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THE TRANSMISSION MECHANISM FOR QUANTITATIVE EASING

Evidence from the United States at the Zero Lower Bound

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PREFACE AND ACKNOWLEDGMENTS

While I have had a long-lasting passion for development economics, my Master's degree in International Economics at Erasmus University Rotterdam got me to also further develop my interest in monetary economics. The current global economic conjuncture, with advanced economies having faced liquidity constraints for seven consecutive years and the resulting debates on monetary policies implications, further spur my interest in monetary economics.

Quantitative easing (QE), or the large-scale purchase of assets by central banks, has been one of the central policy measures undertaken by monetary authorities to boost the economy. Understanding its effectiveness to stimulate the recovery and the risks associated to it is therefore critical to central bankers to better define which policy measures to take in a liquidity constraint context, to scholars to determine the monetary transmission mechanism through which QE works, and most importantly to the civil society to understand how fundamentals such as the inflation rate and the unemployment rate are ultimately affected.

Focusing exclusively on US data (due in part to high data availability), this research investigates the presence of a portfolio balance effect and a liquidity effect, identified in the literature as core channels through which QE impacts the economy by decreasing longer-term yields.

The present Master's thesis has been performed individually throughout the period October 2014 to July 2015. Writing this paper was both enriching and challenging. The amount of thrilling and relevant topics related to QE made the definition of the research question a lengthy and demanding task. My research question was finally defined thanks to a thorough examination of the literature on QE, of available data, and of the feasibility to use particular methodologies.

I am very grateful to my supervisor, Professor Casper G. de Vries, holding the Chair of Monetary Economics at Erasmus University Rotterdam, who has guided me throughout my research with patience and who considerably assisted me in defining my research question by introducing me to relevant literature. Receiving recommendations from a scholar with substantial experience in the practice and analysis of monetary economics has been an honour. I would also like to thank my second reader, Pr. Lorenzo Pozzi, who kindly accepted to set time aside to review and grade my Master's thesis.

I am also grateful to Professor Matthew Raskin, Director in Cross-Market Monitoring and Analysis at Federal Reserve Bank of New York, for responding in no time to my enquiry on the availability of US debt stock-related data, and for kindly providing me with a large dataset that was very germane for my analysis.

Finally, I would like to thank my family and my friends for the incredible support and inspiration they offered me over the past months, independent of the distance separating them from me, including Ali Bou-Abdallah, Fewzia Bou-Abdallah, Rédouane Bou-Abdallah, and Lavinia Dobromir, Michaela Burianova and Simon Fellermeyer.

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ABSTRACT

Since November 2008, quantitative easing (QE) has become the workhorse of the US monetary policy to create accommodative conditions beyond the short-term interest rate. This paper reviews the implementation of unconventional monetary policy measures undertaken by the Federal Reserve since 2008, with a particular focus on QE, and presents an overview of the theories on the transmission mechanism underlying traditional monetary policy in general as well as those relative to QE. Moreover, this paper offers an empirical analysis of two transmission channels through which QE is expected to influence interest rates, namely, the portfolio balance channel and the liquidity channel. Focusing exclusively on US data, there is not enough statistical evidence found in favour of either channel after accounting for a trend.

Keywords: Quantitative Easing, Monetary Policy, Transmission Channel, Liquidity Trap, Zero Lower Bound

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I. INTRODUCTION

As a response to the 2007-2008 global financial crisis, monetary authorities of advanced economies have broadened their portfolio of monetary policy instruments. Typically, central banks would guide the short-term interest rate – the rate at which financial institutions borrow overnight – to keep inflation close to target, a practice commonly known as conventional monetary policy. Specifically, if there were a relatively high level of uncertainty about the future real value of money and if investment declined, monetary authorities would reduce the short-term interest rate so as to decrease banks' funding costs. In turn, this would boost banks' lending operations, thereby stimulating the economy as a whole. Conversely, if credit and spending were rising too fast, central banks would raise the short-term interest rate to stabilize prices and prevent runaway inflation. However, when such conventional measures are not effective anymore, central banks must rely on so-called unconventional monetary policy measures[1].

Quantitative easing (QE), or the large-scale purchase of publicly-held financial assets by central banks, is one of them. By acting on the size and composition of a central bank's balance sheet, large-scale asset purchases are meant to create accommodative conditions for the market to invest in new assets and for financial institutions to increase lending, so as to ultimately stimulate job creation and ensure that inflation is on track to meet the target set by monetary authorities. This process is expected to happen through various transmission channels affecting market prices, conditions and expectations beyond the short-term rate. The portfolio balance channel, predicting a positive relationship between bond term premiums (and thus bond yields) and publicly-held debt stock, is presented in much of the literature as the prominent channel through which QE acts on the economy (see e.g. Gagnon et al. 2011, and Bernanke 2012). The liquidity channel, less studied in the context of QE, assumes the same positive relationship between bond yields and publicly-held debt supply, but through an effect on the liquidity premium embedded in bond prices.

[1] Also referred to as non-standard or extraordinary monetary policy measures.

A. RESEARCH QUESTION

Focusing exclusively on US data, this paper aims at answering the following question: ***did the large-scale asset purchase (LSAP) programme implemented by the United States Federal Reserve from November 2008 to October 2014 reduce longer-term yields through a portfolio balance effect and/or a liquidity effect?***

B. RELEVANCE

The relevance of this question lies on four grounds. First, investigating the mechanism through which asset purchases may have had an impact on yields gives further insight into whether, how and to which extent QE has helped to contain the recent crisis and to boost the US economy. Second, this question is particularly relevant in the current context, given that inflation has dropped by more than 1 percent in the US since the Fed stopped QE in October 2014 (refer to Figure 4 and note 9). Understanding the effectiveness of the LSAP programme in this context will thus offer some clues on whether or not the Fed was right to stop it last October. Third, with advanced economies at the zero lower bound, monetary authorities have less policy leeway to influence market conditions, and face greater uncertainty and risk than during normal times. Since academics and central bankers have less grasp over the behaviour of fundamentals at the zero lower bound, and therefore over what monetary policy measures are most adequate in this context, further analysis of the transmission mechanism of key unconventional measures, such as QE, is critical. Investigating the existence and importance of the portfolio balance channel and the liquidity channel, both identified as playing a major role in affecting yields during the recent crisis, appears germane for monetary policy implementation. Fourth and last, the effects of QE have been extensively analysed in Japan, but to a much smaller extent in the US and the UK, given the more recent introduction of QE in the latter economies. So far, findings have been ambiguous and have differed across countries (see Bernanke *et al.*, 2004; Hausken *et al.*, 2013; and Fawley *et al.*, 2013). While the findings in the present paper are specific to the US and cannot be generalized to other economies, they provide some insight into the US experience with QE to advanced economies experiencing a somewhat similar economic conjuncture. Although the Eurozone and the US have dissimilar financial[2] and political structures, evidence on the impact of QE in the US is likely to serve as relevant comparative and forecasting information for the European monetary authorities,

[2] While the capital market is the major financing source in the US, financing is mainly procured by banks in the Eurozone (see paper of ESRB's Advisory Scientific Committee, 2014).

particularly since the European Central Bank (ECB) launched its first QE round last March, after having exhausted most of its other monetary policy options.

C. MAIN FINDINGS

After providing a detailed review of the theories on traditional monetary transmission channels in general, and of QE's transmission channels in particular, this paper analyses the presence of a portfolio balance effect and a liquidity effect relative to the Fed's LSAPs. This paper argues that neither the portfolio balance channel nor the liquidity channel have played a role in lowering longer-term yields in the US. In other words, there is not enough statistical evidence that the Fed's LSAPs reduced longer-term Treasury yields through either channels.

D. SUMMARY OF CONTRIBUTION AND METHOD

In comparison with other studies, this paper uses different measures and data sources for control variables to test the relationship between bond yields and publicly-held debt supply. To test the portfolio balance channel, the paper follows Thornton (2014) by using two yield-related measures, namely, the ten-year Treasury yield term premium and the ten-year Treasury yield. In addition to the work in Thornton (2014), this paper also investigates a portfolio balance effect using the spread between the ten-year Treasury yield and the fed funds rate. Furthermore, this paper adds to the literature by testing the liquidity channel using for the first time the yield spread between formerly- and newly-issued Treasuries.

All models considered are estimated over the period 1984 to 2008, prior to Lehman's collapse in September 2008. Thereafter, the estimated models are used to quantify the out-of-sample effect of the Fed's LSAPs, which started in November 2008 with the so-called first QE round. The estimations are performed using ordinary least squares with heteroskedastic variances to overcome the presence of heteroskedasticity and autocorrelation.

E. STRUCTURE

The research proceeds as follows: section 2 presents the crisis and recession context faced by Western advanced economies since 2008, justifying the socioeconomic relevance of the research question. Section 3 reviews the theory on the traditional monetary transmission mechanism. Section 4 describes the Fed's response to the crisis. Section 5 presents the transmission channels through which QE is

expected to act on the economy. Section 6 reviews the literature on the transmission mechanism for QE. Section 7 presents new empirical evidence with regard to the portfolio balance channel and the liquidity channel in the US. Section 8 concludes. Finally, the Appendix describes the preliminary work performed prior to define the research question as such.

II. CRISIS AND POST-CRISIS ECONOMIC CONTEXT

A. THE US, THE UK AND THE EUROZONE

When the 2007-2008 crisis hit, major central banks, including the Federal Reserve (Fed), the European Central Bank (ECB), and the Bank of England (BOE), cut their key policy rates to almost zero in order to stimulate the economy (The Economist, 2015). In the United States, the primary discount rate[3] and the target fed funds rate[4] were gradually cut from 2.5 percent and 2.25 percent in March 2008 to 0.5 percent and to a range of 0 to 0.25 percent in December 2008, respectively[5]. In the Eurozone, the main refinancing operations (MRO) rate was progressively cut from 4.25 percent in July 2008 to 1 percent in May 2009[6]. As for the United Kingdom, the official bank rate was gradually cut from 5 percent in April 2008 to 0.5 percent in March 2009[7]. However, even at the zero lower bound, production kept on falling far short of productive capacity.

The situation in which conventional monetary policy, consisting of guiding the short-term interest rate, loses its potency, despite the necessity for more monetary easing, was referred to "liquidity traps" by Keynes (1936). More precisely, an economy is said to be in a liquidity trap when, even at a zero short-term interest rate, private demand fails to be stimulated, and spending is well below what would be needed for full employment. Hence, the US, the Eurozone, and the UK could be considered in a liquidity trap, or at least significantly liquidity constrained.

To avoid entering a prolonged period of recession and be haunted by the phantom of some "lost decades" similar to those of Japan, monetary authorities decided to undertake unconventional measures by acting on the size and composition of their balance sheet. QE became the cornerstone of monetary policy in the US and the UK starting in the fall of 2008 and in the spring of 2009, respectively. On the other hand, the Eurozone decided to focus on a set of alternative measures, before turning to QE very recently, in March 2015.

[3] The primary discount rate, also called the primary credit rate, is the Fed's key policy rate. Eligible depository institutions borrow from the Fed at this rate.
[4] The feds fund target rate is set by the Federal Open Market Committee (FOMC) to guide the rates at which depository institutions, generally banks, trade balances held at the Fed with each other.
[5] Numbers provided by the New York Fed and the Fed Discount Window (refer to bibliography).
[6] Numbers provided by the ECB (refer to bibliography).
[7] Numbers provided by the BOE (refer to bibliography).

Over the years following the crisis, the US and the UK have had more or less better results than the Eurozone in terms of two key macroeconomic measures, namely the unemployment rate and the inflation rate (refer to Figure 1 to 6)[8]. As illustrated in Figure 1 and 2, the unemployment rate has dropped in the US and the UK from 9.9 percent in 2010 to 5.5 percent in 2015, and from 8.4 percent in 2012 to 5.7 percent in 2015, respectively. In contrast, Figure 3 shows that the unemployment rate has risen in the Eurozone from 7.2 percent in 2008 to 12 percent in 2013, and has declined very sluggishly since then, from 12 percent in 2013 to 11.2 percent in 2015.

Figure 1: United States Unemployment Rate (2008-2015)

Figure 2: United Kingdom Unemployment Rate (2008-2015)

[8] Graph and data extracted from www.tradingeconomics.com.

Figure 3: Eurozone Unemployment Rate (2008-2015)

Moreover, while inflation reached a pick low below -2 percent in 2009 in the US, it has been positive since then, and has almost remained stable at the set target of 2 percent over 2012 to 2014, before dropping again below zero since the termination of QE in October 2014 (Figure 4). In the UK, inflation has been declining since 2011 but has remained positive (Figure 5). In the Eurozone, while reaching a pick low of almost -1 percent in 2009, inflation has increased to 3 percent over the course of 2011, and has been declining since then, reaching negative levels again since the fall of 2014 (Figure 6).

Figure 4: United States Inflation Rate (2008-2015)

Figure 5: United Kingdom Inflation Rate (2008-2015)

Figure 6: Eurozone Inflation Rate (2008-2015)

Whether QE is one of the reasons for which the US and the UK have had relatively better recoveries than that of the Eurozone in terms of employment, inflation and other macroeconomic and monetary factors remains ambiguous. Since inflation dropped back to negative levels in the US[9] right after the Fed decided to shut down its last QE round in October 2014, while moderately rising in the Eurozone[10] after the announcement by the ECB of the start of its first QE round in March 2015, crucial questions are raised regarding the necessity and the effectiveness of QE.

[9] from 1.7 percent in October 2014 to -0.1 percent in March 2015 (Trading Economics).
[10] from -0.6 percent in January 2015 to -0.3 percent in February 2015 (Trading Economics).

B. WAS THE FED RIGHT TO STOP QE?

The Federal Open Market Committee (FOMC) has launched three rounds of QE since the fall of 2008, raising the Fed's balance sheet to an all-time high 4.48 trillion dollars (Kearns *et al.*, 2014). On October 2014, despite the sluggish recovery, the FOMC decided to shut down its asset purchase program[11]. A crucial question is raised: was the Fed right to stop QE given the existing context?

The Fed is juggling between two mandates: maximum employment and price stability. On the one hand, the Fed aims at bringing on the conditions propitious for job creation until full employment is attained. On the other hand, the Fed intends to reach a satisfactory inflation level – set at 2% – that would boost investment and private spending. Despite important ameliorations[12] in the economy since the launch of the asset purchase program, and although the central bank has more or less achieved price stability as it defines it, the economy remains far from maximum employment, and inflation remains below its target of 2 percent (Krugman, 2012). Specifically, in October 2014 the unemployment rate was still slightly above 5 percent, and the inflation rate still below 1.5 percent (Fed website, 2014). Hence, in the current context, further economic stimulus is still much needed.

The asset purchase program is expansionary, and is thereby expected to be inflationary and create the conditions for economic stimulus and job creation. Krugman (2014) explains that this is precisely why QE should be pursued, to further boost the economy and inflation towards the FOMC's objectives. Krugman (2012) also affirms that if the Fed decides to avoid taking any risk on the inflation front even though unemployment remains high, "it's violating its own charter". Nevertheless, many do not share Krugman's views. Opinions about the Fed's LSAPs have diverged, within and outside the central bank, on two main grounds since the inception of the program, and even more so since the conclusion of QE in October 2014. Specifically, opinions differ on whether or not: 1) QE presents foreseeable adverse side effects, and 2) QE actually works. Let's ponder those considerations one by one.

1) Does QE present foreseeable adverse side effects?

Concerns about possible negative externalities associated to QE have been expressed, within and outside the Fed, since the inception of the asset purchase program. Particularly, some have warned about the risk of runaway inflation and of a debasement of the dollar through an open letter addressed

[11] Refer to the Fed's press release of October 29, 2014 in the bibliography.
[12] Refer to the Fed's press release of October 29, 2014 in the bibliography.

to former Fed Chair Ben Bernanke (Asness *et al.*, 2010). Runaway inflation implies uncertainty about the future purchasing power of money, which may discourage investment and savings. Calomiris argues that the inflationary risk involved in QE is likely to be so important so as to outweigh the benefits QE might deliver (refer to Krugman (2014)'s article). However, Krugman (2014) affirms that one of the major concerns since the onset of the crisis has been the risk to enter a deflationary spiral similar to that of Japan, rather than the risk of runaway inflation. Indeed, after six years of asset purchases, inflation has rose only moderately and remains below target. Although this does not mean that the Fed should not be cautious about the risk of an inflationary spiral, it suggests that this risk is minimal. Bernanke even asserts that inflation was "never a risk", and it is "not a risk now" (refer to Simonoff (2014)'s article).

So what is it behind this "inflation obsession" as referred to by Krugman (2012)? By eroding the real value of money, inflation diminishes the debt burden of the private sector – which has been one of the major drags on consumption – and renders savings a less attractive option, eventually boosting spending. As a result, inflation stimulates job creation, while decreasing the value of wealth accumulated by net savers. It is therefore good for the poor who get employed and benefit from raises in wages that follow other price increases, but bad for the wealthy who see their hoard of cash devaluating. The stance on whether QE should be pursued or not is therefore, to some extent, an inequality policy stance. However, as far as runaway inflation is concerned, its risk is likely to be minimal in the near future, even if QE were to be pursued.

Moreover, concerns have been raised about the risk that an expansionary policy could create another financial bubble in the medium- to long-run. Specifically, by encouraging investors to rebalance their portfolio towards corporate assets, QE could boost the value of stocks to groundlessly high levels. While this claim remains scientifically unfounded, some preliminary investigations already show that NASDAQ, and other stock exchanges, are estimated at much higher values than their actual value is (Capital, 2015). Furthermore, risks related to the exit from QE are unpredictable and hardly measurable. Such risks could entail, for instance, the uncontrollable increase in interest rates, even if central banks intend to guide rates through careful incremental increases.

Finally, although QE may stimulate the economy while presenting trivial adverse effects in the short-run, it does not address the inherent causes of the financial crisis, nor does it directly act on the real economy. By artificially boosting the economy, QE may represent a temporary solution to get advanced

economies on their feet, but not necessarily the solution to solve the initial issues that engendered the 2003-2007 real estate and financial bubbles and the 2007-2008 financial crisis in the first place.

2) Does QE work?

The asset purchase program is expected to create the conditions that would stimulate the economy. Whether this is the case or not depends on the effectiveness of the transmission mechanism through which QE operates. Because the answer to this question is ambiguous, the deliberation on which monetary policy stance to take, and therefore, on whether or not stopping QE in the US was right remains wide open.

Before analysing the impact of QE and the channels through which it plays a role in the economy, it is relevant to understand how monetary policy and the monetary transmission mechanism typically operate. Section 3 therefore provides a detailed review of traditional monetary theory and the classical monetary transmission channels.

III. MONETARY POLICY

A. TRADITIONAL MONETARY THEORY

A chief objective of monetary theory is to identify the channels through which monetary transmission takes place in the economy. An overview of traditional monetary theories is thus a natural starting point for a discussion on the monetary transmission mechanism.

In the 1970s and 1980s, two monetary frameworks developed parallelly: the Real Business Cycle (RBC) framework and the New Keynesian framework. First, the RBC framework revolutionized macroeconomic analysis in terms of both methodology and theory. From a methodological viewpoint, RBC models introduced the use of dynamic stochastic general equilibrium (DSGE) models, in contrast to previously used static behavioural equations (Galí, 2008). From a theoretical perspective, RBC models postulate the importance of real shocks, rather than nominal shocks, as a source of business cycle fluctuations (Greenwood *et al.*, 1986). Real shocks, also known as productivity or supply shocks, refer to changes in technology and in real factors of production (i.e. capital, land, and labour), while nominal shocks refer to monetary adjustments, such as an increase in the money supply. RBC advocates see economic recessions and booms as efficient responses to real shocks. For instance, Say (1803) explains that recessions are the result of two possible causes: "either [people] have found difficulties in the employment of their productive means, or these means have themselves been deficient". In other words, Say (1803) suggests that losses in factors of production (i.e. "deficient means" or negative real shocks) are the major sources of recessions. One underlying assumption of the RBC framework is the full flexibility of prices and wages. When all prices adjust fully and instantaneously, monetary shocks have no impact on the real economy. Hence, in RBC settings, monetary policy is thought to be impotent or even counterproductive, and only real shocks are responsible for changes in output produced and available in the economy.

Conversely, the New Keynesian framework assumes the presence of nominal rigidities such as sticky prices and wages. Nominal rigidity implies that, for instance, an increase in the money supply does not transfer fully and instantaneously to prices in the economy. Because of the delay and the lack of completeness in the adjustment of prices, New Keynesian models contend for the non-neutrality of money; that is, monetary policy is thought to affect the real economy (Romer, 2012).

Both the RBC model and the New Keynesian model entail some lacks. On the one hand, the theoretical predictions of the RBC model are not in line with the evidence[13]. This discrepancy can be attributed, in part, to the absence of nominal rigidities in RBC settings in comparison to the real world in which prices and wages adjust gradually, and sometimes incompletely. Although the RBC framework became a reference for macroeconomic analysis among contemporary academics, it gained little interest among central bankers, partly because of this discrepancy between theory and empirics (Galí, 2008). On the other hand, the first generations of New Keynesian models used static behavioural equations, a methodology that rules out the study of the role of monetary factors over time and in a general equilibrium setting. The shortcomings of both frameworks called for a different approach. Eventually, "revisited" models preserving the conceptual basis of the New Keynesian literature, while relying on the DSGE modelling approach of the RBC framework have emerged (Galí, 2008). Those "revisited" New Keynesian models have become the foundation of monetary policy analysis and modelling, and accordingly, monetary policy has regained a central role in the economy.

Based on Keynesian literature, traditional textbook models on monetary policy have been essential to the understanding of the monetary transmission mechanism. For instance, the IS-LM model for autarkic economies and the Mundell-Fleming model for small, open economies provide insights into the functioning of the interest rate transmission channel. Nevertheless, such models disregard some underlying conditions of the transmission mechanism, and make assumptions that are too inconsistent with the real world to be used for policy analysis. For instance, the absence of uncertainty in IS-LM models casts doubts on the role of liquidity, since liquidity preference makes sense only in the presence of uncertain expectations (Romer, 2012). A description of the main monetary transmission channels that goes beyond the approach of basic Keynesian models is therefore necessary to understand how monetary policy actually acts on the economy.

[13] For evidence on the RBC model see, among other literature, Friedman and Schwartz (1963).

B. TRADITIONAL MONETARY TRANSMISSION CHANNELS

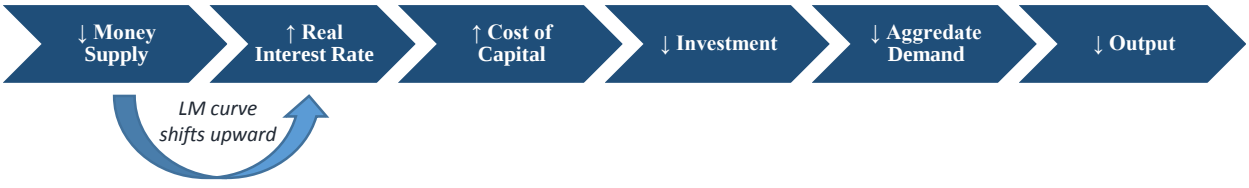
There exist three major transmission channels through which monetary shocks act on the economy: the interest rate channel and the credit channel, which can be divided in two conduits, namely, the bank lending channel and the broad credit channel.

1) The Interest Rate Channel

Since the 1940s, the interest rate channel has become the workhorse of the analysis of the monetary transmission mechanism. This channel can be seen as a conventional transmission mechanism, since it translates monetary policy into *direct* effects on the economy. Specifically, the interest rate channel imputes changes in real factors to central banks' adjustments of short-term, nominal interest rates via their impact on short- and long-term, real interest rates. The transmission from short-term, *nominal* rates to short-term, *real* rates is attributed to the rigidity of prices in the short-run. Moreover, movements in *short-term*, real rates are somewhat transmitted to *long-term*, real rates, since long-term interest rates are "an average of expected future short-term interest rates" (Mishkin, 1996). Investors consider real rates, rather than nominal rates, to avoid losses in purchasing power through inflation. Therefore, real rate movements influence the cost of capital, which, in turn, affects households' consumption and firms' investment decisions, and thereby impacts aggregate demand and output (Bean *et al.*, 2002). The following section examines the effects of interest rates movements driven by monetary policy on diverse relative prices in the economy.

a. Impact on Investment

First, following the traditional IS-LM model, a monetary tightening is followed by a rise in real interest rates, causing an increase in the cost of capital and in the required rate on business investment projects. This, in turn, depresses *investment*, and reduces aggregate demand and output. Although investment only referred to business projects in the original work of Keynes, research subsequently considered households' spending on durables and housing to also be part of investment (Mishkin, 1996).



b. Substitution Effects and Income Effects on Private Consumption

Interest rates also affect the economy through substitution and income effects on households' consumption decisions (Bean *et al.*, 2002). A rise in interest rates decreases the relative price of future to present consumption, leading households to shift their spending toward the future via the *substitution effect*. A rise in interest rates also raises the cost of capital, provoking a decline in net debtors' lifetime income, which, following the permanent income hypothesis, depresses their spending through the *income effect*. The opposite effect applies to net savers.

c. Wealth Effects on Private Consumption

Moreover, interest rates affect the value of financial assets – whether those are equity, fixed income or derivatives. As explained in Modigliani's life-cycle model (1971), households' wealth consists of human, real and financial capitals. By affecting the price of financial assets, movements in interest rates influence the value of financial securities held by households, and thus, influence households' lifetime income. For instance, a contractionary monetary policy raises firms' debt expenses by increasing interest rates, and thereby depresses the value of firms (i.e. firms' stock value) by decreasing their discounted expected future cash flows. Through the so-called *wealth effect*, this decline in the value of stocks that compose households' wealth decreases households' private consumption.

d. Tobin's *q* Theory and its Impact on Investment

From a different standpoint, monetarists suggest that after a rise in interest rates, households decrease their spending in equity. Increases in interest rates raise the cost of borrowing, thereby leaving households with less liquidity opportunities. To offset the scarcity in liquidity and in order to raise cash, households are inclined to disinvest in equity, since it is more easily and swiftly traded than other types of investments such as durables and housing (Mishkin, 1996). This, in turn, exacerbates the fall in equity prices, and affects business investment decisions through a decline in *Tobin's q*. Tobin's *q* is defined as the market to book (or replacement) value of firms' assets. When Tobin's *q* is low, the market value of a firm's assets is low relative to the cost of capital required to replace those assets. That is, new property, plant and equipment are expensive relative to the firm's market value; hence, equity is issued at a lower price relative to the actual cost of the property, plant and equipment being bought. In this context, firms refrain from issuing equity and diminish their investment spending. Following a similar reasoning, the Keynesian view suggests that a rise in interest rates renders fixed

income more attractive than equity (Mishkin, 1996). As a result, equity prices fall, implying a decline in Tobin's *q*, and thus, a drop in investment spending. As described by Mishkin (1996), Tobin's *q* theory also applies to land and property. That is, a rise in interest rates diminishes the market value of land and property, and thereby compresses spending in housing.

e. Impact on Net Exports

Finally, interest rates influence countries' *net exports* by affecting the real exchange rate. A rise in interest rates boost the attractiveness of deposits denominated in domestic currency in contrast to those in foreign currency. This provokes an appreciation of the domestic currency, thereby increasing the relative price of domestic to foreign goods, and ultimately shifting consumption towards foreign goods (Bean *et al.*, 2002). With the post-Breton Wood shift towards flexible exchange rates, this channel has become more crucial.

***

In conclusion, due to the presence of nominal rigidities particularly in the short-run, the interest rate channel imputes movements in short- and long-term, real interest rates to central banks' adjustments of short-term, nominal interest rates. Real interest rates movements then have a direct impact on firms' investment and households' consumption decisions, which, in turn, affect aggregate demand and output.

2) The Credit Channel

Unlike the interest rate channel, the credit channel does not directly and by itself act on the economy. Rather, the credit channel works parallelly to the interest rate channel, and amplifies the effects that the latter has on credit supply in the economy (Bernanke *et al.*, 1995). More specifically, the credit channel attributes the impact of monetary policy on credit supply to endogenous changes in the external finance premium (de Graeve, 2007). The external finance premium corresponds to the wedge between the cost of capital internally accessible to firms (via retained earnings), and that raised externally by firms (via bank loans as well as via bond and equity issues). This wedge arises as a result of market imperfections in credit markets, and exists as long as external financing is more expensive than internal financing; that is, as long as external financing is not fully collateralized. Full collateralization happens only when borrowers have at least as much internal funds as those borrowed for their project, so as to ensure full repayment to lenders even if their project fails. In this context, lenders take no risk

whatsoever in funding a project. As shown by Bernanke *et al.* (1999), the external finance premium is negatively related to the value of borrowers' collaterals; hence, the smaller the value of borrowers' collaterals, the larger the premium.

While the external finance premium arises as a result of the above-described market imperfections, the latter stem from asymmetric information in credit markets. De Graeve (2007) describes how lenders must resort to costly verification and contract enforcement procedures in order to overcome the issues of asymmetric information. For instance, lenders incur agency costs when assessing the creditworthiness of borrowers in order to avoid funding risky projects for which full repayment would be unlikely. Moreover, in the case repayment is dependent on whether the project is successful or not, borrowers have incentives to disguise the real state of their project (i.e. to present a successful project as unsuccessful) so as to avoid full repayment. This situation is described in Bernanke *et al.* (1999)'s model in which lenders must incur a "fixed auditing cost" to identify borrowers' actual "realized return".

Monetary policy affects credit supply through the credit channel by altering the degree of asymmetric information present in credit markets, which, in turn, affect the size of the external finance premium (de Graeve, 2007). For example, a monetary tightening induced by higher interest rates implies that lenders take the risk of losing the repayment of a larger portion of interest rates when lending to a pool of unknown borrowers. By exacerbating the issue of asymmetric information, this causes lenders to engage into further verification and contract enforcement procedures, which, in turn, translates into a larger external finance premium incurred by borrowers, thereby compressing the credit market. The credit channel can take place via two different conduits: the bank lending channel and the broad credit channel.

2.1) The Bank Lending Channel

The bank lending channel is based on the view that certain borrowers can obtain credits only through banks, because alternative credit sources are too difficult of access. On the one hand, the high fixed cost associated with financial market participation prevents certain borrowers, particularly small firms, from issuing bonds and equity (Bean *et al.*, 2002). On the other hand, banks are unique in terms of their ability to deal with asymmetric information in credit markets. As a result, borrowers for which thorough screening is needed can access credit merely through banks (Mishkin, 1996).

Monetary policy can influence the supply of funds available to banks for credit supply (i.e. banks' liabilities, and particularly, deposits in banks), and thereby can influence the amount of credit banks are willing to offer (i.e. banks' assets) (Bernanke *et al.*, 1988). For instance, a contractionary monetary policy is thought to reduce the amount of money that the public deposits in banks. Because no substitutable fund source can cover the decline in deposits, banks must decrease their supply of credit to comply with reserve requirements, and parallelly, must rely on higher interest-bearing funds such as uninsured debt. By lending money that comes from more costly sources, banks become more vigilant about whom they supply credit to. Accordingly, the external finance premium widens, eventually leading to credit rationing and underinvestment through the bank lending channel (Bean *et al.*, 2002).

A consequence of the bank lending channel that appears to have been relevant in the recent financial crisis is that monetary policy has a higher impact on small firms, which, unlike large firms, are unable to switch to alternative sources of credit (Nilsen, 2002). The importance of the bank lending channel thus depends, in part, on the relative number of bank-dependent borrowers in the economy (Mishkin, 1996). The larger this number relative to the overall number of borrowers, the larger the impact of monetary policy on bank credit supply. Moreover, the larger the elasticity of money demand with regard to the interest rate, the higher the sensitivity of bank credit supply in response to a change in monetary policy (Bean *et al.*, 2002).

The bank lending channel focuses on the impact of monetary policy on firms' investment decision. A similar mechanism applies to households' spending on durables and housing since households typically have no access to alternative sources of credit, just like small firm (Mishkin, 1996). For example, a monetary tightening induces a decline in bank loans supplied to households, which decreases their consumption on durables and housing. Concurrently, a rise in interest rates reinforces the contraction of households' consumption due to the fall in their disposal of cash.

2.2) The Broad Credit Channel

The broad credit channel, also called the balance-sheet channel, attributes the impact of monetary policy to changes in the supply of broad credit, besides those by banks. Mishkin (1996) suggests that this channel acts through the impact of firms' net worth on the external finance premium. Lower net worth implies that borrowers have less collateral to offer to lenders against the capital they demand. As a result, lower-net-worth borrowers entail a higher adverse selection problem. Lower net worth also means that borrowers most likely own a smaller equity share in their firm, giving them more incentives

to take on riskier projects. Accordingly, less-financially-healthy borrowers also involve higher moral hazard by exposing lenders to higher risk levels. By exacerbating the issues of adverse selection and moral hazard in the broad credit market, lower-net-worth borrowers enlarge the external finance premium, thereby causing a reduction in lending and investment spending.

Monetary policy can influence the broad credit supply by affecting borrowers' level of collateralization through (Mishkin, 1996). A contractionary monetary policy have an impact on both firms' cash flows and firms' net worth: it reduces cash flows by inducing higher interest rates, and it decreases firms' net worth by depressing equity prices as explained earlier. Both phenomenon intensify the asymmetric information problem, which, in turn, depresses credit supply, thereby contracting investment spending and output. The transmission mechanism that affects cash flows differs from the traditional one operating in the preceding channels, such as in the interest rate channel: here, it is the *short-term, nominal* interest rate, rather than the long-term, real interest rate, that affects cash flows and investment.

Bean *et al.* (2002) argue that because the broad credit channel affects firms' cost of capital through firms' net worth, this transmission will be more significant when "the terms of the debt contracts are re-negotiable" so as to match changes in firms' credit quality. This is the case with bonds containing embedded options as well as with other variable-rate credits for which lenders can make adjustments depending on borrowers' credit quality. However, most loans are at fixed, long-term rates, casting doubts on the importance of the broad credit channel. Bean *et al.* (2002) affirm nevertheless that even in the case of fixed, long-term rates, the credit channel operates in "the proportion of the debt stock that is new every period".

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To conclude, the bank lending channel and the broad credit channel attribute the effects of monetary policy on credit supply in the economy to the existence of market imperfections. The presence of market imperfections cause lenders to incur costly verification and contract procedures in order to protect themselves against less-creditworthy borrowers, thereby widening the external finance premium. Monetary policy can influence the size of the external finance premium by affecting the level of asymmetric information in credit markets. The size of the external finance premium, in turn, affect borrowers' cost of capital, and thereby, impacts investment and output via a contraction in credit supply.

C. MONETARY POLICY IN A LIQUIDITY TRAP

Monetary policy has often been seen as doomed when the short-term, nominal interest rate is at the zero lower bound. In reality, monetary policy might be the most suitable tool in such a context. In fact, when trapped at the zero lower bound and when experiencing deflation, an economy requires a swift, large, and sustainable stimulus, that can allow a quick recovery and prevent a prolonged recession. In such a situation, fiscal policy is inadequate, at least as a short-run tool, since its implementation is complex and lengthy, with extensive legislation debates required among politicians. On the contrary, monetary policy can be quickly determined and implemented by monetary authorities (Mishkin, 1996). As a result, an expansionary policy is likely to be one of the most effective tools to boost an economy in deflation through the credit channels described above.

IV. THE FED'S RESPONSE TO THE CRISIS

To restore financial and macroeconomic stability after the collapse of Lehman Brothers in September 2008, the Fed reduced its target short-term rate, the fed funds rate, from 5¼ percent in September 2007 to almost zero in December 2008 (Fed website, 2015). As discussed in Section III on transmission channels, the manipulation of the target short-term rate is considered a conventional policy, and aims at putting downward pressure on longer-term rates. A fall in longer-term rates is then expected to foster spending on durable goods, real estate and capital goods, thereby boosting the economy. With the fed funds rate close to zero in the end of 2008 but the need for still further monetary easing, the Fed had exhausted its options of conventional monetary policy tools. To prevent deflation and boost the economy, the Fed intensified the use of its conventional policy tools while parallelly embarking on unconventional monetary policy measures that aimed at rendering conventional policy more effective, at providing liquidity to financial markets, and at directly affecting longer-term rates. The range of instruments used by Fed during the crisis can be classified in three categories described below.

1) The Fed as the Lender of Last Resort

First, the Fed aimed at acting as the "lender of last resort" by providing short-term liquidity to financial institutions – including banks and other depository institutions (Fed website, 2014). Such provision took place via diverse facilities including the Fed's traditional discount window, already existent prior to the crisis, and the Term Auction Facility (TAF), Primary Dealer Credit Facility (PDCF), and Term Securities Lending Facility (TSLF)" created in 2007-2008 (Fed website, 2014). To ease the financial stress in funding markets, and particularly in term funding markets[14], the Fed started by increasing the liquidity available to eligible financial institutions via the discount window. However, since banks were primarily concerned about appearing as sound financial institutions to the market, many passed on the opportunity to borrow at the discount window, fearing that their borrowing would be viewed as a sign of financial distress by investors (Fed website, 2014). The TAF was thereof created in December 2007 to provide liquidity more directly and without the bias associated with borrowing at the discount window. The facility allowed for the provision of 28-day loans starting December 2007, and 84-day loans starting August 2008, before providing its last loans in March 2010. All loans were fully collateralized and accessible via an auction in which bidders stated a desired amount of funds (up to a

[14] Markets for loans with terms longer than overnight.

given bound) they would like to borrow, and a corresponding interest rate. Ultimately, the same interest applied to all borrowers, and corresponded either to the rate at which the auction would close, or, if funds were still available after all bids were taken, the lowest bided rate. Beyond fueling banks with liquidity without them having to bear any stigma, the TAF allowed the Fed to serve more diverse parties and to use more diverse collateral than it usually did through open market operations.

The PDCF was opened from March 2008 to February 2010 to respond to the stress in "the triparty repurchase agreement market and the resulting liquidity pressures faced by primary dealers" (Fed website, 2014). Primary dealers trade, principally Treasury securities, with the Fed through open market operations. The PDCF served as an overnight loan facility for primary dealers so as to ease securities markets by assisting them to provide liquidity to market participants. All credits provided via this facility were fully collateralized. The PDCF ultimately eased financial conditions on a broader level than merely for repos.

Moreover, the TSLF was established in March 2008 as a "weekly loan facility" for primary dealers to trade Treasury securities held by the System Open Market Account (SOMA) (Fed website, 2014). The loans were auctioned from March 2008 to February 2010 and aimed at easing Treasury markets, and financial markets more broadly by providing further funding.

Finally, to ease financial conditions worldwide, the Fed facilitates the "provision of dollar liquidity" to foreign banks, by engaging in "lateral currency swap agreements" with foreign monetary institutions (Fed website, 2014). That is, the Fed supplied dollars to foreign central banks in exchange for their local currencies, allowing other economies to meet their "dollar funding needs" (Bernanke, 2012).

2) Reconfiguration of the Asset Side of the Fed's Balance Sheet

The Fed also employed another set of tools that aimed at easing financial conditions in specific sectors of the financial market. This method, consisting of providing liquidity directly to borrowers and investors in strategic credit markets, is referred to as "credit easing". The use of credit easing by the Fed was already customary prior to Lehman's collapse, but was intensified thereafter, enlarging the composition and size of the Fed's balance sheet. The principal targeted sector was debt issued by Freddie Mac and Fannie Mae, both government-sponsored agencies acting to enhance the secondary mortgage market by securitizing mortgages in the form of mortgage-backed securities (MBS).

The tools introduced by the Fed to support strategic credit markets include the Commercial Paper Funding Facility (CPFF), Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF), Money Market Investor Funding Facility (MMIFF), and the Term Asset-Backed Securities Loan Facility (TALF). The CPFF was established to provide liquidity to commercial papers'[15] issuers in the case they could have access to it through the market. Commercial papers were hardly funded after Lehman's collapse since investors were themselves experiencing liquidity strains. Consequently, interest rates on longer-term commercial papers rose substantially, and refinancing them became urgent to prevent further financial distress. Hence, the CPFF aimed at facilitating the continuation of lending from investors. Moreover, since investors started to withdraw their funds from money market mutual funds (MMMFs) during the crisis, the latter funds experienced increasing difficulty in satisfying investors' demands for reclamations, particularly on asset-backed commercial papers (ABCPs). The AMLF was therefore created to help MMMFs meet investors' demand for reclamations on ABCPs as well as to fuel money markets, and the ABCP market in particular, with liquidity. Parallelly, the MMIFF was launched to provide MMMFs with liquidity so as to help them meet redemption demands from investors, and boost investments in money markets more generally. Finally, to overcome the disruption in asset-backed security markets, the Fed introduced the TALF, which aimed at spurring the issuance of securities backed by consumers' and businesses' loans, and at smoothing financial conditions in relevant markets.

3) Large-Scale Expansion of the Fed's Balance Sheet

Besides focusing on supporting specific sectors of the financial market by engaging in credit easing, the Fed also embarked on a series of QE rounds. In contrast to credit easing, QE involves the expansion of the overall liability side of a central bank's balance sheet, without a particular focus on specific financial sectors. The significant scale of asset purchases involved in QE is what makes it an unconventional policy tool compared to standard open market operations undertaken in normal times. At the onset of the crisis, the Fed intended to restore financial stability by merely using credit easing and the other tools described above. Many, inside and outside the Fed, were reluctant to use QE due to the fear of runaway inflation and dollar debasement as well as to the Japanese experience, which casted doubt on the effectiveness of QE to restore financial stability. However, by March 2009, as financial conditions were not meliorating, the Fed decided to introduce its first QE round as an ultimate recourse.

[15] Commercial papers are short-term, negotiable promissory notes issued by enterprises or financial companies.

By altering its use of open market operations through large-scale purchases of longer-term Treasury-guaranteed and government-sponsored enterprise (GSE)-guaranteed mortgage-backed securities (MBS), the Fed expected to see a reduction in longer-term yields, which in turn was predicted to enhance the functioning of credit markets by creating accommodative financial conditions while the economy was at the ZLB.

The Fed's LSAPs were funded by electronically creating new money, which was reflected by a rise in reserves of depository institutions on the liability side of the Fed's balance sheet. Owing to the TARP legislature voted by Congress in an urgent response to the crisis, the Fed was allowed to pay interest rates on depository institution reserves, a policy so far only pursued by the ECB and the BOE (Lenza *et al.*, 2010). The remuneration of reserves aimed at supporting the independence between liquidity and monetary policy objectives. Specifically, by remunerating reserves, the Fed could encourage the accumulation of deposits at the central bank without a substantial impact on market interest rates. Nevertheless, since numerous investors did not have access to the remunerated deposit capacity, the overnight rate was hardly stabilized. While the reserves were remunerated at 0.25 percent, the Fed still decided to set its target fed fund rate range between 0-0.25 percent, making the remuneration less relevant than desired.

The Fed's LSAPs were launched in three rounds, namely QE1, QE2, and QE3. QE1 was launched on December 2008 and its last purchased was done on March 2010. This first round initially consisted of purchasing $600 billion in agency MBS and agency debt, and was further expanded on March 2009 by an extra $750 billion in purchases of agency MBS and agency debt, and $300 billion in purchases of Treasury securities. Thereafter, QE2 was undertaken from November 2010 to June 2011, and resulted in the purchase of $600 billion of long-term treasuries at a pace of $75 billion per month. From September 2012, the FOMC announced the start of QE3 consisting of the purchase of $40 billion agency MBS per month for an unlimited period of time – until the labor market would better to a desired threshold level. QE3 was expanded in January 2013, and added to the initial monthly purchases, those of $45 billion worth of longer-term treasuries. In December 2013, the Fed started to slowly diminish the monthly rate of asset purchases since labor market conditions were continuously improving and inflation was going up towards the FOMC's 2% target. The last round of QE was then closed on October 2014.

The following section presents the monetary transmission channels through which large-scale purchases of assets can theoretically act on the economy.

V. HOW DOES QE WORK?

There are a variety of channels through which QE acts on the economy.

1) The Portfolio Balance Channel

Bernanke (2010) argues that the portfolio balance channel is the principal conduit through which LSAPs affect long-term yields. This channel was first described in the 1950s and 1960s by a range of prominent economists including Tobin (1958), and remerged recently in the literature (sometimes referred to as the duration channel[16]), since QE was launched by the Fed and the BOE. The portfolio balance channel contends that once short-term interest rates have reached the zero lower bound, central banks' purchases of securities from the public can affect long-term yields by changing the amount and composition of assets held by the public (Bernanke, 2010).

Long-term yields consist of two elements: 1) the average level of short-term, risk-free interest rates expected over the maturity of the asset, and 2) the risk premium corresponding to the additional return investors require for bearing the risk of holding the asset. Gagnon *et al.* (2011) assert that QE can impact long-term yields by influencing either of the two elements. Nevertheless, the Fed's LSAPs were intended to reduce only that part of the long-term yield corresponding to the risk premium. Indeed, while purchasing long-term assets, the Fed simultaneously put "upward pressure on short-term interest rates" via the increase of rates it pays on banks' reserves, so as to boost market participation (Bernanke, 2012). Moreover, the Fed started communicating its exit strategy from the policies undertaken already at the onset of its first QE round, including the use of "reserve-draining tools" and the selling of Fed-portfolio assets, so as to reverse "the effects achieved by LSAPs" at the appropriate time (Bernanke, 2012). The latter communication aimed at stabilizing inflation expectations and at having a better grasp over short-term rates. Hence, any fall in long-term yields most probably originated from a decline in risk premiums rather than in expected short-term, risk-free rates (Gagnon *et al.*, 2011).

The premium required by investors can be attributed to the asset's default risk, liquidity risk or duration risk. With regard to Treasury securities, default risk is theoretically zero and liquidity risk is typically lesser than on other securities with comparable duration. Therefore, the premium relating to Treasuries can mostly be associated to the additional return required by investors for bearing the risk to hold those

[16] See, for instance, Krishnamurthy *et al.* (2011) and D'Amico *et al.* (2012).

assets for long durations (Gagnon *et al.*, 2011). The additional return required for duration risk is referred to as the "term premium".

By purchasing long-term securities such as Treasuries, the Fed eliminates from the market a significant amount of assets with high maturity, and at the same time raises the amount of short-term, risk-free bank reserves held by the public. The portfolio balance channel holds that with less duration risk in investors' portfolio, the premium investors require for that risk ought to decline (Gagnon *et al.*, 2011). Hence, by decreasing the amount of long-term securities held by the public, LSAPs reduce the term premiums on securities *across maturities*. The "duration channel", defined as the process through which term premiums decrease across maturities as a result of the removal of aggregate duration from investors' portfolio, and referred as such by Krishnamurthy *et al.* (2011) and D'Amico *et al.* (2012), is very similar to the portfolio balance channel.

For the above processes to materialize, investors must be willing to make the necessary adjustments on their portfolio. Gagnon *et al.* (2011) affirm that investors would engage in selling high maturity assets to the Fed only if the return on those assets is expected to fall; that is, only if the large-scale purchases "bid up the price[s]", and thus lower the yields of the assets in question. This is possible since, according to a key premise of the portfolio balance channel, different classes of assets are imperfect substitutes in investors' portfolio. For instance, some investors may not meet the legal conditions to hold certain types of assets, or may be loath to hold assets that involve high transaction costs, or for which hedging is too costly (Bernanke, 2010). As a result, changes in the supply of certain asset classes, for example, through purchases of Treasury, agency debt, and agency MBS by the Fed, can boost the prices and depress the yields of those assets, and drive investors to reallocate their holdings towards other asset classes, such as long-term, high-grade corporate bonds, thereby boosting the prices and depressing the yields on the latter assets too (Bernanke, 2010).

Vayanos *et al.* (2009) model the duration risk channel. The authors do not rely on the traditional approach used to determine the term structure of interest rates – that is, by linking interest rates for a given maturity to a representative agent's inclination to substitute present to future consumption. Instead, they base their model on the preferred habitat theory. The preferred habitat theory suggests that there exist "investor clienteles with preferences for specific maturities, and that interest rates for a given maturity is influenced by demand and supply shocks local to that maturity" (Vayanos *et al.*, 2009). The authors generate the duration risk premium based on the interaction between that portion

of investors with preferences for specific maturities (resulting from the preferred habitat theory) and another portion of risk-averse arbitrageurs. Because arbitrageurs are risk averse, changes in "clienteles' demand for bonds affect the term structure and constitute an additional determinant of bond price to current and expected future short rates" (Vayanos *et al.*, 2009). Arbitrageurs thus represent the marginal investors for pricing duration risk. The authors then derive the risk premium for bonds with a given maturity by multiplying the duration of that bond by the price of the corresponding duration risk, which is a function of the level of duration risk taken by the marginal investor and this investor's risk aversion.

Krishnamurthy *et al.* (2011) argue that an important question when using the above model is whether the preferred habitat theory applies merely to a specific asset type (e.g. merely to Treasury bonds), or whether it applies more generally to all fixed income instruments. Vayanos et *al.* (2009) do not answer this question, nor has any other author done so far. Gagnon *et al.* (2011) and Krishnamurthy *et al.* (2011) use the same model as if it applies to all fixed income assets. I follow the same assumption in the empirical analysis that will follow. Based on this assumption, QE is expected to "decrease the yield on all long-term nominal assets, including Treasuries, Agency bonds, corporate bonds, and MBS" through the portfolio balance channel, and to have a stronger impact on longer-maturity bonds (Krishnamurthy *et al.*, 2011).

2) The Scarcity Channel

D'Amico *et al.* (2012) postulate that large-scale purchases of assets within a given maturity sector raise the prices and reduce the yields of other assets *with similar maturities* through the so-called "scarcity channel". The scarcity channel somewhat correspond to a subpart of the portfolio balance channel, but is categorized separately since it acts only along assets within similar maturity sectors, rather than across maturities.

Moreover, D'Amico *et al.* (2010) find evidence that QE flattens the yield curve via both a "stock effect" and a "flow effect". The "stock effect" attributes persistent variations in prices of assets in a given maturity sector to expected changes in the supply of assets belonging to that sector, rather than to analogous expected changes in other sectors. This conduit directly relates to the logic behind the scarcity channel and substantial the existence of the latter channel. In contrast, the "flow effect" attributes "response of prices" for a given maturity sector to the "ongoing purchase operations" in that sector. The primary difference between the "stock effect" and the "flow effect" lies in that response of prices are the result of *expectations* about future changes in asset supply with regard to the former, and

of ongoing purchases with regard to the latter. D'Amico *et al.* (2010)'s findings suggest that the stock effect is stronger than the flow effect. Bernanke (2010) argues that the trivial immediate effects that the interruption of the Fed's purchases of agency debt had on long-term yields in March 2010 corroborate the stronger impact of a stock effect as compared to a flow effect as suggested by D'Amico *et al.* (2010).

3) The Signalling Channel

Krugman (1998) suggests that if the central bank credibly "commit[s] to being irresponsible" by keeping interest rates low (i.e. lower than the rate required by a Taylor rule) even after the economy recovers, QE could provoke a decline in real rates. By signalling that assets' expected future returns will be affected, purchases of long-term assets by the Fed are likely to have an impact on today's asset prices and yields, and more relevantly on real, long-term yields. Gagnon *et al.* (2011) explains that today's asset prices must reflect expected future asset returns, or else the market could make excess profits from selling later to the Fed the assets bought today. As a result, a credible commitment by the Fed to engage in QE at a future date should decrease today's interest rates. While this is expected to affect all interest rates through the expectation channel, the impact is likely to be larger on short- and medium-term yields, since the promise to follow accommodative policies holding rates low is expected to apply until the economy escape the recession (Krishnamurthy *et al.*, 2011). Bernanke (2010) affirms that the signal sent by LSAPs can also boost confidence in the market and in the real economy by reducing worries about "tail risks such as deflation".

But how could such a "promise [by the central bank] to be irresponsible" be credible (Krugman, 1998)? If monetary authorities raise rates (rather than committing to the initially-promised low rates), the value of long-term assets purchased would drop. To the extent that the central bank accounts for such losses in its objective function, the announcement of engaging in QE could be perceived as a *credible* commitment to keep interest rates low (Clouse *et. al.*, 2000). Moreover, Krishnamurthy *et al.* (2011) argue that, because some QE announcements include information on future fed funds rate policies, the market is likely to associate QE announcements to a signal that interest rates will be kept low for a long period of time.

4) The Liquidity Channel

QE is thought to enhance liquidity and market functioning, and accordingly to decrease the liquidity premium embedded in the price of the purchased assets and assets with similar maturity (Joyce *et al.*, 2011). Acting as a reliable and major buyer of a significant amounts of long-term assets, the central bank provides an assurance for investors and encouraging them to take larger positions on those assets and to trade them more actively, as they could sell them to the central bank if necessary (Gagnon *et al.*, 2011).

In early stages of the crisis, the market was under severe liquidity pressure since investors could not quickly and easily sell certain classes of assets. Particularly, the spreads between yields on agency debt and MBS and yields on Treasury had reached a historic high – "even after adjusting for the convexity risk in MBS associated with the high interest rate volatility at that time" – and so did the spreads between the yields on formerly issued Treasury and the yields on recently issued Treasury (Gagnon *et al.*, 2011). Gagnon *et al.* (2011) argue that these spreads were to some extent the result of poor market functioning and of firms' capital constraints. In fact, the considerable capital losses experienced by firms and the limitations to raise new funds seriously weighted on the high yield spreads. The authors pursue that "capital constraints put agency-related debt at a disadvantage relative to Treasury securities", since the former have a 20% risk weighting in contrast to 0% for the latter.

In this context, the first LSAP programs may have alleviated the market from liquidity pressures and smoothened trading of agency-related securities and old Treasury. This, in turn, is likely to have reduced the liquidity risk of those assets, and therefore their liquidity premiums and yields.

5) The Inflation Channel

Expansionary monetary policies, such as QE, are thought to raise inflation expectations since part of the increase in money supply may be permanent (Cihak *et al.*, 2009). The debate on the effects of inflation expectations provoked by QE has been controversial since the launch of the LSAP program. On the one hand, when nominal interest rates have hit the zero lower bound but the economy remains sluggish, expected inflation is thought by some economists, such as Paul Krugman, Scott Sumner, and David Beckworth, to boost the economy. Because nominal rates cannot go below zero, expected inflation can cause real rates to turn negative instead, thereby incentivizing the public to borrow and spend, which in turn will boost the real economy (Krugman, 1998). In this case, inflation expectations

can also have the advantage of forestalling the risk of a deflation spiral. On the other hand, other economists, including William Kristol, Michael Boskin, John Cogan, Niall Ferguson, and John Taylor, among others, contend that inflation expectations arising from QE may increase the risks of "currency debasement and inflation" (refer to letter to Bernanke: Asness *et al.*; 2010). Although dollar depreciation did occur, other economists such as Paul Krugman did not perceive the magnitude of the depreciation as presenting significant risks for the US economy (Krugman, 2015).

6) The Safety Premium Channel

Krishnamurthy *et al.* (2010) argue that there exist a large demand for long-term safe (i.e. low default risk) assets in the market that lowers the yields on those assets. When the supply of long-term safe assets declines, the demand for those assets is more difficulty met, lowering their yields further and expanding the wedge between the yields on long-term safe assets and long-term less safe assets (e.g. between Baa bonds and Aaa bonds). This wedge is the result of the safety premium that investors require for holding a smaller amount of safe assets in their portfolio.

Krishnamurthy *et al.* (2010) distinguish the risk premium of a traditional CAPM model from the safety premium, which they associate to a "preferred habitat" of investors that applies only to safe assets. While traditional CAPM models suggest that investors require higher premiums for riskier assets, and thus that there is a wedge between the yields of lower- and higher-risk assets, the safety channel suggests that this wedge is larger the smaller the supply of lower-risk assets. In "preferred habitat" vocabulary, the clientele's marginal willingness to pay for safety rises as the supply of safe assets declines, thereby increasing the safety premium (Krishnamurthy *et al.*, 2010).

By purchasing Treasury and agency bonds, the Fed reduces the amount of safe assets available to investors, which widens the safety risk premium, and in turn is expected to lower the yields on safer assets relative to that on riskier assets. Krishnamurthy *et al.* (2010) warn that, among all assets purchased by the Fed, a distinction must be made between Treasury and Agency bonds on the one hand, and Agency MBS on the other. While the former are perceived as highly safe assets by the market[17], the latter are considered riskier due to the prepayment risk they involve, and are therefore not part of the clientele's "preferred habitat" (Krishnamurthy *et al.*, 2010). Hence, through the safety

[17] Since Treasury, theoretically, have a zero default risk, and since agency bonds became government-owned when Fannie Mae and Freddie Mac were announced to be taken over by the government on 9/7/2008, prior to QE1 and QE2, both asset types are considered highly safe by the market.

premium channel, QE is expected to reduce the yields on safe assets such as Treasury, agencies bonds and high-grade corporate bonds relative to the yields on less-safe assets including lower-grade corporate bonds and MBS-like bonds entailing prepayment risk.

7) The Prepayment Risk Premium Channel

Investors require a premium for the risk of prepayment involved in agency MBS. By purchasing large amounts of MBS, the Fed may decrease the prepayment risk premium embedded in MBS yields. Prepayment risk implies that the duration of MBS decreases when interest rates fall and increases when interest rates rise. Gagnon *et al.* (2011) explain that due to the variations in duration, MBS have negative convexity; that is, in contrast to prices of non-callable bonds with comparable coupons and maturities, prices of MBS increase less when rates fall and decrease more when rates rise. Issuers of MBS may exercise the call option embedded in those securities, and thereby, they may pay back the principal at an earlier date than that for which it was initially due. This causes investors to miss out on future interest payments associated with that part of the principal that was paid in advance. As a result of MBS' prepayment risk and of the high cost to hedge against it, investors require a premium, causing MBS yields to be higher than those of non-callable securities with comparable coupons and maturities (Gagnon *et al.*, 2011). This premium depends on the level of prepayment risk borne by investors. Over QE1 (Fed website, 2008), the Fed purchased a substantial amount of MBS, which is expected to have lowered the prepayment risk premium embedded in MBS yields via the prepayment risk premium channel.

8) The Default Risk Channel

Holders of lower-grade bonds require a premium that corresponds to the price of the default risk associated to the bonds. By stimulating the economy and by boosting confidence in the market, QE is likely to reduce businesses' default risk and investors' risk aversion, respectively. In turn, this is expected to diminish the default risk premium required by investors, thereby depressing the yields on the corresponding bonds.

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A series of high-frequency and low-frequency studies using US data have investigated the statistical significance of the channels through which QE is expected to lower longer-term yields. Next is a review of the most prominent US empirical literature on QE.

VI. EVIDENCE FROM THE LITERATURE ON QE

Several studies investigate the impact of the maturity structure of debt on yield spreads during Operation Twist launched in 1961 in the US. Over the period 1962-1964, the US Treasury and the Fed attempted to flatten the debt term structure. They did so by having the Fed purchase long-term Treasury debt partly from the proceeds of the sale of short-term Treasury debt (with three years or less maturity). While the expected decline of long-term rates aimed at boosting growth through investment, the expected rise of short-term rates was meant to improve the balance of payments. Contemporary studies (including Modigliani *et al.*, 1966; Ross, 1966; Wallace, 1967; Holland, 1969) evaluating this program find little evidence of its impact. Solow *et al.* (1987) argue that the small volume of asset purchases and the issuance of long-term debt soon after the program may explain its small impact. Nevertheless, a more recent event study by Swanson (2010) suggests that the program was more effective than what was found in earlier studies.

Subsequent research[18] studying more recent asset purchases by the Fed than those realized during Operations Twist typically find a larger impact of the maturity structure of debt on yield spreads. A possible explanation is that, in contrast to the studies on Operation Twist, more recent investigations tend to use data over longer time spans as well as data collected over periods of much higher variation in the average maturity of Treasury debt. Moreover, in the case of the Fed's recent asset purchases, a major difference can be noted when comparing the latter purchases to those of Operation Twist. While the recent purchases were made through the expansion of reserves, Operation Twist's purchases were realized with the proceeds of the sales of short-term debt. Whether this difference translates into a variation in the impact of QE is unclear. In fact, since both banks reserves and short-term debts currently have roughly the same interest rate, they can be seen as substitutes, and therefore the impact on the term spread could be expected to be similar (Gagnon *et al.*, 2011).

Rather than focusing strictly on the effect of the maturity structure of debt on yield spreads, other researches investigate the impact of changes in public debt supply on yield spreads. Krishnamurthy *et al.* (2007) find a negative correlation between debt-to-GDP ratio and the spread between corporate bonds and Treasury bonds. The authors argue that this negative correlation reflects "variation in the

[18] See, for example, Friedman, 1981; Roley, 1982; Frankel, 1985; Agell *et al.*, 1992; Bernanke *et al.*, 2004; Kuttner, 2006; Greenwood *et al.*, 2008; Vayanos *et al.*, 2009; Hamilton *et al.*, 2010; Gagnon *et al.*, 2010; Doh, 2010; Greenwood *et al.*, 2010; D'Amico *et al.*, 2010; Krishnamurthy *et al.*, 2010; Baumeister *et al.*, 2010; Kitchen *et al.*, 2010; Hancock *et al.*, 2011.

"convenience yield" on Treasury securities, rather than variation in the default risk of corporate borrowers". The authors follow that investors view Treasury securities as particularly valuable, somewhat independent of their cash flows. This so-called "convenience value" of Treasury securities becomes marginally larger when the volume of debt is low (Krishnamurthy *et al.*, 2007). In this case, the market "bid up the price of Treasuries relative to other securities such as corporate bonds", provoking a fall in the yield of Treasuries further below that of corporate debt, thereby enlarging the spread; the opposite happens when the volume of debt is high (Krishnamurthy *et al.*, 2007). Krishnamurthy *et al.* (2007) also find that the effects of supply are larger for debt with longer maturities, which in their view reflects the lack of good substitutes for long-term government bonds compared to short-term ones in the private sector.

The recent crisis has revived interest in preferred habitat models (see e.g. Vayanos *et al.*, 2009). Greenwood *et al.* (2014) base their study on Vayanos *et al.* (2009)'s model of preferred habitat in which clienteles trade with arbitrageurs dependent on their preferences for specific maturities. The authors corroborate the larger effects of public debt supply on yield spreads for debt with longer maturities, and also find a positive relation between maturity and term spread. Other analyses investigating the impact of changes in public debt supply independent of their maturity structure confirm that increases in public debt supply generally raise longer-term yields (See Galeand Orszag, 2004; Engen *et al.*, 2005; Laubach, 2009). Warnock *et al.* (2009) also find that foreign official purchases of US government bonds tend to depress long-term yields. They quantify at 90 basis point higher the 10-year Treasury yield if there would have been no foreign official flows into US debt over the first years of the recent crisis.

Estimating the impact of MBS supply on mortgage yield spreads, Stroebel *et al.* (2009) find little evidence in favour of the effectiveness of the recent MBS purchase program. The authors attribute most of the decline in spreads between MBS yields and swap yields, and between MBS yields and Treasury yields to prepayment risk and default risk rather than to the program itself. Analysing the same program, Hancock *et al.* (2011) identify three channel via which the Fed's purchase of $500 billion in MBS acted on the economy: 1) "improved market functioning in both primary and secondary mortgage markets", 2) "clearer government backing for Fannie Mae and Freddie Mac", and 3) "anticipated portfolio rebalancing effects", also referred to as "stock effect". The first channel was expected to comfort the market by having a significant and reliable buyer purchase MBS "under all

market conditions"; the second channel served at mitigating investors' concerns "about the value of the implicit government guarantee against credit risk that was offered by Fannie Mae and Freddie Mac after they were placed into conservatorship in September 2008"; the third channel was meant to "induce (…) investors to adjust their portfolios" by changing the size and type of securities held by the private sector (Hancock *et al.*, 2011). Specifically, the portfolio rebalancing channel aimed at reducing the amount of longer-term securities while "increasing the amount of short-term, risk-free, bank reserves held by the private sector", thereby bidding up the prices and lowering the yields of the purchased longer-term securities (Hancock *et al.*, 2011). Unlike Stroebel *et al.* (2009), Hancock *et al.* (2011) find that the MBS purchase program played a role in depressing mortgage rates. Particularly, the authors contend that the announcement of the program had strong effects: roughly half of the fall in mortgage rates can be associated with improved market functioning and clearer government backing, and the other half with portfolio rebalancing (Hancock *et al.*, 2011).

Looking into the impact of public debt supply in general on yield spreads during the recent crisis, Kozicki *et al.* (2010) find that increases in the size of central bank's balance sheet are associated with declines in long-term forward rates using time-series data. D'Amico *et al.* (2010) suggest that there was an "imperfect substitution" or "segmentation" within the Treasury debt market during the crisis. The authors find evidence that yields corresponding to a given maturity sector were more sensitive to changes in debt volumes in that sector than to similar changes in other sectors (the "stock effect") and that asset purchases provoked an average fall in yields in the sector purchased on the days when those purchases took place (the "flow effect"). Based on D'Amico *et al.* (2010)'s model, the stock effect suggests that the roughly $300 billion purchase of Treasury is expected to flatten the yield curve by 45 basis point within 10 to 15 years. This effect seems to be very dependent on the announcement of purchases (D'Amico *et al.*, 2010). Neely (2010) confirms that Fed announcements about LSAPs had an important impact on US and foreign bond yields and exchange rates. On a study realized prior to the recent crisis, Bernanke *et al.* (2004) find that long-term yields fall substantially on the dates of purchase announcements when investigating events of future issuance or purchases of long-term Treasury securities.

D'Amico *et al.* (2012) identify three channels through which QE can affect long-term yields and term premiums. First, the "scarcity channel" suggests that a decline in the stock of asset with a given maturity available to the public decreases prices of securities with similar maturities. Second, the

"duration channel", which resembles the portfolio balance channel, sustains that by removing aggregate duration risk from the market, asset purchases diminish term premiums on securities across maturities. Third, the "signalling channel" is based on the expectations hypothesis and "captures changes in the expected path of future short rates that arise from perceived new information that the LSAP announcement conveys about the state of the economy and the Federal Reserve's reaction function" (D'Amico *et al.*, 2012). The authors' contribution mainly lies in the new dataset they use. They find evidence in favour of the scarcity and duration channels, even though the latter appears to play a very small role in the impact of asset purchases compared to the former. Finally, they find no statistical significance for the signalling channel (D'Amico *et al.*, 2012).

Hamilton *et al.* (2012) suggest that changing the maturity structure of Treasury held by the public would be effective at lowering long-term yields both during normal times and when the economy is at the zero lower bound (ZLB). The authors state that in their model of the ZLB, the capacity to affect long-term yields stems from "investors' perceptions of what fundamentals are going to be after normal conditions have returned". Therefore, a policy that merely withdraws debt from the market when the economy is at the ZLB, like QE does, is expected to have a small impact (Hamilton *et al.*, 2012).

Gagnon *et al.* (2011) use two methodologies to measure the effect of LSAPs: a time-series analysis and an event study. In the time-series analysis, the authors examine the impact of debt supply on longer-term Treasury yields. In the present paper, I follow a similar approach to Gagnon *et al.* (2011)'s time-series analysis. Specifically, the authors estimate a model that "explains the historical variation (prior to the LSAP programs) in the term premium". For that purpose, they incorporate in their model a set of variables related to "the business cycle, the uncertainty about economic fundamentals, and the net public-sector supply of longer-term dollar-denominated debt securities" (Gagnon *et al.*, 2011). The authors thereafter use the estimated model to quantify the out-of-sample effect of the Fed's LSAPs corresponding to a fall in long-term debt supply to the public. Their findings suggest that the announced purchases of $1.725 trillion debt diminished the ten-year term premium by 38 to 82 basis points (Gagnon *et al.*, 2011). While both the event study and the time-series analysis reveal similar outcomes, the former finds a larger effect of the LSAPs. This may suggest that the LSAPs' impact is more important at the ZLB (Gagnon *et al.*, 2011).

Thornton (2014) uses the methodologies of Gagnon *et al.* (2011) and Krishnamurthy *et al.* (2012) to analyse how the Fed's LSAPs affected yields via the portfolio balance channel. The authors use

different types of public debt, maturity and yield measures. Once they include a linear trend in their model, they find no evidence in favour of "a positive relationship between either the term premium or the ten-year Treasury yield and any of the ten supply measures". The trend accounts for almost 80 % of the variation of the term premium and 60% of the variation in debt supply. Thornton (2014) does find a statistically significant but very small relation between the "slope of the yield curve" and "public debt with maturities longer than 10 years" as well as between the "slope of the yield curve" and the "duration of the public's holding of the debt".

The following section presents new evidence with regard to the impact of the Fed's LSAPs on longer-term yields.

VII. EMPIRICAL ANALYSIS OF A PORTFOLIO BALANCE EFFECT AND A LIQUIDITY EFFECT FOR QE

This section presents new evidence on the portfolio balance channel and the liquidity channel relative to QE. Specifically, three claims are considered:

1) A decline in publicly-held long-term government debt supply provoked by government debt purchases, diminishes longer-term yields on broadly similar assets as well as across maturities, as predicted by the portfolio balance channel,

2) Government debt purchases close the gap between longer-term and shorter-term Treasury yields, as predicted by the liquidity channel, and

3) Government debt purchases ultimately decrease corporate bond yields.

A. PERFORMED EXERCISE

To test the above claims, the following exercise is performed. First, various model specifications, aiming at capturing the variation in longer-term Treasury yields due to changes in publicly-held debt stock, are estimated. This estimation is performed over the period 1984 to 2008, prior to Lehman's collapse in September 2008. Thereafter, the estimated models are used to quantify the out-of-sample effect of the Fed's LSAPs, which started in November 2008 with the so-called first QE round.

B. CONTRIBUTION

The empirical analysis presented in this section contributes to the literature on three aspects.

First, to analyse the presence of a *portfolio balance effect*, this paper uses different *data* and *measures* of *control variables* than those used in previous research. This serves as a robustness check for past findings.

Second, in addition to test the effects of publicly-held debt supply on Treasury yields and Treasury yield premiums, this paper adds to the literature by testing the portfolio balance effect on another *dependent variable*, namely, the *spread between the ten-year yield and the policy rate*.

Third, to analyse the existence of a *liquidity effect*, this paper employs a *new model specification* (based on the theories in the literature) that assesses the effect of publicly-held debt supply on the spread between the ten-year Treasury yield and the two-year Treasury yield.

Fourth, to assess the ultimate impact that QE is expected to have on *corporate bond yields*, this paper evaluates the effect of publicly-held debt supply on a corporate yield index.

C. DATA

The following time series analyses use monthly data over the period January 1984 to June 2008. Using pre-crisis data (considering that the crisis started with Lehman's collapse in September 2008) allows for the estimation of different models, used thereafter for quantify the out-of-sample effect of the Fed's LSAPs, which started in November 2008 (see above section Performed Exercise for more details). While part of the data was provided by the Federal Reserve Bank of New York[19] for the purpose of the present study, the rest of the data comes from the Saint Louis Fed database.

1) Bond Yields as Dependent Variables

The impact of public debt supply is tested on four different Treasury-yield-related dependent variables, namely:

- **the ten-year Treasury yield term premium** based on Kim-Wright (2005)'s model,
- **the ten-Year Treasury yield** calculated as in Gagnon *et al.* (2011),
- **the spread between ten-year Treasury yield and two-year Treasury yield**[20], and
- **the spread between ten-year Treasury yield and fed funds rate**.

The first three dependent variables are used to assess the presence of a portfolio balance effect, while the third one is used to assess the presence of a liquidity effect. The Kim-Wright term premium is based on an arbitrage-free three-factor term structure model of Kim and Orphanides (2004) used to estimate a decomposition of the term structure of nominal interest rates into expected future short rates and term

[19] Pr. Matthew Raskin, Director of Cross-Market Monitoring and Analysis at the Federal Reserve Bank of New York, kindly provided part of the data used in the present research.
[20] Both interest rate spreads are from the Saint Louis Fed database.

premiums. This estimation is done over a sample that does not include a major financial crisis or monetary policy constrained by the zero bound on nominal interest rates.

Additionally, the impact of public debt supply is tested on a corporate bond yield index, namely:

- **Moody's Aaa seasoned corporate bond yield index**[21].

Unlike the yield and the yield premium variables, both used in Thornton (2014), the spread variables are used for the first time to test the transmission mechanism for QE. Moreover, the corporate bond index is used for the first in the specifications tested in this paper.

2) Public Debt Stocks as Independent Variables

To increase robustness, this paper follows Gagnon *et al.* (2011) by using two different measures of **public debt supply**: an **unadjusted measure** and a **duration-adjusted measure** that takes into account the diverse composition of securities.

Using the following variables[22]:

(a) publicly-held Treasuries with at least one year to maturity (including securities held by private investors, by the Fed and by foreign official institutions),
(b) Treasuries held in the Fed's SOMA portfolio with at least one year to maturity, and
(c) Treasuries held by foreign official agencies with at least one year to maturity.

the ultimate unadjusted measure of Treasury supply is calculated by subtracting Treasuries held by foreign officials (c), from publicly-held Treasuries net of SOMA (a) – (c). The resulting series is then expressed as a percentage of nominal GDP, and corresponds to $\frac{\{(a) - (b) - (c)\}}{(Nominal\ GDP)}$.

This series differ from the one used in Gagnon *et al.* (2011). In addition to subtract Treasuries held by foreign officials from publicly-held Treasury net of SOMA, the authors also that subtract agency securities and corporate debt held by foreign officials. As noted by Thornton (2014), the latter calculation is unsuitable since agency securities and corporate debt held by foreign officials are not included in publicly held Treasury, net of SOMA.

[21] The index series come from the Fed database: http://www.federalreserve.gov/releases/h15/data.htm
[22] Data provided by Pr. Matthew Raskin.

Moreover, using the following variables[23]:

(d) Non-SOMA Treasury holdings with less than one year to maturity, excluding TIPS,

(e) Duration of non-SOMA Treasury holdings with less than one year to maturity, excluding TIPS, and

(f) Duration of on-the-run ten-year Treasury yield.

the duration-adjusted measure of Treasury supply is calculated as follows: $\frac{\{(d)*(e)\}}{(f)} - c$.

3) Control Variables

In order to capture the variation in term premium due to the business cycle and to "fundamental uncertainty", I use a set of regressors[24] based on existing model specifications found in the literature (particularly in Thornton, 2014 and Gagnon *et al.*, 2011).

Relative to the variation due to the business cycle, the following regressors are used[25]:

- **Unemployment gap**, and
- **Core CPI inflation**[26].

Relative to the variation in term premium due to fundamental uncertainty, the following are used:

- **Long-run inflation disagreement**[27],
- **Six-month realized daily volatility of the on-the-run ten-year Treasury yield**[28], and

Finally, to model the expected path of policy rates, this paper also uses the following variables:

- **Target federal funds rate**, and
- **Slope of the near-term Eurodollar futures**.

[23] Data available on Barclays Capital.
[24] This data comes from Bloomberg except from the inflation disagreement, which is from the Michigan survey. Since the survey "did not include the long-run inflation question during some months during the 1980s", I use the series from Gagnon *et al.* (2011) which is "linearly interpolated (…) where data are missing".
[25] This data comes from Bloomberg except from the inflation disagreement, which is from the Michigan survey. Since the survey "did not include the long-run inflation question during some months during the 1980s", I use the series from Gagnon *et al.* (2011) which is "linearly interpolated (…) where data are missing".
[26] Mankiw, Reis, and Wolfers (2004) demonstrate that inflation disagreement, the level of inflation, the absolute value of the change in inflation, and relative price variability are positively correlated.
[27] The long-run inflation disagreement series was provided by Pr. Raskin and is calculated as the interquartile range of five-to ten-year-ahead inflation expectations, based on the Michigan Survey of Consumers.
[28] The volatility measure control for interest rate uncertainty.

In comparison to what is present in the literature, this paper uses additional measures[29] of control variables as a robustness check, including:

- **Unemployment rate**,
- **Level of CPI** excluding food and energy, for urban customers, and
- **Money supply M1 and M2**[30].

D. METHODOLOGY

Using the Jarque-Bera test, the null hypothesis of normally distributed residuals is not rejected. However, the null hypotheses of homoscedasticity and independently distributed data are rejected by the Breusch-Pagan-Godfrey test and the Breusch-Godfrey serial correlation test, respectively. Moreover, the correlogram corroborates the presence of autocorrelation. Moreover, to test for the presence of endogeneity in the different model specifications, the lagged value of the public debt supply variables is used as an instrument. The correlations between the error terms of the main regressions and the error terms of the public debt supply variables regressed on their own lagged value is roughly equal to zero for all model specifications. Hence, the debt supply variables are not endogenous to the models considered, and there is therefore no need for a two stage least square estimation.

Based on the above considerations, the following analyses use OLS with Newey-West variances and twelve lags, since the data is used on a monthly basis.

All regressions that follow are estimated first without a trend and then with a trend to evaluate the robustness of the results and assess whether the models are influenced by a trend.

1) Portfolio Balance Effect

a. Impact of Asset Purchases on Treasury Term Premium

The first equation estimated and presented in Table 1 and 3 is as follows:

$$tp_{10} = \alpha + \beta d_t + \gamma X_t + \varepsilon_t \qquad (1)$$

[29] Data available from the Saint Louis Fed database.
[30] Money supply measures are used to capture inflation expectations, but neither is significant in none of the model tested.

where tp_{10} is the nominal ten-year-yield term premium, d_t is publicly-held Treasury, and X_t is a set of control variables from those described above. LSAPs' effects are likely to be reflected for the most part in the term premium, even though other elements of the risk premium are probably affected to a smaller extent. Equation 1 thus aims at capturing only that part of the effect of LSAPs that affect the term premium.

b. Impact of Asset Purchases on Treasury Yield

The second equation estimated and presented in Table 2 and 4 is as follows:

$$tsy_{10} = \alpha + \beta d_t + \gamma X_t + \varepsilon_t \qquad (2)$$

where tsy_{10} is the nominal ten-year Treasury yield, d_t is publicly-held Treasury, and X_t is a set of control variables. This specification using the ten-year Treasury yield as the dependent variable serves as a robustness check. As explained in section IV, the Fed's LSAPs primarily aimed at decreasing the term premium component of longer-term yields. By estimating the impact of government debt supply on the Treasury yield in equation 2, I also aim at focusing on the impact on the term premium. To do so, two additional control variables, which are not present in equation 1, are included, namely, the target fed funds rate and the slope of the near-term Eurodollar futures. Provided that the latter two variables capture the expected path of policy rates (as predicted by Gagnon *et al.* (2011)'s specification), the estimation of the rest of the coefficients ought to reflect their impact on the ten-year term premium.

c. Impact of Asset Purchases on Spread between Yield and Fed Fund Rate

Since the Fed aimed at reducing the risk-premium component of longer-term yields via its LSAPs, while concurrently increasing short-term rates so as to stimulate investors' participation, it can be expected that LSAPs may have decreased the spread between longer-term Treasury yields and the fed funds rate. The latter claim is tested in the following equation, which results are presented in Table 5 and 6:

$$tsy_{10} - ffr = \alpha + \beta d_t + \gamma X_t + \varepsilon_t \qquad (3)$$

where $tsy_{10} - ffr$ is the spread between the ten-year Treasury yield and the Fed funds rate, d_t is publicly held Treasury, and X_t is a set of control variables.

2) Liquidity Effect

d. Impact of Asset Purchases on Spread between Long- and Short-Term Yield

According to the liquidity risk channel, LSAPs are likely to have alleviated the market from liquidity stress, and thereby reduced the yields between longer-term Treasury and short-term Treasuries, which had widened during the crisis. To verify the latter claim, the following equation is estimated and presented in Table 7 and 8:

$$tsy_{10} - tsy_2 = \alpha + \beta d_t + \gamma X_t + \varepsilon_t \qquad (4)$$

where $tsy_{10} - tsy_2$ is the yield difference between ten-year Treasury and two-year Treasury ten-year, d_t is publicly held Treasury, and X_t is a set of control variables.

3) Effect on Corporate Bond Yields

To assess the impact that large-scale asset purchases are ultimately expected to have on corporate bond yields, this paper estimates the following equation, which results are presented in Table 9 and 10:

$$corpo = \alpha + \beta d_t + \gamma X_t + \varepsilon_t \qquad (5)$$

where $corpo$ is a corporate bond yield index, d_t is publicly held Treasury, and X_t is a set of control variables.

E. RESULTS

1) Portfolio Balance Channel

The results regarding equation 1 (presented in Table 1) bring evidence in favour of the portfolio balance channel. First, the control variables are all significant at the one-percent level and have the expected sign. Specifically, one-percentage-point increases in the unemployment gap, core CPI, inflation disagreement, and realized volatility raise the term premium by roughly 20, 30, 40, and 100 basis points, respectively. Most importantly, both measures of debt supply are significant at the one-percent level, and have the expected sign based on the portfolio balance channel theory. A one-percent increase in longer-term Treasury supply out of GDP raises the ten-year term premium by 5 basis points and 5.8 basis points for the unadjusted and adjusted debt stocks, respectively.

The regression estimates remain almost the same whether the unemployment gap or the unemployment rate is used. However, both debt measures become insignificant when employing inflation level rather than core CPI inflation. Since there is evidence that inflation level is highly correlated to inflation disagreement, as demonstrated in Mankiw *et al.* (2004), using inflation level is likely to create an endogeneity problem.

Furthermore, the Schwarz Criterion (or BIC) is below 2 and does not differ much across the different models, suggesting that there is no overfitting issue and the likelihood remains high across models.

The Fed's asset purchases of $1.725 trillion that were undertaken over the period December 2008 to March 2010 represent about 12 percent of 2009 nominal GDP[31], which suggest that LSAPs decreased the term premium by 60 basis points[32] when using the unadjusted debt stock measure. The latter result is slightly larger than the 52 basis-point reduction in term premium found in Gagnon *et al.* (2011), but remain very similar. Furthermore, the Fed's asset purchases of $850 billion of ten-year equivalent debt (as estimated by Gagnon *et al.*, 2011), representing about 6 percent of 2009 nominal GDP, suggest that LSAPs decreased the term premium by 35 basis points[33], when using the adjusted debt stock measure. This result is again very close to the 38 basis-point finding in Gagnon *et al.* (2011).

More generally, the above findings overlap with those in the rest of the literature. Investigating the impact of the Fed's purchases of $300 billion in long-term securities between March and October of 2009, D'Amico *et al.* (2010) find that these purchases reduced the ten-year Treasury yield by roughly 50 basis points. The latter purchases represent 2 percent of 2009 nominal GDP, suggesting a reduction in yield of 10 basis points based on my findings, which remain in a comparable range to the 50 basis-point result in D'Amico *et al.* (2010). Moreover, Deutsche Bank (2010)'s study reveal that the $1 trillion in longer-term asset purchases was likely to have reduced long-term yields by 5 basis point. The latter purchases represent 7 percent of nominal GDP, suggesting a 35 basis-point decline in the ten-year Treasury term premium based on my findings, which again remains in a comparable range.

[31] 2009 nominal GDP = $14418.7 billion (Saint Louis database)
[32] 12*5 = 60
[33] 6*5.8 = 34.8

Table 1: OLS Regression with Ten-Year Yield Term Premium calculated as Dependent Variable (1984-2008)

Regressor	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Constant	-1.950	-2.551	-2.192	-2.853	-3.208	-2.848
Unemployment Gap	0.273***	0.204***	0.205***			
Core CPI	0.491***	0.328***	0.289***	0.423***	0.281***	0.244***
Inflation Disagreement	0.266***	0.378***	0.396***	0.258***	0.372***	0.390***
Realized Volatility	1.084***	1.109***	1.036***	1.054***	1.091***	1.020***
Unemployment Rate				0.230***	0.166***	0.165***
Unadjusted Debt to GDP		**0.050*** **			**0.050*** **	
Adjusted Debt to GDP			**0.058*** **			**0.057*** **
Adjusted R^2	0.79	0.84	0.85	0.79	0.84	0.85
Standard Error of Regression	0.45	0.39	0.37	0.45	0.39	0.37
p-value (F stat)	0.000	0.000	0.000	0.000	0.000	0.000
Schwarz Criterion	1.31	1.05	0.96	1.32	1.07	0.98

*Note 1: ***, ** and * indicate significance at the 1, 5, and 10 percent levels respectively.*
Note 2: Newey-West standard errors (12 lags).

To ensure the robustness of the above results, I estimate a model that uses the ten-year Treasury yield as the dependent variable (refer to equation 2). Since equation 1 is based on Kim-Wright (2005)'s ten-year term premium measure, which was calculated over a period that does not include major financial disruptions nor a zero lower bound context, testing an alternative specification by replacing the term premium by the ten-year Treasury yield allows to verify the reliability of the previous results. In this new specification, I include the target fed funds rate and the slope of the near-term Eurodollar futures curve to take into account variation in expected future policy rates. As explained by Gagnon *et al.* (2011), provided that the two additional variables capture the expected path of policy rates, the rest of the variables estimated in the model ought to reflect the impact on the term premium.

Using the ten-year Treasury yield as the dependent variable as the dependent variable has another advantage. One of the major goals of LSAPs is to reduce longer-term yields across a range of securities.

Since many longer-term yields are strongly correlated with ten-year Treasury yields, the impact of asset purchases on the latter provides insights into their effectiveness across diverse securities (Gagnon *et al.*, 2011).

Table 2 presents the results of this alternative specification. Column 2 and 3 show higher coefficients for either measure of debt stock compared to those found in Table 1. Both coefficients remain significant at the one-percent level. Specifically, a one-percent-GDP-increase in longer-term Treasury supply raises the ten-year Treasury yield by 8.4 and 7.9 basis points for the unadjusted and adjusted measures, respectively. Based on the latter findings, the $1.725 trillion asset purchases, representing 12 percent of nominal GDP, reduced the ten-year Treasury yield by 101 basis point[34]. Moreover, the ten-year equivalent purchases of $850 billion, corresponding to about 6 percent of 2009 nominal GDP, reduced the ten-year Treasury yield by 47.4 basis points[35]. Those results are very much in line with those found in other literature.

Using unemployment rate rather than unemployment gap, and inflation level rather than core CPI inflation (while removing inflation agreement to avoid endogeneity), the debt stock coefficients become smaller and less significant. Specifically, a one-percent-GDP-increase in longer-term Treasury supply raises the ten-year Treasury yield by 3.3 and 2.8 basis point for the unadjusted and adjusted debt measures, respectively, with significance levels of 10 percent and 5 percent, respectively (refer to column 5 and 6 in Table 2).

[34] 12*8.4 = 100.8
[35] 6*7.9 = 47.4

Table 2: OLS Regression with Ten-Year Treasury Yield calculated as Dependent Variable (1984-2008)

Regressor	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Constant	0.270	0.283	0.864	8.309	6.136	6.485
Target Fed Funds Rate	0.836***	0.480***	0.505***	0.363***	0.408***	0.395***
Euro-Dollar Slope	0.752***	0.760***	0.523**	0.420	0.528*	0.442
Unemployment Gap	0.879***	0.148	0.343**			
Core CPI	0.073	0.274*	0.253**			
Inflation Disagreement	-0.076	0.067	0.032			
Realized Volatility	1.337***	0.906***	1.046***	0.350	0.530	0.527
Unemployment Rate				0.134**	0.127**	0.156**
CPI excl.				-0.030***	-0.023***	-0.024***
Unadjusted Debt to GDP		**0.084*** **			**0.033** **	
Adjusted Debt to GDP			**0.079*** **			**0.028***
Adjusted R^2	0.87	0.89	0.90	0.91	0.91	0.91
Standard Error of Regression	0.51	0.44	0.44	0.46	0.45	0.46
p-value (F stat)	0.000	0.000	0.000	0.000	0.000	0.000
Schwarz Criterion	1.61	1.34	1.34	1.40	1.38	1.40

*Note 1: ***, ** and * indicate significance at the 1, 5, and 10 percent levels respectively.*
Note 2: Newey-West standard errors (12 lags).

Next, the regressions estimated in Table 1 and 2 are re-estimated in Table 3 and 4, respectively, after accounting for a trend. The findings presented in Table 1 and 2 provide evidence in favour of the portfolio balance channel. However, as soon as a simple linear trend is included in the, both debt supply measures become insignificant – even at the ten-percent significance level, and independently of the model specification. This corroborates with and provide further robustness to the results of Thornton (2014).

Series of Treasury yields, Treasury yield term premiums, as well as debt supply all vary along a trend. Two variables trending in a similar direction can seem to be positively correlated even if they are independent from one another. This can result in so-called spurious regressions, that is, regressions presenting significant coefficients due to the presence of a unit root in the series trending together,

rather than to an actual statistically significant relationship between the relevant variables. As a result, Table 3 and 4 are likely to reveal that the regressions using the different Treasury yield measures and debt supply measure are spurious. This invalidates the evidence in favour of the portfolio balance channel presented in Table 1 and 2, and corroborates the findings of Thornton (2014) suggesting that there is not enough evidence in favour of this channel.

Table 3: OLS Regression Ten-Year Yield Term Premium – Accounting for the Trend

Regressor	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Constant	1.696	1.327	0.867	0.511
Unemployment Gap	0.204***	0.199***		
Core CPI	0.091*	0.102*	0.063	0.074
Inflation Disagreement	0.190***	0.206***	0.197***	0.215***
Realized Volatility	0.506**	0.557***	1.532**	0.582***
Unemployment Rate			0.150***	0.147***
Trend	-0.009***	-0.008***	-0.008***	-0.007***
Unadjusted Debt to GDP	**-0.015**		**-0.011**	
Adjusted Debt to GDP		**-0.009**		**-0.005**
Adjusted R^2	0.88	0.87	0.87	0.87
Standard Error of Regression	0.34	0.34	0.35	0.35
p-value (F stat)	0.000	0.000	0.000	0.000
Schwarz Criterion	0.81	0.82	0.86	0.86

Note 1: ***, ** and * indicate significance at the 1, 5, and 10 percent levels respectively.
Note 2: Newey-West standard errors (12 lags).

Table 4: OLS Regression Ten-Year Treasury Yield – Accounting for the Trend

Regressor	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Constant	3.357	3.873	7.672	1.927
Target Fed Funds Rate	0.443***	0.457***	0.419***	0.358***
Euro-Dollar Slope	0.489***	0.413***	0.586	0.348
Unemployment Gap	0.243	0.318**		
Core CPI	0.157	0.129		
Inflation Disagreement	-0.006	-0.028		
Realized Volatility	0.774***	0.796***	0.506	0.515
Unemployment Rate			0.119**	0.132*
CPI excl.			-0.040	0.033
Trend	-0.007***	-0.008***	0.008	-0.025
Unadjusted Debt to GDP	**0.025**		**0.046**	
Adjusted Debt to GDP		**0.013**		**-0.023**
Adjusted R^2	0.90	0.90	0.91	0.91
Standard Error of Regression	0.42	0.43	0.45	0.46
p-value (F stat)	0.000	0.000	0.000	0.000
Schwarz Criterion	1.31	1.32	1.40	1.41

*Note 1: ***, ** and * indicate significance at the 1, 5, and 10 percent levels respectively.*
Note 2: Newey-West standard errors (12 lags).

The findings regarding the impact of the Fed's LSAP program on the spread between longer-term Treasury yield and the fed funds rate (equation 3) are presented in Table 5. As predicted, a one-percent GDP increase in debt supply appears to raise the spread between the ten-year Treasury yield and the fed funds rate by almost 10 basis points in the specification presented in columns 2 and 3, and by roughly 3 basis points in an alternative specification presented in columns 5 and 6. The latter estimates are significant at the one-percent level for the first specification, and at the five- and ten-percent levels for the second specification with the unadjusted- and adjusted-debt stock measures, respectively.

Based on the findings of the first specification (column 2 and 3 of Table 5), the $1.725 trillion of asset purchases, reduced the spread between the ten-year Treasury yield and the fed funds rate by 110 basis points[36]. Moreover, the ten-year equivalent purchases of $850 billion reduced the spread by 56 basis points[37].

Table 5: OLS Regression with Treasury Yield minus Fed Funds Rate calculated as Dependent Variable (1984-2008)

Regressor	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Constant	-0.198	-0.057	0.545	6.847	4.539	4.969
Target Fed Funds Rate	-0.241***	-0.427***	-0.458***	-0.560***	-0.513***	-0.528***
Euro-Dollar Slope	1.528***	1.105***	0.951***	0.399*	0.513**	0.422*
Inflation Disagreement	0.531***	0.408***	0.470***			
Realized Volatility				0.470	0.661**	0.652*
Unemployment Rate				0.165**	0.157**	0.187***
CPI excl.				-0.026***	-0.018***	-0.019***
Unadjusted Debt to GDP		**0.092*** **			**0.035** **	
Adjusted Debt to GDP			**0.094*** **			**0.028***
Adjusted R^2	0.78	0.88	0.87	0.88	0.89	0.89
Standard Error of Regression	0.62	0.47	0.49	0.46	0.45	0.46
p-value (F stat)	0.000	0.000	0.000	0.000	0.000	0.000
Schwarz Criterion	1.97	1.42	1.51	1.39	1.37	1.39

*Note 1: ***, ** and * indicate significance at the 1, 5, and 10 percent levels respectively.*
Note 2: Newey-West standard errors (12 lags).

However, once again, debt supply coefficients become insignificant in three of the four specifications when a linear trend is introduced (refer to Table 6). Therefore, just like regression 1 and 2 testing the impact of debt stock on Treasury term premium and yield, regression 3 testing the impact on the spread between the Treasury yield and the fed funds rate is likely to be spurious. Using a different dependent

[36] 12*9.2 = 110.4
[37] 6*9.4 = 56.4

variable than in the rest of the literature, this result confirms again the findings of Thornton (2014) that there is not enough statistical evidence in favour of the portfolio balance channel.

Table 6: OLS Regression Ten-Year Treasury Yield minus Fed Funds Rate – Accounting for the Trend

Regressor	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Constant	3.337	5.370	6.239	-0.513
Target Fed Funds Rate	-0.542***	-0.592***	-0.500***	-0.572***
Euro-Dollar Slope	0.722***	0.540***	0.577**	0.308
Inflation Disagreement	0.265***	0.179**		
Realized Volatility			0.634**	0.637*
Unemployment Rate			0.148**	0.159**
CPI excl.			-0.038	0.048
Trend	-0.007***	-0.012***	0.008	-0.030
Unadjusted Debt to GDP	**0.033****		**0.050**	
Adjusted Debt to GDP		**-0.012**		**-0.033**
Adjusted R^2	0.89	0.88	0.89	0.89
Standard Error of Regression	0.45	0.46	0.45	0.45
p-value (F stat)	0.000	0.000	0.000	0.000
Schwarz Criterion	1.37	1.39	1.39	1.40

*Note 1: ***, ** and * indicate significance at the 1, 5, and 10 percent levels respectively.*
Note 2: Newey-West standard errors (12 lags).

2) Liquidity Channel

The results regarding the impact of government debt supply on the yield spread between formerly- and recently-issued Treasuries (refer to equation 4) are presented in Table 7. The debt stock measures are both significant at the one-percent level, independent of whether core CPI inflation or inflation level is used. However, both debt stock measures have the opposite sign than what is predicted from the liquidity channel. Specifically, a one-percent-GDP-increase in longer-term Treasury supply decreases the yield spread by roughly 2 and 3 basis-point for both the unadjusted and adjusted debt measures,

when using the specifications with core CPI inflation and CPI level, respectively (refer to column 2, 3, 5 and 6 in Table 7).

Based on the findings of the first specification (column 2 and 3 of Table 7), the $1.725 trillion of asset purchases, increased the yield spread between formerly- and newly-issued Treasuries by 23 basis points[38]. Moreover, the ten-year equivalent purchases of $850 billion reduced the spread by 10 basis points[39].

Table 7: OLS Regression with Ten-Year minus Two-Year Treasury Yield calculated as Dependent Variable (1984-2008)

Regressor	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Constant	0.309	0.297	0.180	-0.332	1.157	1.214
Target Fed Funds Rate	-0.161***	-0.087*	-0.095**	-0.048	-0.069	-0.069*
Euro-Dollar Slope	0.728***	0.729***	0.778***	0.850***	0.731***	0.807***
Unemployment Gap	0.204***	0.363***	0.316***	0.337***	0.422***	0.358***
Core CPI	0.141*	0.088	0.098			
Realized Volatility	0.420***	0.473***	0.446***	0.485*	0.406***	0.341
CPI excl.				0.002	-0.003	-0.004**
Unadjusted Debt to GDP		**-0.019*** **			**-0.030*** **	
Adjusted Debt to GDP			**-0.017*** **			**-0.030*** **
Adjusted R^2	0.92	0.92	0.92	0.92	0.92	0.92
Standard Error of Regression	0.23	0.23	0.23	0.24	0.23	0.23
p-value (F stat)	0.000	0.000	0.000	0.000	0.000	0.000
Schwarz Criterion	0.03	0.01	0.00	0.09	0.00	0.01

*Note 1: ***, ** and * indicate significance at the 1, 5, and 10 percent levels respectively.*
Note 2: Newey-West standard errors (12 lags).

Once including a simple linear trend in regression 4 testing the relationship between debt supply and old- versus new-Treasury yield spread, coefficients of both debt supply measures remain significant at least at the five-percent significance level (refer to Table 8). Unlike regressions 1, 2, and 3, regression

[38] 12*(-1.9) = -22.8
[39] 6*(-1.7) = 10.2

4 is unlikely to be spurious. Moreover, debt supply coefficients do not only preserve the same sign, but also are larger than in the specification without the trend. Therefore, there is significant evidence in favour of the fact that a decline in debt supply through asset purchases increases the spread between old- and new-Treasury yield spread, contrary to the prediction of the liquidity channel.

Table 8: OLS Regression Ten-Year minus Two-Year Treasury Yield – Accounting for the Trend

Regressor	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Constant	0.748	0.725	-2.392	-4.465
Target Fed Funds Rate	-0.098**	-0.108**	-0.079**	-0.120***
Euro-Dollar Slope	0.697***	0.762***	0.585***	0.694***
Unemployment Gap	0.367***	0.307***	0.464***	0.310***
Core CPI	0.067	0.070		
Realized Volatility	0.421***	0.364***	0.476***	0.318***
CPI excl.			0.039**	0.064**
Trend	-0.001	-0.001	-0.018**	-0.030***
Unadjusted Debt to GDP	**-0.027****		**-0.062*****	
Adjusted Debt to GDP		**-0.027****		**-0.090*****
Adjusted R^2	0.93	0.92	0.93	0.93
Standard Error of Regression	0.23	0.23	0.22	0.22
p-value (F stat)	0.000	0.000	0.000	0.000
Schwarz Criterion	0.01	0.01	0.01	-0.02

*Note 1: ***, ** and * indicate significance at the 1, 5, and 10 percent levels respectively.*
Note 2: Newey-West standard errors (12 lags).

3) Impact on Corporate Bonds' Yields

The impact of the Fed's LSAPs on corporate yields is presented in Table 9 (without a trend) and Table 10 (with a trend). Using the specification of equation 1 with the corporate yield index instead of the Treasury term premium as the dependent variable, and without accounting for a trend, the debt stock measures are both significant at the one percent level and have the expected sign (see Table 9). Moreover, the impact of asset purchases on corporate yields appears to be stronger than on Treasury

yields, namely a one-percent-GDP-increase in longer-term Treasury supply decreases the corporate yield index by roughly 9 and 10 basis-point when using the unadjusted and adjusted debt measures, respectively, and independent of whether the unemployment gap and the unemployment rate measures are used. All control variables have the expected sign and are significant at the one percent level except from unemployment measures, which are negative in all specifications. This is in conflict with the hypothesis that a decline in the unemployment rate is expected to decrease corporate yields.

Table 9: OLS Regression with Corporate Yield Index calculated as Dependent Variable (1984-2008)

Regressor	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Constant	0.614	-0.418	0.182	1.179	0.568	1.188
Unemployment Gap	-0.197	-0.317***	-0.319***			
Core CPI	0.991***	0.710***	0.630***	1.022***	0.777***	0.698***
Inflation Disagreement	0.665***	0.857***	0.898***	0.665***	0.862***	0.905***
Realized Volatility	1.851***	1.893***	1.764***	1.843***	1.907***	1.783***
Unemployment Rate				-0.133	-0.242**	-0.225**
Unadjusted Debt to GDP		**0.086*** **			**0.086*** **	
Adjusted Debt to GDP			**0.103*** **			**0.104*** **
Adjusted R^2	0.81	0.86	0.88	0.80	0.86	0.87
Standard Error of Regression	0.81	0.62	0.57	0.73	0.62	0.58
p-value (F stat)	0.000	0.000	0.000	0.000	0.000	0.000
Schwarz Criterion	2.28	1.98	1.83	2.29	2.01	1.85

*Note 1: ***, ** and * indicate significance at the 1, 5, and 10 percent levels respectively.*
Note 2: Newey-West standard errors (12 lags).

When accounting for a trend, the debt stock measures become less or no more significant and have the opposite sign of what is expected from the theory for most specifications presented in Table 10. Using the unemployment rate measure rather than the unemployment gap measure, the debt stock measures become more significant but remain negative. Those findings suggest that there is some evidence against the theory that LSAPs decrease corporate yields, thereby conflicting with my initial claim.

Table 10: OLS Regression with Corporate Bond Index calculated as Dependent Variable – Accounting for the Trend

Regressor	**Coefficient**	**Coefficient**	**Coefficient**	**Coefficient**
Constant	8.321	7.274	9.784	8.845
Unemployment Gap	-0.317***	-0.332***		
Core CPI	0.224***	0.252***	0.283***	0.310***
Inflation Disagreement	0.470***	0.516***	0.467***	0.507***
Realized Volatility	0.652**	0.800***	0.644**	0.784***
Unemployment Rate			-0.280***	-0.290***
Trend	-0.018***	-0.016***	-0.018**	-0.017***
Unadjusted Debt to GDP	**-0.048***		**-0.053****	
Adjusted Debt to GDP		**-0.031**		**-0.037*****
Adjusted R^2	0.91	0.91	0.91	0.91
Standard Error of Regression	0.48	0.49	0.48	0.49
p-value (F stat)	0.000	0.000	0.000	0.000
Schwarz Criterion	1.50	1.55	1.50	1.54

Note 1: ***, ** and * indicate significance at the 1, 5, and 10 percent levels respectively.
Note 2: Newey-West standard errors (12 lags).

VIII. CONCLUSION

With policy rates hitting the zero lower bound, monetary authorities of advanced economies decided to expand their portfolio of monetary policy instruments to unconventional monetary policy tools, such as quantitative easing (QE), in an attempt to boost the economic recovery. In this paper, I investigate the transmission mechanism and impact of the Federal Reserve's Large-Scale Asset Purchase (LSAP) programme, a QE programme, on longer-term yields. LSAPs aimed at creating accommodative conditions for the market to rebalance their portfolio towards a range of assets including longer-term corporate debt, and for financial institutions to increase their lending operations. In turn, the increases in investment and lending were expected to boost both investment in business projects and private spending.

The impact of LSAPs is supposed to take place through a variety of channels. This paper analyses the existence and effectiveness of two channels in particular, the portfolio balance channel and the liquidity channel. The portfolio balance channel is considered by many economists, including former Fed Chairman Ben Bernanke (2012), as the most prominent channel through which QE acts on the economy. This channel suggests that by removing a large amount of assets with high duration from the market, and thus, by removing the maturity-related risk associated to those assets from the market, LSAPs are expected to reduce longer-term yields across different asset classes. On the other hand, the liquidity channel relates to the improvement in market functioning caused by large-scale asset purchases, which ultimately also depress yield spreads across different asset classes.

Using data from the United States, this paper finds no evidence in favour of either the portfolio balance channel or the liquidity channel. The portfolio balance channel initially appears to be highly significant (at the one-percent level) and to produce the expected effect on longer-term yields. Specifically, the first round of QE, amounting to $1.725 trillion in asset purchases, is found to have reduced the ten-year Treasury term premium by roughly 60 basis point, and the ten-year Treasury yield by roughly 100 basis points. Those results are very comparable to those found in the literature, such as in Gagnon *et al.* (2011) and Hamilton *et al.* (2012). However, the introduction of a simple linear trend in the estimated regressions renders the results insignificant, implying that the regressions are likely to be spurious. This corroborates the findings in Thornton (2014). Furthermore, although debt supply measures are significant with and without the presence of a linear trend when testing the liquidity channel, their coefficients have the opposite sign than what is expected from this channel. Finally,

testing the impact of LSAPs directly on a corporate yield index, which they are ultimately expected to impact negatively, I find evidence of a positive impact, conflicting with the theory that LSAPs decrease corporate yields.

Hence, the findings in this paper suggest that there is not enough statistical evidence that QE has had a negative impact on longer-term yields in the US as it is expected, through either the portfolio balance channel or the liquidity channel. Nevertheless, the present empirical analysis, just like most analyses of monetary policy in a liquidity constraint context, suffers from a methodological limitation that must be taken into account. Specifically, my findings are based on a sample period (1984-2008) that does not encompass significant financial disruptions or serious liquidity constraints. The effect of LSAPs is quantified using out-of-sample calculations based on pre-crisis estimated models. As analysed in a range of literature (see, for instance, Lenza *et al.*, 2010), important financial disruptions, such as those experienced in 2007-2008, as well as a zero lower bound context are likely to provoke considerable changes in the behaviour of fundamentals and of the monetary transmission mechanism. Therefore, further research on the transmission mechanism in periods of financial distress and liquidity constraints is needed in order to better investigate and grasp the impact of monetary policy, and of QE in particular, during those periods.

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APPENDIX

PRELIMINARY RESEARCH

Before deciding to focus exclusively on US data, this paper initially aimed at analysing the effectiveness of non-standard monetary policy measures undertaken by the ECB from September 2008 to August 2014, and later on, at quantifying the interest rate pass-through for the Eurozone and the United States in the context of the recent financial crisis. After a thorough exploration of the literature relative to the latter topics as well as of the possibilities to contribute further, several constraints were encountered and it was decided to focus on the analysis of transmission channels for QE using US data only. This section is meant to retrace this process, which involved several months of work and lead to the definition of the research question as it is today.

A. EFFECTIVENESS OF THE ECB'S NON-STANDARD MONETARY MEASURES

The question of the effectiveness of the ECB's non-standard measures (labelled "enhanced credit support") implemented after the collapse of Lehman Brothers in September 2008[40] has been a crucial one to assess whether and to which extend they have helped to contain the recent financial crisis and its propagation to the economy. This question has become even more crucial under the pressure of a liquidity trap.

Much of the literature has already analysed the impact of traditional monetary policies on the economy during the business cycle. However, studies on the macroeconomic impact of unconventional monetary policies and on the transmission channels during a major crisis using Eurozone data are scarce. The inadequacy of existing theoretical models to analyse the transmission mechanism over the recent financial crisis illustrates this gap in the literature (Giannone *et al.*, 2011). Moreover, most of the studies on unconventional measures have focused on their impact on yields[41], but few have analysed their transmission to real economy fundamentals, namely the inflation rate and the unemployment rate. In this context, an analysis of unconventional measures' transmission channels, and an empirical

[40] Before Lehman's collapse, the ECB's policy stance was still mainly based on the level of short-term interest rates (Lenza *et al.*, 2010).
[41] Studies on this topic include, inter alia, Cihák *et al.* (2009), Pattipeilohy *et al.* (2013), Peersman (2011).

analysis of their impact on the real economy is essential for policymakers as well as for researchers to build more adequate theoretical monetary models.

1) Relevant Literature on the ECB's Non-Standard Measures

Lenza *et al.* (2010) find that non-standard measures have had a significant effect on the euro area economy, acting principally via interest rates rather than only via "quantity effects" of money supply. Using a Bayesian vector autoregression model, the authors quantify the impact of non-standard measures by comparing how the reduction of money market spreads is transmitted to the broader economy under two scenarios: a "policy" and a "no policy" scenario. Using the same model, Giannone *et al.* (2011) compare forecasts to actual observations of key variables to assess whether the ECB's non-standard measures have offset the effects of the crisis. Both studies find that, although non-standard measures have had a positive impact on some variables, they cannot act as a cure to structural problems inherent to the financial industry.

The technical difficulties faced when studying the effectiveness of non-standard measures and the transmission channels via which they act are tremendous. Separating the macroeconomic impact of monetary policies from that of the financial crisis itself, as well as the effects of unconventional versus conventional measures is challenging; even more so when the behavioural relationship of the variables involved might have changed of nature during the crisis. Also, the well-documented issue of disentangling credit demand from credit supply shocks remains (Peersman, 2011). Peersman (2011) identifies the effects of three credit supply shocks associated to 1) interest rate policies, 2) non-conventional policies, and 3) credit multiplier shocks (independent from any policy). He finds that the macroeconomic effects for the shocks related to both interest rate policies and non-standard policies are similar, but that the transmission processes differ. Moreover, Giannone *et al.* (2009) show that the underlying behavioural relationship among key variables has remained roughly the same in the pre- and post-crisis periods.

As a result, much remain to be done in the literature relative to the modelling of the transmission mechanism of unconventional monetary policy in order to estimate the impact of the ECB's enhanced credit support package, among others. However, several obstacles are met when attempting to engage in contributing to this question.

2) Considered Methodology

The approach considered to estimate the effectiveness of the ECB's non-standard measures was to use a multiple regression counting similar but fewer variables than those identified by Giannone *et al.* (2009) in order to avoid overfitting. This model would then be estimated using maximum likelihood. Following the exercise performed by Giannone *et al.* (2011), it was considered to start by estimating the model over the pre-crisis (or pre-Lehman) period (January 1999 to August 2008). Using the same model, a forecasts for the pre- and post-Lehman periods (January 1999 to August 2014) could then be generated, given the actual behaviour of economic activity. These forecasts correspond to "standard" monetary transmission – based on the economic behaviour of the variables over the pre-crisis period – given the fall in economic activity associated to the crisis. The forecasts would then have been compared to the actual path of the relevant variables.

The actual series would consist of at least three components, as suggested by Giannone *et al.* (2011): 1) the crisis-related drop in economic activity, also incorporated in the forecasts, 2) the effects of the financial crisis, and 3) the effects of the ECB's non-standard measures. Hence, the extent to which the actual path of the key variables mirrors that forecasted with the model gives an appreciation of whether the non-standard measures have compensated the effects of the financial crisis on the economy (Giannone *et al.*, 2011).

At least two elements of this exercise were supposed to differ from the exercise performed by Giannone *et al.* (2011): 1) the statistical technique: while Giannone *et al.* (2011) uses a vector autoregression (VAR) model estimated by Bayesian shrinkage to cope with the sparcity of the data induced by the model's large dimension (issue referred to as the "curse of dimensionality"), I intended to estimate different multiple regressions using two stage least squares to overcome endogeneity issues. This approach would have offered insights into whether the results of Giannone *et al.* (2011) are replicable when using a different statistical method. 2) The time period: the post-Lehman period would incorporate the most recent data available to assess the effectiveness of the ECB's latest non-standard measures.

3) Obstacles

Following this initial proposal was hindered by three main issues. First, replicating the exercise of Giannone *et al.* (2011) using a different econometric approach appeared complex due to the impossibility to find relevant instrumental variables. Second, a regression analysis appeared as a too simplistic approach to capture the complexity of the model assessed. Third, estimating such a model without accounting for the identification problems to disentangle the effects of unconventional measures from those of the crisis itself, and from conventional measures, seemed to produce trivial results. However, developing a model for identification would have represented a research questions to approach on its own and which would deviate from the initial proposal. Based on those three considerations, it was decided to change topic.

B. INTEREST RATE PASS-THOUGH

Due to the impediments to analyse the effect of unconventional monetary measures, it was considered to assess the interest rate transmission mechanism for the Eurozone and the United States in the context of the recent financial crisis. More specifically, the idea was to investigate 1) how fast have lending and deposit rates adjusted in response to changes in the policy and the interbank rates in the period September 2008 to September 2014, and 2) to what degree has this interest rate transmission taken place.

1) Considered Methodology

To analyse the speed and the extent to which retail rates (i.e. deposit and lending rates that commercial banks apply to non-financial corporations and individuals) have responded to changes in wholesale rates (i.e. policy and interbank rates), the disaggregated general-to-specific model (GETS) was considered. This model has only been used once in the relevant literature by Karagiannis *et al.* (2010). Such a model allows to draw conclusions on the transmission of interest rates and to estimate the short- and long-run interest rate elasticities (Karagiannis *et al.*, 2010). The model is as follows:

$$\Delta i_{R,t} = \lambda_0 + \lambda_0 T + \sum_{i=1}^{j1} \beta_{R,t}^{-} \Delta i_{R,t-i}^{-} + \sum_{i=0}^{j2} \beta_{W,t}^{-} \Delta i_{W,t-i}^{-} + \theta^{-}\left(i_{R,t} - \varphi_0 i_{W,t}\right)_{t-1} + \sum_{i=0}^{j3} \beta_{W,t}^{+} \Delta i_{W,t-i}^{+} + \sum_{i=1}^{j4} \beta_{R,t}^{+} \Delta i_{R,t-i}^{+} + \theta^{+}\left(i_{R,t} - \varphi_1 i_{W,t}\right)_{t-1} + \xi_t$$

where $i_{R,t}$ and $i_{W,t}$ stand for the retail and the wholesale rates respectively, θ^+ and θ^- represent the speed of adjustment as a response to a positive and negative change in the wholesale rates respectively, φ_0 and φ_1 are the long-run price transmission rigidities in the negative and the positive change scenarios correspondingly, $\beta_{W,t}^{+}$ and $\beta_{W,t}^{-}$ are the elasticities with regard to the wholesale rates, similarly $\beta_{R,t}^{+}$ and $\beta_{R,t}^{-}$ are the elasticities with regard to the lagged retail rates, T is the time trend, and ξ_t the error term.

Following the exercise performed by Karagiannis *et al.* (2010), the idea was to estimate 1) the short- and long-run interest rate rigidities of the retail rates, and 2) the speed of transmission from wholesale to retail rates. The author use pre-crisis data to make inferences on the nature of the transmission mechanism in "normal" times in the euro area and the US. This aims at enlightening policy makers on how to strengthen the interest rate channel as a policy vehicle to boost the economy. Contrastively, this paper intended to employ post-crisis data (from September 2008 to September 2014) to evaluate how the transmission processes have evolved as the wholesale rates have been repetitively driven down by both the ECB and the Fed. The research was then meant to compare the results between the US and the Eurozone.

2) Obstacles

The idea to capture the effect of incremental changes in central bank rates[42] and in money market rates[43] on retail rates[44] using post-crisis data was not feasible since those rates plummeted to almost zero right after the crisis and remained at the zero lower bound for a prolonged period thereafter. The variation in the independent variables was therefore too low for an estimation to produce insightful results.

[42] The MRO rate and the overnight EONIA rate for the Eurozone, and the discount rate for the US.
[43] The 3-month Euribor rate for the Eurozone and the federal funds rate for the US.
[44] Approximated by deposit and lending rates in the euro area and the US

C. QE TRANSMISSION MECHANISM IN THE EUROZONE

Another option initially considered and later abandoned was to apply the empirical exercise of the present paper for the US and the Eurozone in order to compare the magnitude of the portfolio balance effect and the liquidity effect between both economies. This task appeared very challenging for the Eurozone since the in-sample estimation of the models considered was to be performed in the pre-Euro period. As a result, the exercise required the development of a model that would capture the exchange rates risk for all currencies of European economies prior to the introduction of the Euro. However, data was scarce for many European countries and the creation of a model capturing exchange rates risk appeared to be a topic to treat on its own and which deviated from the initial proposal.

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To conclude, several gaps were identified in the literature relative to the transmission mechanism of unconventional monetary policy, particularly with evidence from the Eurozone. Those gaps appear particularly critical to fill, both from a social and scientific perspective, in the current context of recession and liquidity constraint. After analysing where it would be most feasible and effective to contribute to the literature, it was decided to focus exclusively on US data.