government interest payments, which leads it to increase taxes or reduce spending, validating central banks' objective. The exceptions are the times of fiscal deficits, wherein monetary policy will be limited by governments' condition. In this case, the price level will be determined by the government-debt valuation equation, which shows that the real value of government debt (right-hand side) has to equal the present value of its future primary surpluses (left-hand side):

$$\frac{M_t + B_t}{P_t} = E_t \int_{\tau=0}^{\infty} \frac{\Lambda_{t+\tau}}{\Lambda_t} (T_{t+\tau} - G_{t+\tau})\, d\tau \tag{2.3}$$

In case government debt is simply composed by short-term debt, a decline in expected future surpluses $\left[E_t \int_{\tau=0}^{\infty} (T_{t+\tau} - G_{t+\tau})\right]$ increase inflation expectations, because private

sector knows that the money government prints to pay its maturing debt will not be absorbed by future surpluses. Negative expectations regarding government's condition and the fear of forthcoming inflation leads private sector to use the money of redeemed short-term debt to consume goods and services, increasing current price level (P_t). When long-term government bonds are added to the model, the difference is that inflation expectations do not increase P_t, as it leads investors to sell long-term bonds (exchanging it for short-term ones for example), which decreases its nominal value (B_t) and reestablishes the equality of 2.3. In this way, because LSAPs decrease the quantity of long-term government bonds available for private sector, it increases the possibility of current inflation over future one, although Cochrane reckons only a huge amount of purchases will change inflation timing.

2.5.3 Allan H. Meltzer, John Taylor and Martin Feldstein: The Inflation View

John B. Taylor (2010c) and Allan H. Meltzer (2012) criticize the implementation of LSAPs with the argument that it represents a deviation from the rules-based policy Fed once pursued, and which allowed the U.S. economy to achieve good economic results. For these authors the program follows a very discretionary approach, as Fed does not obey any predetermined rule when applying it and the decision to implement it depends on the state of the economy. Because of this, and the fact that there are a lot of doubts regarding its unwinding, effects, *et cetera*, Taylor (2012) adds that LSAPs bring uncertainty and volatility to markets. He believes the housing bubble and subsequent financial crisis and recession are a product of another deviation from rules-based policy, as during 2002 to 2005 Fed's interest rate were lower than what the Taylor rule would suggest.

Taylor (2010a) states that the Taylor rule has been used to justify the implementation of LSAPs, because some authors argue that according to this rule nominal interest rates should be negative. As the latter cannot go below zero and Fed has targeted a 0 to 0.25% interest rate, the program represents a way to give more accommodation to the economy. Nonetheless, Taylor does not agree with this idea. First, according to his proposal for the Taylor rule, interest rates should be positive and slightly higher than what Fed targeted. And second, Taylor does not believe LSAPs stimulate the economy. Stroebel and Taylor (2012) or calls attention to the fact that the program had little effect

on interest rates and Taylor (2013) talks about a counter-productive influence on employment and economic growth, as these are lower than Fed's initial expectations.

Taylor (2010b) and Meltzer (2010) state that Friedman would also be against LSAPs because he is an advocate of rules-based monetary policy. In their point of view, as he favor the creation of a rule to keep the growth rate of money supply constant; he would not be happy with the fact that the program brings fluctuations in money supply, mainly in the interval of its different rounds. Big increases in money supply should only happen in case of deflation, like the one experienced in the Great Depression or Japan. There is another factor Friedman would not approve, which is Fed attempt to affect the unemployment rate through inflation (Taylor and Meltzer believe LSAPs will substantially increase price-level, as it will be seen below) since he supports the idea that unemployment is an unexpected result of inflation.

The interesting point here is that Meltzer does not agree with the implementation of LSAPs, but his work is used by Fed to support the idea that massive asset purchases stimulate economic activity. It was explained, in chapter 2.3.1, that a rise in real asset prices makes existing assets more expensive than new ones, increasing investment in the latter. Although Meltzer recognizes LSAPs have a portfolio-balance effect on asset prices, he states that investment is not reacting to this change (Meltzer, 2014). Feldstein (2012) thinks the program have raised these prices and decreased interest rates but not stimulated real economy. Meltzer and Feldstein (2013a) regard LSAPs as a treat to financial stability because low interest rates induce investors to take on more risks and higher asset prices can lead to asset price bubbles. Additionally, an unwinding of purchases will decrease asset prices through interest rate increases. This will harm their holders, mainly the ones who borrowed money to buy them.

Nonetheless, the main argument that led Meltzer (2009), Taylor (2009) and Feldstein (2009) to stand against the program when the Federal Reserve System began implementing it is the fact that it would create serious inflation in the economy. Their argument is based on the credit channel described in **Figure 2.4**. These authors had expected, as a result of asset purchases, a massive increase in money supply that would raise aggregate demand and lead to a surge in the general price-level. But they knew this would not occur right away as the U.S. economy was still depressed and banks were holding almost all their funds as excess reserves. Inflation would come, in case of Fed failure to reverse the surge in excess reserves, when the economy started to recover and banks to lend its funds to the private sector.

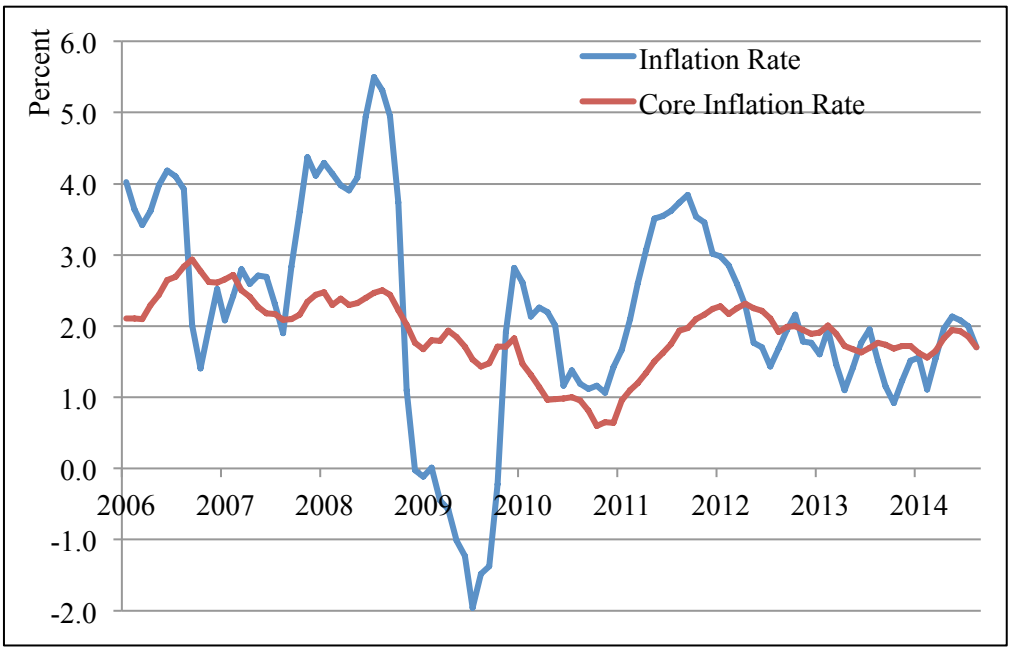

Figure 2.6: Evolution of Inflation with LSAPs

Source: Federal Reserve Bank of Saint Louis. Note: The inflation rate is represented by the percentage change (from last year) of the monthly Consumer Price Index (CPI) and the core inflation rate by the percentage change (from last year) of the monthly CPI without taking into consideration food and energy prices.

And they believe the Federal Reserve System can be constrained in the ability to reverse the expansionary monetary policy, as it can suffer government pressure not to increase interest rates. LSAPs have allowed government to finance its debt at a low interest rate, and an increase in the latter can compromise government budget deficit. The authors argue that the Federal Reserve System has put its independence in risk by involving in fiscal areas through purchases of long-term Treasuries, among others activities engaged to stabilize financial markets. Another factor that can limit Fed's capacity to fight inflation is the fact that it may lack the necessary quantity of government debt to soak up the excess reverses, since banks may be unwilling to give away its funds as an exchange for private debt. In fact, the possibility of Fed not reducing banks' reserves fast enough makes them believe inflation risk still is present.

Nonetheless, five years have passed and the program hasn't had these authors' expected effects on money growth (as shown in **Figure 2.3**) or inflation (**Figure 2.6**), since banks' credit has been increasing at a relatively slow pace. Meltzer (2013) and Feldstein (2013b) justify this outcome with Fed's implementation of interest on reserves (IOR), which drive banks away from lending to a more secure way of profiting. Meltzer even thinks IOR are counter-productive, as it hinders economic growth by preventing

banks from lending to more risky agents like fist-time borrowers, small companies and start-ups. Krugman (2013b) states that if IOR is postponing an increase in money supply and inflation then it will be easy for Fed, just by paying IOR, to control price volatility. Krugman has been arguing, since Krugman (1998), that expansionary monetary policy simply does not increase money supply in a liquidity trap, even if banks are in a good financial condition. For example, Japan did not pay IOR during its Quantitative Easing period (2001-2006) but the program had the same lack of effect on money supply.

In the World Economic Outlook of April 2013 the International Monetary Fund presents a study, which supports the idea that central banks can continue with their expansionary policy that it won't increase inflation. The analysis shows that in the past ten years inflation expectations have been anchored and inflation has become less reactive to changes in economic activity. The first result is due to central banks increased credibility in achieving price stability, which is anchoring inflation expectations around central banks target. And the second result may be due to inflation low levels, which makes firms reluctant to change prices as they face costs (menu costs) to do it. Low levels of inflation can be a consequence of central banks' low inflation targeting. The key conclusion of the study is that anchoring of expectations is the main contributor to stable prices and that's why it is important to maintain central banks' independency. As long as inflation is anchored, LSAPs won't steeply increase inflation.

Fed purchases of long-term securities have created a lot of debate regarding its potential effect in the price-level. While some authors claim for a substantial rise in the latter, others consider there will be no significant effect in it, at the same time that there are economists pointing to an inflation decrease. For example, Williamson (2013) presents a model in which LSAPs decrease the inflation rate of the economy. In this model, all private sector and financial institutions debt has to be collateralized and the liquidity premium of an asset increases with its capacity to be a collateral plus the scarcity of total collateral existent in the economy. The yield curve of government debt is upward sloping, as the liquidity premium of short-term government debt is positive. The latter is assumed to be a better collateral than long-term government debt and the value of total collateral limited compared to the efficient level of credit and trade.

Like Fama and Cochrane, Williamson regards LSAPs as a swap of short term-debt (reserves) for long-term ones as Fed is paying interest on excess reserves. The swap raises the value of total collateral existent in the economy (by increasing the supply of

short-term debt, a higher value collateral), which decreases the liquidity premium on short-term debt, and this in turn, reduces bond yields. The unexpected result is the decrease in inflation. The increase in the value of collateralizable assets reduces the limit the assumption of scarce collateral imposes on the exchange level, increasing banks' credit and the volume of trades. In order to induce people to hold more currency and materialize the increase in transactions, currency has to provide a higher rate return, which means the inflation rate must decrease. In Williamson's model LSAPs produce another unexpected effect, which is an increase in real bond interest rates that results from the rise in the value of collateralizable assets.

It was in this context that was born the idea to study the relationship between monetary policy and inflation in two different regimes, considering the regimes where monetary policy is constrained by the zero lower bound nominal interest rates and when is not. This analysis will be done in the next chapter.

3. Large Scale Asset Purchase and Inflation: An Empirical Analysis of the U.S. Case

3.1 Introduction

The basic purpose of this chapter is to study the monetary side of inflation. According to the old dictum of Milton Friedman (1963), inflation "is always and everywhere a monetary phenomenon, in the sense that it cannot occur without a more rapid increase in the quantity of money than in output." For such purpose, a TVAR approach will be applied on U.S. data, covering the period from the third quarter of 1981 to the first quarter of 2014.

More than fifty years after the Freidman's dictum came to light, there is still a huge controversy about the link between money and inflation. The financial crisis that erupted in the late 2000's and the dramatic increase in the monetary base in the U.S. (and in many other countries) provides a natural ground for analyzing whether or not inflation is mainly (or strictly) caused by monetary factors. In particular, the implementation of Fed's Large Scale Asset Purchase allows us to study the link between money and inflation in a regime-switching scenario. In such an approach we have two different regimes: one before LSAP implementation (which will be called by "before LSAP" regime), and the other regime with LSAP at full pace, simply called by the "LSAP" regime.

The quantitative theory of money (hereafter, QTM) stipulates the following relationship:

$$p = v + (m - y) \tag{3.1}$$

where p stands for the inflation rate over a given period of time, v is the growth rate of money velocity, $(m - y)$ are the growth rates of, respectively, money and real output. Unfortunately the real GDP was not included on this analysis, as at first, our objective was to solely study the relationship between money and inflation.

This option could be considered an unfortunate and major limitation of the empirical work conducted in this chapter. However, there are some reasons why such option may not produce significant limitations to the results that will be presented later on: one of them is historical. From an historical point of view most major and seminal works in

this area have also overlooked the relationship between inflation and real GDP, by concentrating explicitly only on the relationship between money and inflation. These are the largely influential studies by Lucas (1980) and (2014), Christiano and Fitzgerald (2001) and (2003), Benati (2005) and (2009), Wallace (1981), the most quoted study in this area McCandless and Weber (1995), among others.

The next step would to have real GDP in this analysis to see whether the results reported below would be drastically altered, or not. Because of time constraints this was not possible so this chapter deals exclusively with the monetary side of inflation. No real variable is taken into account in our study.

The remaining part of this chapter is organized as follows. In section 3.2 we present a brief review of the literature related to this particular issue. Section 3.3 deals with the methodology used in the econometric exercise in this chapter. Section 3.4 describes the data sets used in this chapter, while section 3.5 discusses the main results obtained by our TVAR approach to the link between inflation and money creation. The final section puts forward some concluding remarks.

3.2 Related Literature

When the Fed announced the implementation of LSAPs in late November 2008, there was an immediate large chorus of voices of highly respected economists worldwide claiming that the Fed was entering into the world of hyperinflation and the debasement of the dollar (Chapter 2.5.3). Some names include John Cochrane, John Taylor, Martin Feldstein, Larry Kotlikoff (2013), among many others. For example, Kotlikoff wrote down the following sentence, five years after the process of LSAP had been started:

> "I hope you're getting the point. Having addicted Congress and the Administration to the printing press, there is no easy exit strategy. Continuing on the current QE path spells even great risk of hyperinflation. But calling it quits requires much higher taxes, much lower spending, or much more net borrowing (with requisite future repayment) from the public."

In 2013 there were no signs of inflation in the U.S. economy, never mind signs of hyperinflation, neither there is now any such symptoms two years after the strong words of Kotlikoff became public. Why do all those highly respected economists defended so strongly that LSAPs would inevitably lead to high inflation or even hyperinflation?

Because all of them base their arguments upon the basic prescriptions of the Quantitative Theory of Money. If one assumes that the growth rate of real GDP (y) is relatively constant over the long term, and dismiss any relevance to the rate of growth of the money velocity (v), there will be a one for one relationship between p and m. It is this simple and strange relationship that lies at the heart of the criticisms directed at the implementation of LSAP policy, a relationship that despite its suspicious robustness has survived decades of criticisms from the part of mainstream Keynesian economists.

There is already a large and extensive literature on the empirical side of the QTM. This literature can be broken down in three main groups: (i) cross section studies, (ii) smoothing techniques, and (iii) time series approaches.

As far as cross section studies are concerned, the most cited paper in this area is that of McCandless and Weber (1995). They used data covering a 30-year period for 110 countries using three de definitions of money (M0, M1 and M2), and their main conclusion is:[13]

> "In the long run there is a high (almost unity) correlation between the rate of growth of the money supply and the rate of inflation. This holds across three definitions of money and across the full sample of countries and two subsamples." (emphasis added)

This result was largely consistent with many cross section studies, which basically apply an OLS regression of the inflation rate (π_i) on the rate of growth of some major money aggregate (m_i).

$$p_i = \alpha_1 + \alpha_2 m_i + \epsilon_i$$

A summary of the empirical findings of many of those studies can be found in Table 1 of DeGrawe and Polan (2001). As De Grauwe and Polan emphasized, a value for α_2 close to one, as predicted by the QTM, depends upon the particular periods that are chosen, and in particular, it depends crucially on the samples of countries that are included in the cross section exercise. This argument can be easily confirmed by inspecting **Figure 3.1** below.[14] The strong correlation between inflation and money

[13] They also analyzed two subsamples of their data (one subsample consisted of 21 OECD countries and the other contained 14 Latin America Countries), but their conclusion was not changed in any relevant way.

[14] This figure is nothing else than figures 2 and 4 in the paper by De Grauwe and Polan (2001). The data set includes a large number of countries (165 and 159 for the regressions of inflation on the growth rates

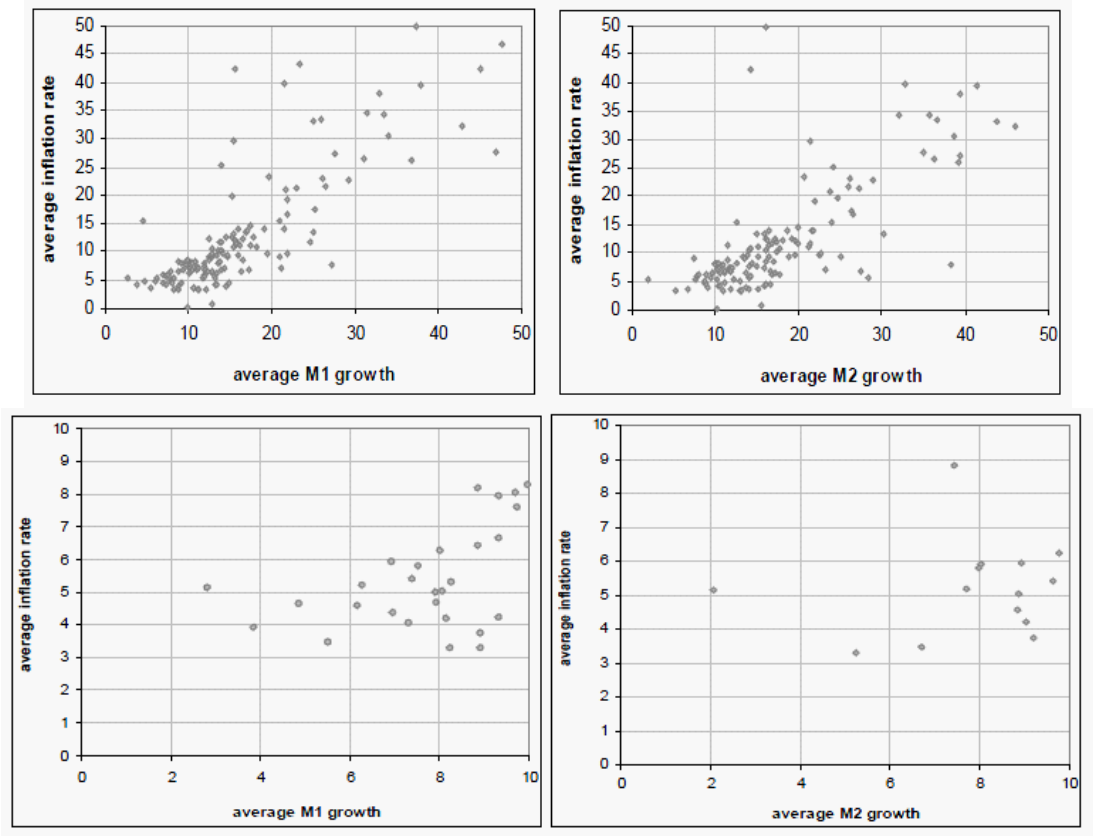

Figure 3.1: The QTM in low and high inflation countries

growth vanishes when we consider only a subset of countries with relatively low inflation (inflation below 10%), which can be spotted in the two bottom panels. In contrast, if we consider a set of countries that experienced high inflation rates (rates between 0% and 50%), as in the two top panels, a high and positive correlation can be easily accepted.

The criticisms that we may put forward against the rather biased result of a robust one-for-one relationship between inflation and money growth still have to face the evidence that have been presented by the second group of studies in this area: smooth filtering techniques. Major works include those of Lucas (1980) and (2014), Christiano and Fitzgerald (2001) and (2003), and Benati (2005) and (2009). By using some form of moving average filter (Hodrick-Precott, band-pass, or some other similar smoothing procedure), the papers above arrived at the same conclusion, which was emphatically described by Lucas (2014):

"The filtering process loses a lot of information, but in return provides a

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of M1 and M2, respectively), covering the years 1969-1999.

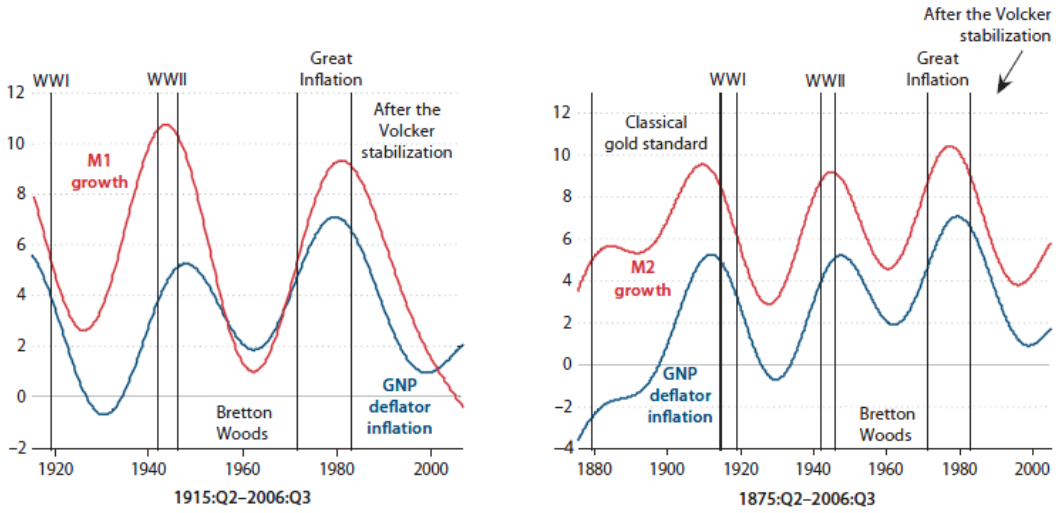

Figure 3.2: Filtered inflation and money growth for the US economy

crystal clear picture of the long-run relation between base money and inflation rates. These two filtered time series exhibit exactly the same one-for-one relation seen in the cross sections!" (Lucas, 2014: 204)

The results presented by all the papers above seem quite consistent about the strong positive relationship between inflation and money growth in the long run. However, there is one major point about the filtering procedures that deserve some attention. Consider for example, Figure 3.2.[15] Looking at the right panel, why should we have cycles of a huge length of around thirty-five years? Or why, sometimes, the length of the cycles of inflation and those of money growth diverge significantly (as we can see in the left hand side panel), in order to get a high positive correlation?

As we all know very well, a crucial characteristic of any smoothed filtering procedure in economics is the number of minimal and maximal number of periods per cycle, because we do not really know (observe) the deterministic component of the original process. So the removal of noise in any economic process is essentially arbitrary. And if it is totally arbitrary, then the particular choice of how many observations per cycle we are ready to accept will give too high correlation, too little, or no correlation at all. Benati (2009) acknowledges (in a footnote) this particular problem, but offers no explanation to justify the reason for the choice of such long cycles in the relationship

[15] This figure is extracted from Figure 8 in Lucas (2014).

between money growth and inflation.

Therefore, by applying the same filtering techniques as those of Lucas, Benati, or Chrsitiano and Fitzgerald, we may reach a totally opposite result: correlation may be highly negative. All depends on how much time periods are we ready to accept per cycle.

The third major types of studies that have concentrated on the link between inflation and money growth are based on some form of a time series approach. There have been a large number of empirical studies using such a framework, and it seems hardly possible to present here a balanced review (even if only a short one) of such a large amount of literature. Possibly, the best option is to direct the reader to chapter 8 of Bardsen et al. (2005), who presents a well-developed review of this particular issue, or to the survey by McCallum and Nelson (2010). For the purpose of this thesis, we will just review here three major approaches in this area: VAR studies, the highly influential P*-model of inflation, and the Markov Switching model by Amisano and Fagan (2012).

In the 1990s there were a large interest on the application of VAR structures to the study of the link between money and inflation. Hoffman and Rasche (1996) presented a highly cited study where five variables were analyzed: (m) log of real M1 money balances; (inf) quarterly inflation rate (in % per year), (cpr) commercial paper rate, (y) log real GDP (in billions of 1987 dollars) and (tbr) treasury bill rate. In a pretty standard VAR approach, the authors could find that the link between money and inflation was not as strong as initially believed to be. A coefficient estimate of -0.023 implies that, ceteris paribus, nominal money ($m + inf$) increases somewhat less than proportionally with the inflation rate.

A highly influential line of research in this field is the P* model of inflation, see Hallman, Porter and Small (1991) and Tödter and Reimers (1994). Apparently, the main reasons for such popularity of this model are basically two. Firstly, there is the fact that such particular model was apparently highly used in the Bundesbank before the Euro creation, and also in the ECB after such creation. Secondly, it looked like a variation on the Keynesian Phillips curve with the real money gap simply replacing the output gap in such a curve. In fact, compared to the conventional backward-looking Phillips curve, where inflation depends on lagged inflation and the output gap, we have a similar structure but now having money inside.

Following Gerlach and Svensson (2000), the P* model can be described as follows. Firstly, define velocity v_t by the quantity equation

$$v_t = p_t + y_t - m_t$$

where p_t ,y_t, and m_t are the (logs of the) price level, output and (nominal) money. The long-run equilibrium is straightforward

$$p_t^* = v_t^* - y_t^* + m_t^*.$$

Now let us make the assumption that inflation dynamics is given by

$$\pi_t = (1 - a)\pi_{t-1} + a\Delta p_{t-1}^* - \beta(p_{t-1} - p_{t-1}^*) + \varepsilon_t \quad (3.2)$$

where $\pi_t = p_t - p_{t-1}$, ε_t as an idd (independent and identically distributed) shock with zero mean, and the following constraints should be satisfied: $0 \leq a \leq 1$, $\beta > 0$. Notice that in the previous equation inflation is determined by lagged inflation, lagged P* inflation, and the lagged price gap.

In order to express equation 3.2 in terms of real balances, we have just to consider that

$$p_{t-1} - p_{t-1}^* = -m_t + p_t + m_t - p_{t-1}^* = -(\ddot{m}_t - \ddot{m}_t^*)$$

where $\ddot{m}_t$ is the log real balances. By applying the long run equilibrium condition above, it is straightforward to arrive at the fundamental equation of the P* model to be estimated

$$\pi_t = \pi_{t-1} + \beta(\ddot{m}_{t-1} - \ddot{m}_{t-1}^*) + a\Delta(\ddot{m}_{t-1} - \ddot{m}_{t-1}^*) + \varepsilon_t$$

Therefore, it is now easy to see that in such a simple construction inflation depends on lagged inflation (π_{t-1}), on the lagged real money gap ($\ddot{m}_{t-1} - \ddot{m}_{t-1}^*$), and also on the change in the lagged real money gap [$\Delta(\ddot{m}_{t-1} - \ddot{m}_{t-1}^*)$]. In the words of Gerlach and Svensson (2000), the model seems to be highly supported on empirical terms:

> "We find that the so-called P* model has substantial empirical support. Thus, the "price gap", or equivalently and in our view preferably, the "real money gap" (defined as the gap be- tween current real money balances and long-run equilibrium real money balances) contains considerable information about the future path of inflation. Furthermore, and perhaps surprisingly, the real money gap has more predictive power than the output gap. These results suggest that the real money gap should be an important information variable for the Eurosystem" (Gerlach and Svensson, 2000: 2)

The P* model as well as some variants on the baseline version presented above have performed relatively well up to the early 2000s. However, it is not known whether this interpretation of the determinants of inflation can survive the shock that the financial

crisis brought in after 2007. In fact, the money supply before and after the crisis looks terrible different, suggesting a two regime situation. For this reason, Amisano and Fagan (2010), analyzed the same basic problem (money and inflation) with a Markov Switching model. Their main conclusion is that

> "Our estimates suggest that a smoothed measure of broad money growth, corrected for real-time estimates of trend velocity and potential output growth, has important leading indicator properties for switches between inflation regimes. Thus money growth provides an important early warning indicator for risks to price stability" (Amisano and Fagan, 2010: 4).

As it is well known, there are three main alternatives to analyze the existence of different regimes in a (nonlinear) time series framework. One is the Markov switching model followed by Amisano and Fagan, where the transition from one state to another is purely random. The second is to use a smooth transition framework in a VAR (from which stands the term STVAR), in which the economy evolves from one state to the other gradually. The third approach is to use a threshold in a VAR model. For us, given the existence of a liquidity trap (the threshold), it makes more sense to follow this latter approach, because the economy does not change stochastically (neither gradually) from a liquidity trap state to a non-liquidity trap state on a regular basis.

3.3 Methodology

In order to capture nonlinear behaviors in economic and financial time series there are models that allow for the existence of different states of the world (or regimes) and allow the dynamics to be different between the distinct regimes. Using linear models when nonlinearities are present leads to misspecified models that may yield incorrect estimates and spurious conclusions. This chapter will be used to explain some basic notions and models that were employed to study the existence of a nonlinear relationship between monetary policy and inflation: stationary and unit roots tests; the Hansen nonlinearity test; the TVAR (Threshold Vector Autoregressive) nonlinear model and the Generalized Impulse Response Function (GIRF). The estimation of the final model and its analysis were done based on Schmidt (2013).

3.3.1. Times Series Notions and Models

A time series, $\{y_t\}_{t=1,\dots,n}$, is weak stationary if the mean and variance are constant and

the covariance only depends on the lag and not on time, that is:

1. $E(y_t) = \mu$,
2. $E[(y_t - \mu)^2] = Var(y_t) = \sigma^2 < \infty$,
3. $E[(y_t - \mu)(y_{t-s} - \mu)] = Cov(y_t, y_{t-s}) = \gamma_s$.

Stationary variables are needed to estimate a nonlinear TVAR model (to identify the threshold of the model). In turn, to analyze the stationarity of a time series a unit root test should be employed. There are several unit root tests used to detect the presence and form of non-stationarity, but the most common one is the Augmented Dickey Fuller (ADF) test. Consider the following first order autoregressive model:

$$y_t = \rho y_{t-1} + \beta_0 + \beta_1 t + u_t \tag{3.3}$$

where β_0 is the intercept, $\beta_1 t$ is the linear trend and u_t is a white noise error term. If $\rho = 0$, the time series follows a trend stationary process (TSP); if $\rho = 1$ and $\beta_1 = 0$, then a process characterized by a stochastic trend or a difference stationary process (DSP) results and; if $\rho = 1$, the time series follows a random walk with deterministic linear trend.

If in equation **(3.3)** the term y_{t-1} is subtracted:

$$y_t - y_{t-1} = (\rho - 1)y_{t-1} + \beta_0 + \beta_1 t + u_t$$

than a Dickey-Fuller (DF) unit root test can be defined, where the following null hypothesis is considered:

$$H_0 : (\rho - 1) = 0$$
$$H_1 : (\rho - 1) < 0$$

The null hypothesis $H_0: (\rho - 1) = 0$ means that the variable has a unit root, or the process is non-stationary (TSP, DSP, or random walk with linear trend). Rejecting the null leads to a stationary AR(1) process.

By adding the lagged terms of the independent variable to the Dickey-Fuller equation, that is,

$$\Delta y_t = y_t - y_{t-1} = (\rho - 1)y_{t-1} + \beta_0 + \beta_1 t + \beta_2 \Delta y_{t-1} + \beta_3 \Delta y_{t-2} + \cdots$$
$$+\beta_n \Delta y_{t-(n-1)} + u_t$$

an Augmented Dickey-Fuller (ADF) test regression arrises. The null and the rejection/non-rejection of the null are the same that for DF test. The test regression in

the PP (Phillips-Perron) unit root test is:

$$\Delta y_t = (\rho - 1) y_{t-1} + \beta_0 + \beta_1 t + u_t$$

where u_t is a stationary process, which may be heteroscedastic. The PP tests correct for any serial correlation and heteroscedasticity in the errors u_t of the test regression by modifying the test statistics. The null and the rejection/non-rejection of the null are the same that for ADF test[16].

The decision rule for all the hypothesis tests done in this analysis will be based on the P-Value (probability value), which is the lowest significance level at which the null hypothesis can be rejected and it is defined as:

$$Probability\ (rejecting\ H_0\ when\ it\ is\ true) = \alpha, with\ \alpha = 0.05$$

If $P - Value \geq \alpha$ the null hyphothesis is not rejected and if $P - Value < \alpha$ the null hyphotesis is rejected.

3.3.2. Nonlinear TVAR model

Threshold Vector Autoregression (TVAR) methodology is actually a vector autoregression (VAR) modeling generalized to capture linearity in systems, which arises due to asymmetry, periodic movements and regime changes. One of the main advantages of the TVAR methodology is that the variable by which different regimes are defined (the threshold variable) can itself be endogenous in the VAR. Therefore; this makes it possible that regime switches may occur after the shock to each variable.

The basic linear $VAR(p)$ model (reduced form, VAR of order p) consist in a set of k stationary endogenous variables $y_t = (y_{1t}, y_{2t}, \dots, y_{kt})'$ and T observations, inter-related by the rule:

$$y_t = A_0 + A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t \qquad (3.4)$$

where, A_i are coefficient matrices of type $(k \times k)$, $i = 1, \dots, p$, A_0 is a $k-$dimensional vector containing deterministic terms such as a constant, a linear time trend or dummy variables, u_t is the error term (innovation), that is, a k-dimensional vector with $E(u_t) = 0$ and a positive definite covariance matrix $Cov\ (u_t) = \sum_u$ (white noise).

[16]There exists the Caner and Hansen's (2001) nonlinear TAR unit root tests, but it will be not applied in this thesis.

A Threshold VAR (TVAR with one threshold) model can be represented by

$$y_t = C_1 + \phi_1(L)y_t + [C_2 + \phi_2(L)y_t]I(z_{t-d} > \gamma) + u_t$$

where z_{t-d} is the threshold variable determining the prevailing regime of the system, with a possible lag d. $I[.]$ is an indicator function that equals 1 if the threshold variable z_{t-d} is above the threshold value γ and 0 otherwise. The coefficient and lag polynomial matrices C_1, $\phi_1(L)$, C_2 and $\phi_2(L)$, as well as the contemporaneous error matrix u_t are allowed to vary across regimes. The delay lag d and critical threshold value γ are unknown parameters and determined alongside the parameters. The lag order p and the threshold lag d need to be determined a priori, which in case of p is achieved by applying the normal information criteria in the linear VAR estimation. For the choice of d we can rely on economic reasoning or obtain the value by grid search.

The specification stage consists on two steps according to Terasvirta and Yang (2014). First, the linear VAR model will be tested against the Threshold-VAR Model. Secondly, if the linear specification is rejected, the Threshold-VAR Model will be selected together with the optimal number of lags and the transition variable. The estimation process consists in an equation-by-equation OLS for the T-VAR model. It is important to check if the final model satisfies the assumptions under which it was estimated. In order to do so, three tests should be employed: (i) the no serial correlation test which is derived from the autocorrelation VARMA form, (ii) the test of no additive nonlinearity, to test $m = 2$ against $m > 2$ and (iii) the heteroscedasticity-robust test.

3.3.3. Hansen Nonlinearity Test

In this analysis the threshold of the switching variable is determined endogenously by a grid search over possible values of the threshold variable. To begin with, we perform linearity testing to determine whether a threshold effect exists. If a single regime is rejected, we then determine whether there are two or three regimes, using Hansen's (1999, 2000) approach. In each equation the errors are assumed to be homoscedastic within a regime but heteroscedastic across regimes. If one or more of individual equations in the system involve threshold effects, such threshold effects can feed into the responses of the whole system. For this reason the nonlinearity test is based on an individual equation rather than on the whole system (nonlinearity is tested for each equation of the VAR system).

The grid is trimmed at a lower and upper bound in order to ensure a sufficient number

of data points for the estimation in both regimes. From the grid, the estimated threshold value corresponds to the model with the smallest determinant of the variance-covariance matrix of the estimated residuals (which is the multivariate equivalent to a sum of squared residuals criterion in a univariate model):

$$\gamma^* = arg \min_{\gamma} [\Omega_u(\gamma)]$$

We test whether the chosen thresholds are actually meaningful by employing non-linearity tests for each equation of the VAR system. The null hypothesis that the coefficients of C_2 and $\phi_2(L)$ are equal to zero can be implemented by a Wald test. However, standard inference cannot be applied since the unknown threshold is not identified under the null (Hansen, 1996). One therefore has to apply a sup-Wald test to be able to evaluate the statistical relevance of the endogenously chosen thresholds. Let W be the sup-Wald statistic of all possible statistics over the grid:

$$W^* = \sup_{\gamma} W(\gamma)$$

The distribution of this statistic does not follow a χ^2 distribution since is not identified. The bootstrap procedure of Hansen (1996, 1997) is therefore used to generate an empirical distribution for the sup-Wald statistic from which asymptotic *p*-values can be derived.

3.3.4. Generalized Impulse Response Functions

In order to allow for the possibility of endogenous regime switching, nonlinear impulse responses have to be implemented. The computation of impulse responses in non-linear VAR systems is more complicated than in standard linear VARs. In the linear case, the response to a shock is obtained under the assumption that a shock only hits the economy at a particular point in time but neither before nor during the forecasting horizon (the covariance structure does not change). Linear VARs are thus history-independent and the estimated responses are symmetric both in terms of the sign and of the size of the structural shocks. In contrast, threshold VARs rely on the system being in one of the two regimes. Impulse responses for threshold VARs are thus history-dependent and it is necessary to compute the generalized impulse response functions (GIRFs) as developed by Koop et al. (1996), that is, the difference between the forecasted paths of variables with and without a shock to a variable of interest.

Formally the nonlinear impulse responses functions (NIRF) or generalized impulse

response functions (GIRF) are defined as

$$GIRF_y(h, u_t, \Omega_{t-1}) = E\left(Y_{t+h}|u_t\Omega_{t-1}\right) - E\left(Y_{t+h}|\Omega_{t-1}\right)$$

where Y_{t+h} is a vector of variables at horizon h, Ω_{t-1} is the information set available before the time of shock t. This formulation implies that the impulse response functions depend on the initial conditions and that there is no restriction regarding the symmetry of the shocks.

Therefore, in order to get the complete information about the dynamics of the model, the impulse responses have to be simulated for various sizes and for the signs of the shocks. The algorithm proceeds as follows (Schmidt, 2013):

1. A history Ω_{t-1}^r for all the variables is chosen depending on which regime is assumed; this means that a particular realization ω_{t-1}^r of the threshold variable is drawn randomly based upon the regime criterion. This history comprises all the lags up to order p of the variables in the VAR.
2. Shocks are drawn based on the variance-covariance matrix of the residuals. As a joint distribution of these shocks is assumed, a k-dimensional vector u_{t+h}^b is drawn at each horizon (where k denotes the number of endogenous variables in the VAR).
3. The future evolution of all variables is simulated using the estimated coefficients for both regimes as well as the shock process for $h + 1$ periods. Hence, the model is allowed to switch regimes over the forecast horizon. The resulting sequence is denoted by

$$Y_{t+h}\left(\omega_{t-1}^r, u_{t+h}^b\right)$$

4. Step 3 is repeated but the shock sequence at $t = 0$ is replaced by a shock of size δ_j for the variable j and the corresponding contemporaneous shocks for the other variables. This $k \times 1$ vector is denoted by u_j^* . The resulting sequence is denoted by

$$Y_{t+h}\left(\omega_{t-1}^r, u_{t+h}^b, u_j^*\right)$$

5. Steps 2 to 4 are repeated R times in order for the shocks to average out.
6. Steps 1 to 4 are repeated B times to obtain an average over the respective regime history and - once again - to iterate over a large number of draws of shock sequences, which are, expected to average out.

7. The GIRF is the difference between the simulated forecast assuming the shock u_j^* and the forecast assuming no particular shock:

$$GIRF\left(h, u_j^*, \Omega_{t-1}\right) = \left[Y_{t+h}\left(\omega_{t-1}^r, u_{t+h}^b, u_j^*\right) - Y_{t+h}\left(\omega_{t-1}^r, u_{t+h}^b\right)\right]/(B \times R)$$

Since the number of observations in the high stress regime is rather low, following Koop *et al.* (1996) we derive the confidence bands from the quantiles of the distribution of the average impulse responses rather than assuming normality.

3.4 Data

The database used in this analysis includes information for the United States of America from the third quarter of 1981 to the first quarter of 2014 (quarterly frequency), which makes a total of 131 observations. The variables incorporated in the study are Fed holdings of Treasuries, agency debt and MBS ($LSAP_t$); the federal funds rate (i_t); households one-year inflation expectation [$E_t(\pi_{t+4})$] from the Survey of Consumers of the University of Michigan; and the core inflation rate (π_t), based on the personal consumption expenditure price index (PCEPI) excluding food and energy prices. The (core) PCEPI is Fed's primary measure of inflation. The database was constructed using information from the Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of Saint Louis.

In relation to the Federal Reserve's holdings of securities it was only possible to find the time series from the first quarter of 2003 onwards, because there was a change in the accounting treatment of this variable in December 13, 2002. The full time series was constructed by obtaining its previous values for each week directly from Fed's balance sheet, which is available at the Federal Reserve Archival System for Economic Research (FRASER) of the Federal Reserve Bank of St. Louis. The weekly values were then transformed into quarterly averages. The numerical and computational analysis done in this thesis was accomplished with the help of EViews and MATLAB.

The households' one-year inflation expectation is expressed in levels (%), as the results of the unit root tests performed indicate that the hypothesis of non-stationarity is rejected. This does not happen for the other three variables, for which, to approach stationarity, the first difference of their logarithm values is considered. **Table 3.1** below shows the P-Values of the unit root tests made for each of the four variables used in the analysis.

	ADF	PP
$E_t(\pi_{t+4})$	0.0000*	0.0000*
$ln(LSAP_t)$	0.9987	0.9941
$ln(i_t)$	0.9220	0.9186
$ln(\pi_t)$	0.2708	0.1908
$ln(LSAP_t) - ln(LSAP_{t-1})$	0.0001*	0.0007*
$ln(i_t) - ln(i_{t-1})$	0.0000*	0.0000*
$ln(\pi_t) - ln(\pi_{t-1})$	0.0000*	0.0000*

Table 3.1: P-Values of Unit Root Tests for each Variable
Note: * means the null hypothesis is rejected at 5% significance level

Table 3.2 presents the descriptive statistic of the variables, from which it can be concluded that the they are leptokurtic and asymmetric (kurtosis coefficient greater than 3 and skewness greater or lower than zero), and do not follow a normal distribution, except for the inflation time series.

	$ln(LSAP_t) - ln(LSAP_{t-1})$	$ln(i_t) - ln(i_{t-1})$	$E_t(\pi_{t+4})$ (%)	$ln(\pi_t) - ln(\pi_{t-1})$
Mean	0.025593	-0.042270	3.189313	-0.015855
Median	0.017358	-0.003623	3.100000	-0.015375
Maximum	0.586418	0.405465	6.500000	0.352956
Minimum	-0.306175	-1.336033	1.100000	-0.329883
Standard Deviation	0.071016	0.209414	0.707243	0.100714
Skewness	3.700086	-2.672848	1.776212	0.028716
Kurtosis	36.70168	16.71190	9.222808	4.560639

Table 3.2: Descriptive Statistics of each Variable

Figure 3.3, **Figure 3.4**, **Figure 3.5** and **Figure 3.6** (below) show their evolution throughout the period of time considered in the model. The graphical representation of the variables in study illustrates a high variation around 2008 and different regimes can be distinguished, which suggest some nonlinear phenomena in the data. No linear or quadratic deterministic trend and no seasonality characterize the data. In Appendix 1 it can be found **Figure 6.1**, **Figure 6.2** and **Figure 6.3**, which shows the evolution of the original data (before the transformation to difference of the logarithms).

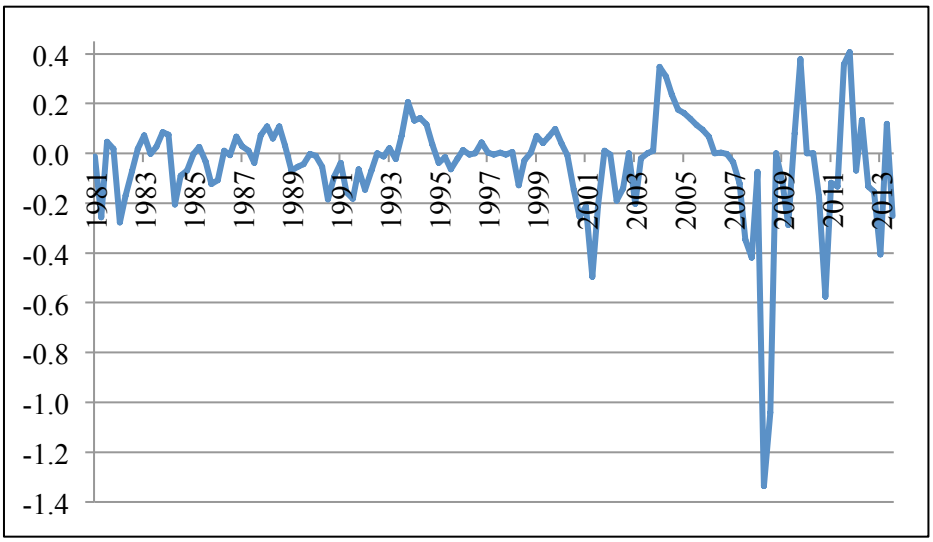

Figure 3.3: Quarterly Change in Federal Funds Rate

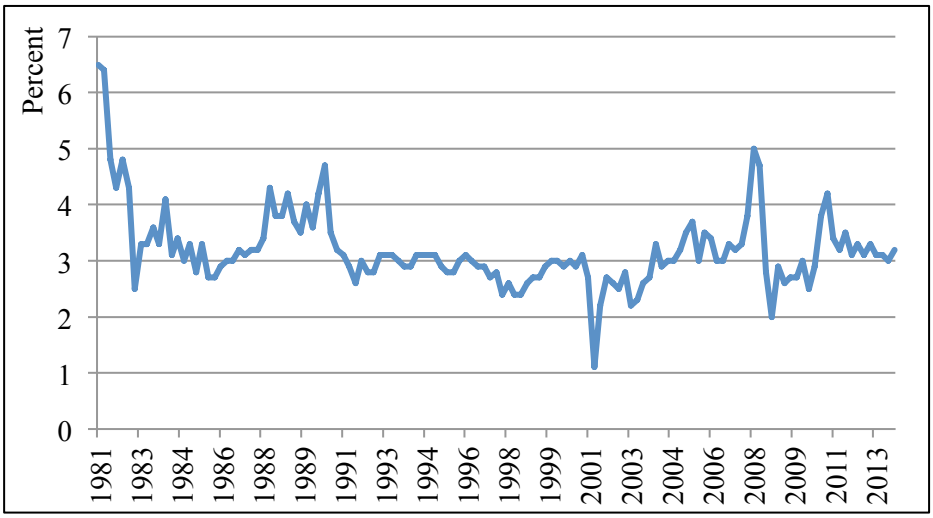

Figure 3.4: Evolution of Households One-Year Inflation Expectation

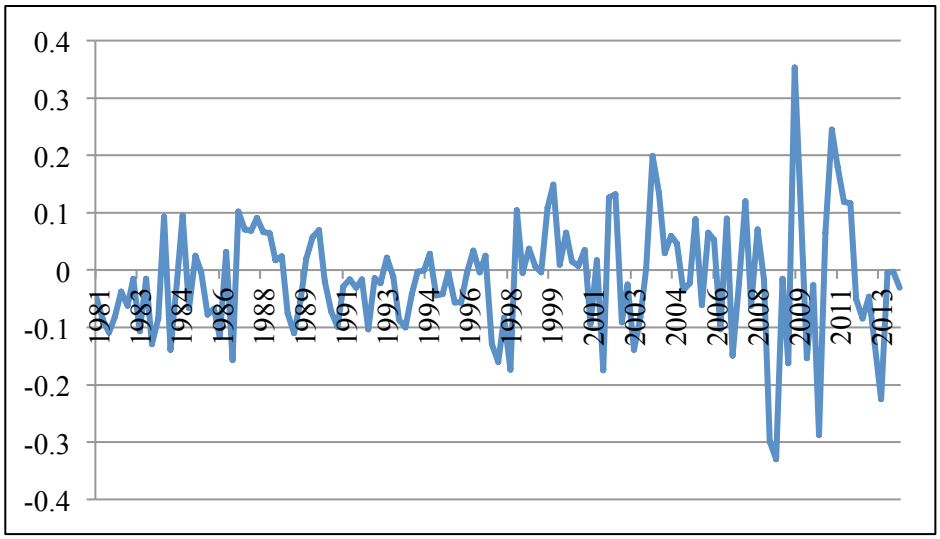

Figure 3.5: Quarterly Change in Inflation Rate

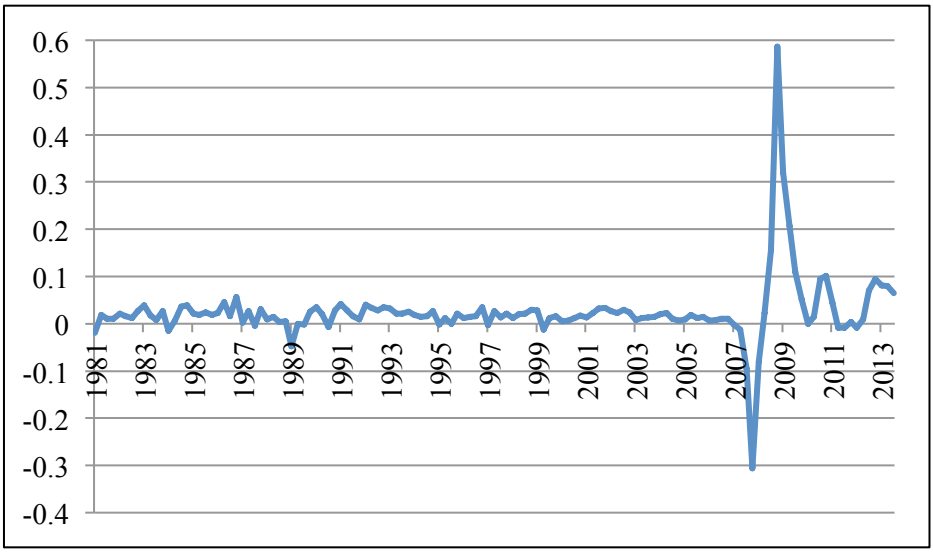

Figure 3.6: Quarterly Change in Fed Holdings of Treasuries, Agency Debt and MBS

In order to analyze the relationship between the variables and; to understand if one of the variables past values can be used to forecast another variable future values, the linear correlation coefficient (**Table 3.3**) and the Granger causality test (**Table 3.4**), respectively, will be presented. In relation to the Granger causality test the following null hypothesis is considered:

$$H_0: y\ does\ not\ Granger\ cause\ x$$

$$H_1: y\ does\ Granger\ cause\ x$$

The analysis of **Table 3.3** allows to conclude that there exists a quite low negative correlation between the federal funds rate and Fed holdings of securities. The highest correlation is between households one-year inflation expectation and Fed holdings of securities and, between the latter and the inflation rate (positive).

Variables	$ln(i_t) - ln(i_{t-1})$	$ln(LSAP_t) - ln(LSAP_{t-1})$	$E_t(\pi_{t+4})$	$ln(\pi_t) - ln(\pi_{t-1})$
$ln(i_t) - ln(i_{t-1})$	1	-0.0616	0.0457	0.2423
$(LSAP_t) - ln(LSAP_{t-1})$	-0.0615	1	-0.2409	-0.0201
$E_t(\pi_{t+4})$	0.0457	-0.2409	1	-0.0201
$ln(\pi_t) - ln(\pi_{t-1})$	0.2423	-0.0201	0.0902	1

Table 3.3: Linear Correlation Coefficient between Variables

Variables	$ln(i_t) - ln(i_{t-1})$		$ln(LSAP_t) - ln(LSAP_{t-1})$		$E_t(\pi_{t+4})$		$ln(\pi_t) - ln(\pi_{t-1})$	
	F	CV	F	CV	F	CV	F	CV
$ln(i_t) - ln(i_{t-1})$	-	-	18.68*	2.68	2.95	3.92	0.87	3.92
$(LSAP_t) - ln(LSAP_{t-1})$	8.76*	3.07	-	-	4.61*	3.07	12.31*	3.07
$E_t(\pi_{t+4})$	7.97*	2.68	6.69*	2.68	-	-	5.05*	3.07
$ln(\pi_t) - ln(\pi_{t-1})$	5.72*	3.92	8.89*	3.07	1.40	3.92	-	-

Table 3.4: Granger Causality Relation between the Variables
Note: * means the null is rejected at 5% significance level

Table 3.4 presents the results of the Granger causality test where $'F'$ denotes the value of the F-statistic and 'CV' the critical value from the F-distribution. The lag length selection is chosen using the Bayesian information criterion. Note that if $F > CV$ the null hypothesis is rejected. The analysis of the table leads to the conclusion that fed funds rate and Fed holdings of securities Granger cause all other variables, inflation expectation Granger cause Fed holdings of securities and Inflation Granger cause Fed holdings of securities and inflation expectation.

3.5 Model and Results

As explained above, first, to conclude whether or not a non-linear VAR is the model that best fits the data, the Hansen non-linearity test was performed for each one of the variables of the VAR system. The latter test assesses the null hypothesis of one-regime AR model against the alternative of two-regime AR model. The P-Values of the test are presented in **Table 3.5**, **Table 3.6**, **Table 3.7** and **Table 3.8** below, and their analysis leads to the conclusion that the hypothesis of linearity and thus one-regime AR model is best rejected when we use $ln(LSAP_t) - ln(LSAP_{t-1})$ as a threshold variable. Thus, Fed holdings of Treasuries, agency debt and MBS is the trigger of non-linearity in this model.

	Homoscedastic P-Values		Heteroscedastic P-Values	
Nº of lags	Asymptotic	Bootstrap	Asymptotic	Bootstrap
1	0.000000*	0.340000	0.240000	0.360000
2	0.000000*	0.000000*	0.000000*	0.000000*
3	0.000000*	0.000000*	0.000000*	0.000000*
4	0.000000*	0.240000	0.230000	0.350000
5	0.000000*	0.150000	0.040000*	0.160000

Table 3.5: Hansen Test with Fed Funds Rate as a Threshold Variable
Note: * means the null is rejected at 5% significance level

	Homoscedastic P-Values		Heteroscedastic P-Values	
Nº of lags	Asymptotic	Bootstrap	Asymptotic	Bootstrap
1	0.000000*	0.010000*	0.030000*	0.010000*
2	0.000000*	0.040000*	0.030000*	0.040000*
3	0.000000*	0.000000*	0.020000*	0.000000*
4	0.000000*	0.010000*	0.010000*	0.000000*
5	0.000000*	0.000000*	0.010000*	0.000000*

Table 3.6: Hansen Test with Fed Holdings of Treasuries, Agency Debt and MBS as a Threshold Variable
Note: * means the null is rejected at 5% significance level

	Homoscedastic P-Values		Heteroscedastic P-Values	
Nº of lags	Asymptotic	Bootstrap	Asymptotic	Bootstrap
1	0.000000*	0.160000	0.020000*	0.350000
2	0.010000*	0.480000	0.080000	0.730000
3	0.000000*	0.110000	0.000000*	0.320000
4	0.290000	0.970000	0.430000	0.970000
5	0.080000	0.770000	0.110000	0.800000

Table 3.7: Hansen Test with Households One-Year Inflation Expectation as a Threshold Variable
Note: * means the null is rejected at 5% significance level

	Homoscedastic P-Values		Heteroscedastic P-Values	
Nº of lags	Asymptotic	Bootstrap	Asymptotic	Bootstrap
1	0.000000*	0.000000*	0.060000	0.020000*
2	0.000000*	0.030000*	0.020000*	0.080000
3	0.000000*	0.000000*	0.060000	0.050000
4	0.060000	0.260000	0.300000	0.510000
5	0.000000*	0.090000	0.100000	0.120000

Table 3.8: Hansen Test with Inflation Rate as a Threshold Variable
Note: * means the null is rejected at 5% significance level

The finding of a threshold variable allows the analysis of the monetary policy effect on inflation in two different regimes, which, in this case, corresponds to a state of the economy where interest rates are low and thus Fed is buying large amounts of securities (Regime 2) and, the opposite state (Regime 1). For this, a two-regime TVAR model with 3 lags will be estimated through Ordinary Least Squares (OLS) using Fed holdings of Treasuries, agency debt and MBS as a threshold variable. The model can be represented by:

$$y_t = C_1 + \phi_1(L_1)y_t + \ (C_2 + \phi_2(L)y_t)\, I(z_{t-d} > \gamma) + u_t$$

where $y_t = \begin{bmatrix} ln(i_t) - ln(i_{t-1}) \\ ln(LSAP_t) - ln(LSAP_{t-1}) \\ E_t(\pi_{t+1}) \\ ln(\pi_t) - ln(\pi_{t-1}) \end{bmatrix}$, $z_{t-d} = ln(LSAP_t) - ln(LSAP_{t-1})$ and the threshold value to consider (estimated by grid search method) is $\gamma = 0.0165$.

In fact we have a system with 4 endogenous variables, where the matrix of all coefficients it is of type $(var \times lags \times 2 \quad var\_con \times lags\_con + 1) \times (var)$ (which means in practice 26x4) whose ordering is the following: lag 1 of variables in data, ..., lag p of variables in data, lag 1 of variables in data if greater than threshold, …, lag p of variables in data if greater than threshold, lag 1 of controls, …, lag p of controls, constant, second constant (if greater than threshold). The matrix of coefficients is presented in **Table 6.1** in Appendix 1. The threshold variable, used to distinguish between different regimes is modeled as a variable in the vector Y_t. This way regime switching is allowed to be endogenously determined in the system.

After the model is selected and the coefficients are estimated, the dynamics of the nonlinear system is evaluated via non-linear impulse response analysis (GIRF). As our

objective is to study the effect monetary policy has on inflation, the GIRFs were obtained for each one of the variables included in this analysis by shocking Fed holdings of Treasuries, agency debt and MBS. The shocks employed were of different characteristics in terms of direction, positive or negative, and size, small (0.5 standard deviations) and large (1.5 standard deviations). But nonlinearities depend not only on the characteristic of the shock but also on the regime (state of the economy) existent at the time of the shock.

The results can be seen in Figure 3.7 (below) and **Figure 6.4** in Appendix shows the Impulse Response Functions (IRF) for the linear VAR. The reaction of federal funds rate to a positive shock (negative) to Fed holdings of Treasuries, agency debt and MBS is the expected one. The rate decreases (increase) with the shock and, as the threshold variable returns to its previous value (decreases/increases), it starts to rise (decline) until normalizing again to its initial amount. The reactions of inflation expectations and inflation can also be characterized as expected, according to the quantitative theory of money, the theory that relates inflation to the amount of money in the economy.

Friedman (1968) states that expansionary monetary policy can decrease interest rates but this decrease represents only the first part of the process, given that it would trigger more developments: it would increase expenditures (through its impact on investment and others) and since the expenditure of one person represented the income of another, the increase in income would increase liquidity preference (because of transactions-motive and precautionary-motive which depended positively on income) and the demand for loans. The increase in expenditures would also raise prices, which would decrease the real amount of money. All these consequences would increase the level of interest rate reversing its initial decrease. Thus, if the monetary authority wanted to keep low levels of interest rate it would have to do larger and larger open market operations, which is what the Federal Reserve System is doing.

And, in Figure 3.7 it can be seen that the reversal of the federal funds rate decrease, seems to be associated, more or less at the same time, with the increase in inflation rate. Friedman adds that there is a lag, which duration is unpredictable between expansionary monetary policy and the increase in inflation. In this case, as the Federal Reserve System is constantly buying long-term securities (constantly shocking Fed holdings of Treasuries, agency debt and MBS) and as per the model estimated, LSAPs will not lead to inflation. Inflation is more likely to decrease than increase. A rise in the level of prices in the long run (when Fed LSAP is finished) will depend on Fed capability to

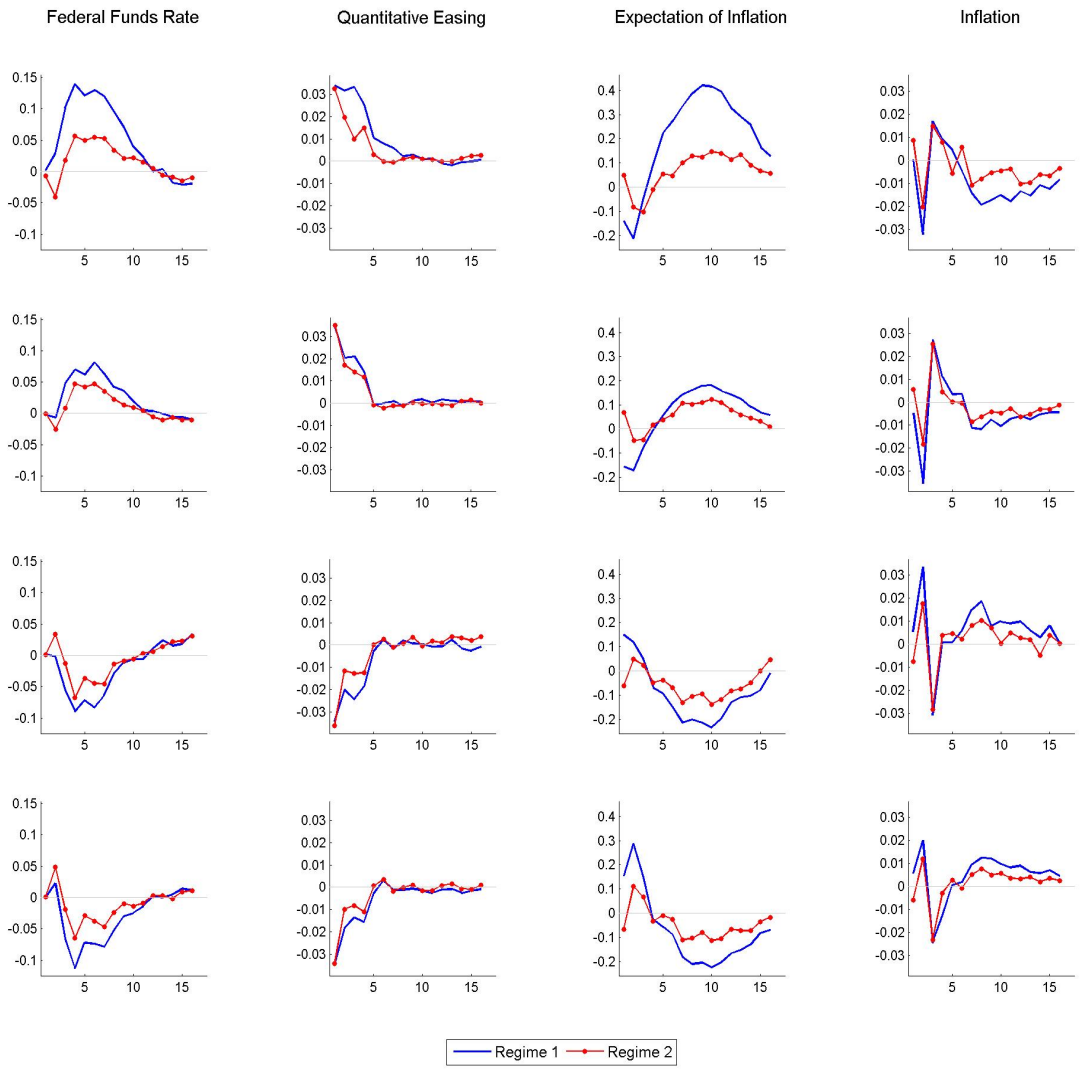

Figure 3.7: GRIFs after a Shock to Fed Holdings of Securities
Note: GIRF after a positive shock (first and second row) of 0.5 standard deviations (first row) and 1.5 standard deviations (second row). GIRF after a negative shock (third and fourth row) of 0.5 standard deviations (third row) and 1.5 standard deviations (fourth row).

prevent a massive increase in money supply. The existence of nonlinear feature in the model does not imply that inflation reacts to monetary policy in opposite ways (according to the state of the economy observed) but it means that the magnitude of the responses are different, with the variables being less reactive when we are in regime two, which corresponds to the state of the economy where interest rates are low and Fed is increasing its holdings of securities.

4. Conclusion

On November 2008, the Federal Reserve System announced is first round of Large Scale Asset Purchases, which consisted in purchases of huge amounts of long-term securities in an attempt to stimulate the U.S. economy. The program was employed as a response to the severe recession and posterior slow recovery the U.S. economy was facing, which was caused by the housing and subsequent financial crisis. As the Fed had decreased its reference rate to almost zero, LSAPs represented a way of providing further accomodation to the economy. As of today, Fed has engaged in three different rounds of the program and, the last one was finished October, 2014.

According to the Fed, purchases should decrease long-term interest rates through the portfolio-balance channel and signalling channel. The first channel is based on ealier works of authors such as James Tobin, Modigliani and Sutch and, Brunner and Meltzer. The signalling channel is based on more recent theories development under the New Keynesian Model. Lower long-term rates should ease financial conditions and, boost economic activity, by fueling asset prices, allowing households to refinance their loans and, reducing the cost of capital for businesses, which would increase consumption and investment. In practice there seems to be great response of the economy to the purchases, but only a detailed analysis can comprove this, as there are many factors which can contribute to results seen, for example, low interest rates (forward guidance) and increased asset prices.

In fact there is a group of economists, which, since the beginning, has been against the program. The motives vary between the facts that it is an ineffective policy to the fact that it harms the economy. One the main factor appointed has a negative consequence of LSAPs is hyperinflation. Economists such as John B. Taylor, Allan H. Meltzer (whose work Fed has been using to justify the implementation of the program) and Martin Feldstein have been prediction severe inflation on the economy, since the start of the purchases. Nonetheless, the U.S. economy has experienced almost 6 years (although not continuous) of the program and no signs of hyperinflation, with fears of deflation being more likely.

It is in this context that the present dissertation proposed to study the possibility of a nonlinear relationship between monetary policy and inflation, looking to find a situation where inflation would react differently to a state of the economy where the zero-lower

bound on nominal interest rates is achieved. Using the Hansen nonlinearity test it was found that there exists a non-linear relationship when Fed holdings of Treasuries, agency debt and MBS is used as a threshold variable. This means that above a certain value of Fed holdings of securities, there will be a certain association between the two variables, which will be different below that value.

The TVAR model employed and the GIRFs obtained allowed to conclude that expansionary monetary policy still leads to inflation when we are at very low levels of interest rate and thus, high values of Fed holdings of securities; although there is a certain lag in this effect. Because of this lag, and the fact that Fed is, throughout the different rounds, constantly buying assets and preventing a normalization of its policy, the U.S. economy will not experience hyperinflation. Furthermore at this stage of the economy, both inflation and inflation expectations are less responsiveness to a shock to Fed holdings of securities. Now that the program seems to have reached a final end, the Fed has to control the money supply and try to avoid any risks of inflation.

The present dissertation represents only a small step in this analysis, which can be further detailed and improved, mainly in the empirical part. For example, as mentioned above, the model estimated can be subject to different tests that should check if satisfies the assumptions under which it was estimated. In order to do so, three tests should be employed (i) the no serial correlation test which is derived from the autocorrelation VARMA form, (ii) the test of no additive nonlinearity, to test $m = 2$ against $m > 2$ and (iii) the heteroscedasticity-robust test. Furthermore, the Caner and Hansen unit root test for nonlinear series can be employed.

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6. Appendix

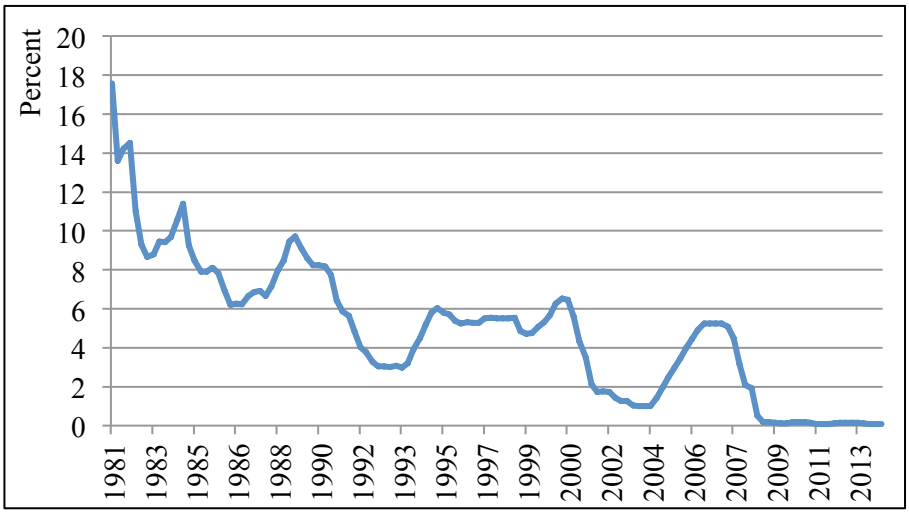

Figure 6.1: Evolution of Federal Funds Rate

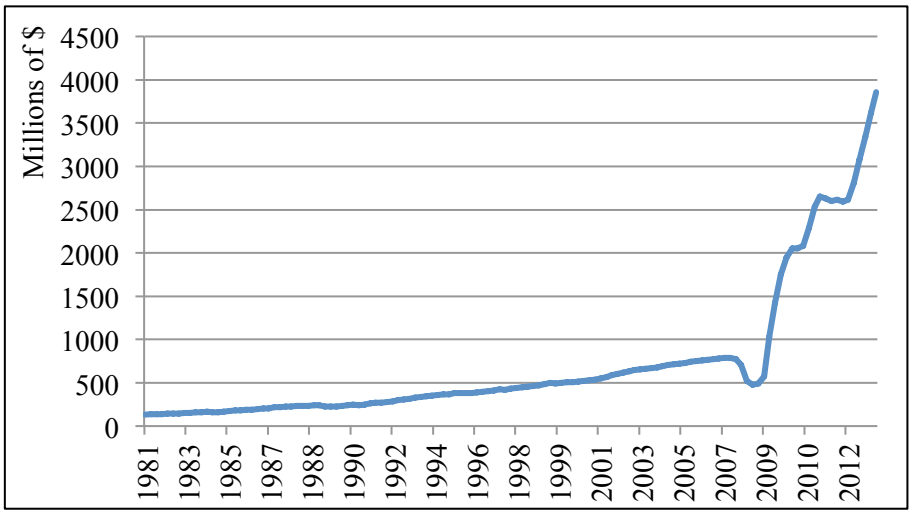

Figure 6.2: Evolution of Fed Holdings of Treasuries, Agency Debt and MBS

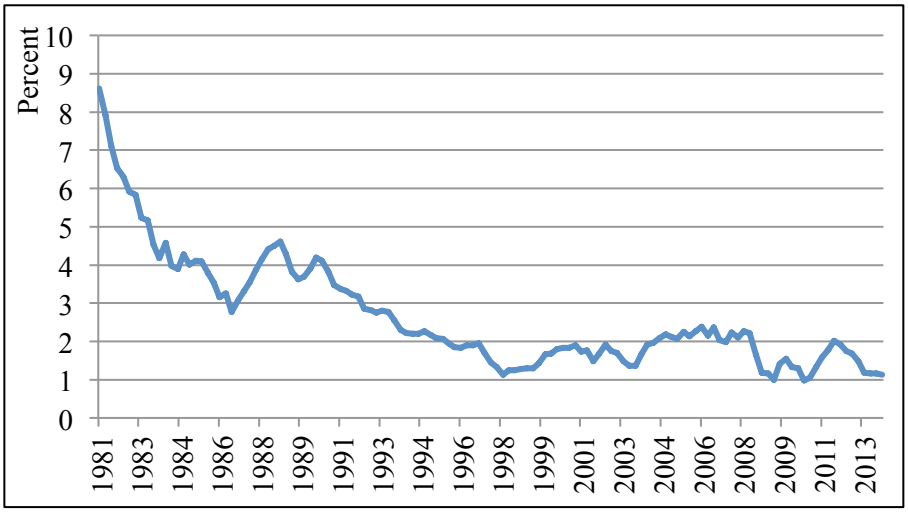

Figure 6.3: Evolution of the Inflation Rate

0,605881	0,126949	0,681252	-0,100053
-1,094240	0,442360	-7,543006	0,262477
0,045685	-0,011118	0,485000	0,057358
0,427964	-0,063126	0,337567	0,061731
-0,218359	-0,083091	1,104046	-0,137172
3,534418	-0,155702	1,707075	0,934169
-0,090515	0,002978	-0,300981	-0,074711
0,081550	-0,135395	0,435608	0,188780
0,199454	0,012297	0,183668	0,035527
1,009069	0,128119	3,220933	-0,304934
0,062693	-0,003989	0,504150	0,011503
0,434920	0,053747	-2,024612	0,022442
-0,105640	-0,190213	-0,169426	0,137659
0,874769	0,123789	7,150018	-0,855477
-0,073674	-0,001003	0,004927	0,005101
-0,111029	-0,047395	0,474969	0,205442
-0,004575	-0,051100	-1,631515	0,006501
-3,074613	0,479696	0,045892	0,539657
-0,023342	-0,007803	0,319359	-0,002354
-0,028505	0,047657	-0,837578	-0,316904
0,094028	0,116395	0,459329	0,099147
-0,986449	-0,359055	-4,565945	-0,372346
0,018939	0,016243	-0,393562	-0,031725
-0,449351	0,019431	1,996773	0,121377
-0,124803	0,047119	0,924809	0,016461
0,296081	-0,032917	0,241936	0,068975

Table 6.1: Matrix of all Coefficients of the Model

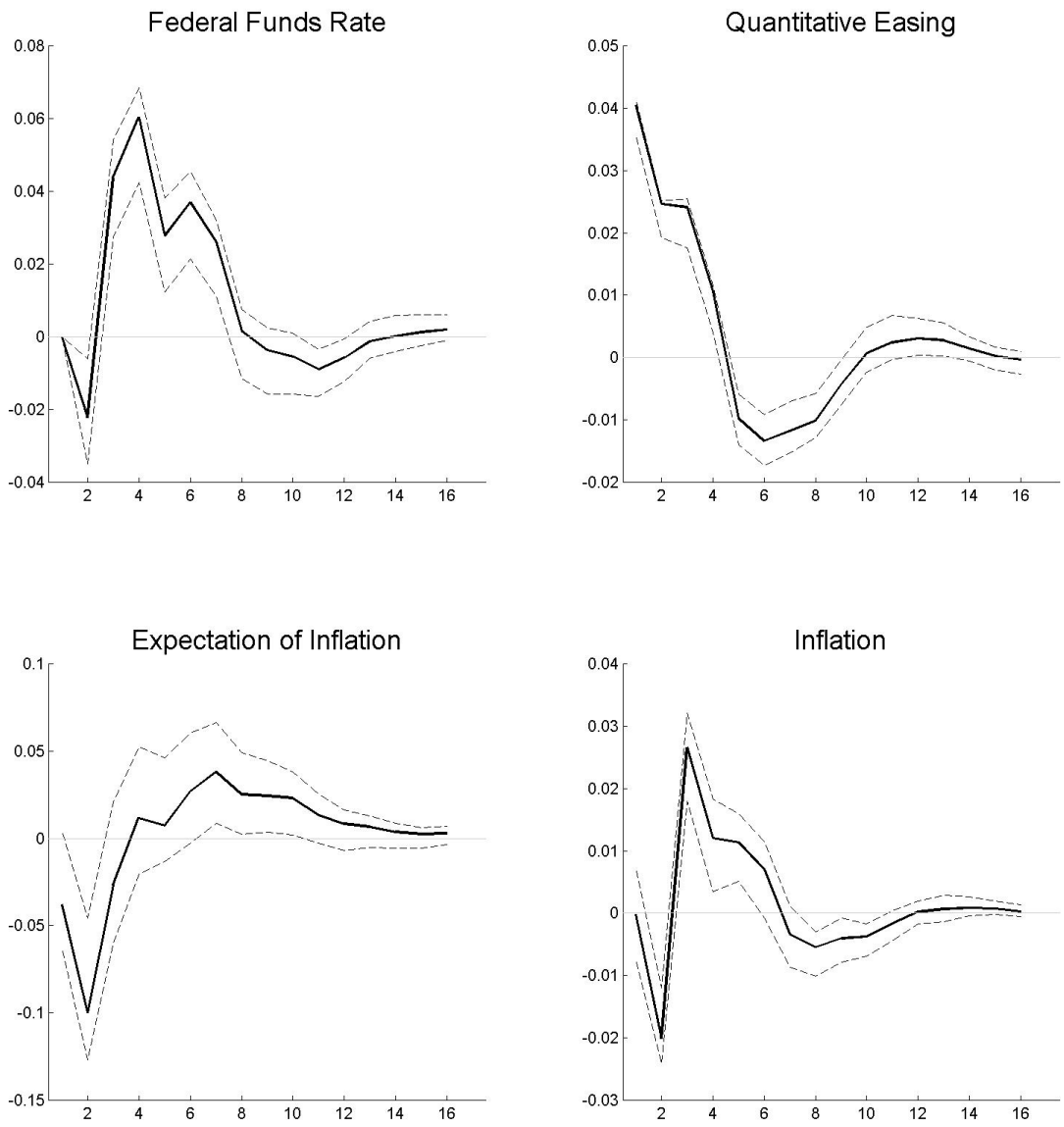

Figure 6.4: Impulse Response Function for the Linear VAR